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**A Wide Lens:**

**Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings**

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Edited by

Kristine Lund, Gerald P. Niccolai, Elise Lavoué, Cindy Hmelo-Silver  
Gahgene Gweon, Michael Baker

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Volume 2

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# Preface

On behalf of the whole CSCL 2019 organizing team, we are delighted to welcome you to Lyon! Our theme is

**A Wide Lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings.**

Promoting productive collaborative interaction in varied contexts requires studying the interdependencies of the complex ecosystems in which collaborative learning takes place (e.g. school, museums, work, play). In Cognitive Science, research under the banner of 4E cognition favors newer paradigms that take into account the role of the body (embodied), the interactions between an organism and its environment (enactive), and the elements and aspects in the environment itself (extended and embedded). At this year's CSCL, we propose 4E *learning* as our theme. Submissions that present results on collaborative learning regarding some combination of embodied, enactive, extended, and embedded learning are welcome. Such a focus translates to studies of various interdependencies in the learning process: social, emotional, cultural, linguistic, cognitive, and technological. Finally, treating 4E learning as inherently collaborative means that as a CSCL community, we need to understand this phenomenon in settings both with and without technology. It is important that as CSCL researchers, we build on work that while not computer-supported has implications for design and research in computer-supported collaborative learning settings. In considering collaborative learning as the interplay of factors in a complex system, we aim to create novel interdisciplinary integrations and thereby extend and reinforce the CSCL Learning Sciences community with new ideas.

We hope you enjoy the program as well as visiting our beautiful city!

Kris Lund, conference chair CSCL 2019 (on behalf of the whole team)

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# Short Papers



# Co-Design for Learner Help-Giving Across Physical and Digital Contexts

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**Abstract:** With the growing integration of technology in the classrooms, learners can now develop collaboration skills by applying them across diverse contexts. While this represents a great opportunity, it also brings challenges due to an increased need to support individual learners across multiple learning activities. We propose a technology-enhanced learning ecosystem called UbiCoS that supports learner help-giving during face-to-face collaboration and across three different digital learning environments: an interactive digital textbook, an online Q&A forum, and a teachable agent. In this paper, we present a first step in the development of UbiCoS: five co-design sessions with 16 learners that give insight into learners' perceptions of help-giving. The findings provided us with technology-related and curriculum-related design opportunities for facilitating learner interaction across multiple platforms.

## Introduction

Computer Supported Collaborative Learning (CSCL) is becoming ubiquitous in part due to the increasing presence of technology in formal learning environments, creating learning scenarios which involve multiple activities distributed across physical and virtual spaces. For example, learners in a classroom may move from having a face-to-face discussion surrounding the speed of a moving car, to watching and commenting on an online video on the same topic, to completing a problem set at home using a digital environment. Given these diverse contexts, Dillenbourg, Järvelä, & Fischer (2009) articulate a growing need for researchers to explore how CSCL fits into broader pedagogical scenarios rather than designing a single CSCL experience for learners.

Integrating multiple CSCL technologies in a classroom creates unique opportunities for understanding and facilitating learner development of collaboration skills. Through interaction via multiple technological platforms (e.g., discussion forums, wikis, online Q&A), learners leverage their skills in different contexts; their collaborative interactions facilitate the development of literacies related to collaboration, problem-solving, and the subject domain. However, while the use of a single CSCL technology in formal education can lead to improvement in learning performance, integrating multiple technologies within a single classroom practice comes with behavioral, pedagogical, and logistical challenges (Dillenbourg & Jermann, 2010). The same learner might behave differently when interacting online rather than face-to-face and may struggle to transfer knowledge and skills across platforms. Our research vision is to explore how we can design multiple technological platforms within a learner-centered classroom to facilitate collaborative skills, with a focus on mutual help-giving. Mutual help-giving involves a collection of behaviors including sharing resources, explaining concepts, giving feedback, and challenging each other's reasoning (Johnson and Johnson, 2009). Learners have many opportunities to engage in these behaviors as part of their schooling, ranging from brief informal interactions while working on an assignment to discussing ideas on an extended group project.

We have created a novel learning environment, called UbiCoS (Ubiquitous Collaboration Support), that includes three platforms where learners engage in help-giving surrounding ratios and proportions concepts. The first technology platform is Modelbook, an interactive digital textbook integrated with a discussion forum which is intended to be used synchronously and collaboratively with one's peers (see Figure 1, left). In the environment, learners can see questions relevant to each page of text (posted by their classmates or teacher) and have a single discussion in response to each question. The interactions in the textbook are intended to be similar to face-to-face discussion in the classroom but lower the barrier for participation since all learners are expected to make contributions, compared to a whole-class discussion where only a subset of learners might participate. The next technology platform is Khan Academy, which we use for asynchronous collaboration with a geographically distributed learning community (see Figure 1, right). While Khan Academy is well-known for its instructional videos, it also has a collaborative learning space where people participate in knowledge construction by commenting on videos to ask and answer questions about the content ([www.khanacademy.org](http://www.khanacademy.org));

Taton, 2011). We expect learners to see similar benefits in answering questions on Khan Academy as on Modelbook, although because interactions are asynchronous, learners can take time to phrase their answer to produce more explicit and thoughtful explanations (Wu & Hiltz, 2004). However, learners may feel less connected to this platform due to its asynchronous nature and anonymous peers (Hiltz, 1998) and limit their help-giving behavior. The third technology is a speech-based teachable agent, Cobi. Learners interact with Cobi using spoken language and a web application. The web application displays a problem description and partial worked-out solution steps in table form to guide the learners in their teaching of Cobi. There is a microphone image that learners use to press and talk to Cobi. Learners walk Cobi through the worked-out problems using spoken language, explaining each step. Cobi listens and responds with questions, self-explanations, and encouragement (Lubold, Pon-Barry, & Walker, 2015). During these interactions, we expect learners to benefit by articulating their reasoning and responding to agent questions. Learners may also feel as though they can make more mistakes when interacting with an agent rather than a peer (Chase, Chin, Oppezzo & Schwartz, 2009). On the other hand, they may be frustrated by the relative limitations of the agent (e.g., imperfect speech recognition, limited ability to explain its reasoning).

The goals for UbiCoS are twofold: Provide a platform for improved understanding of how collaborative skills transfer across activities and support the development of these productive collaborative interactions by scaffolding learner and teacher practices. These goals are difficult to achieve, as there are several designs and logistical challenges related to building such a complex system. In this paper, we take a first step towards the design and development of UbiCoS by investigating the following research question: What are learners' motivations and strategies for help-giving? To shed light on this question, we engaged in five co-design sessions with middle school learners surrounding this theme. Using the results of these sessions, we can begin to design a curriculum and related technological support that facilitates learner help-giving across multiple platforms.

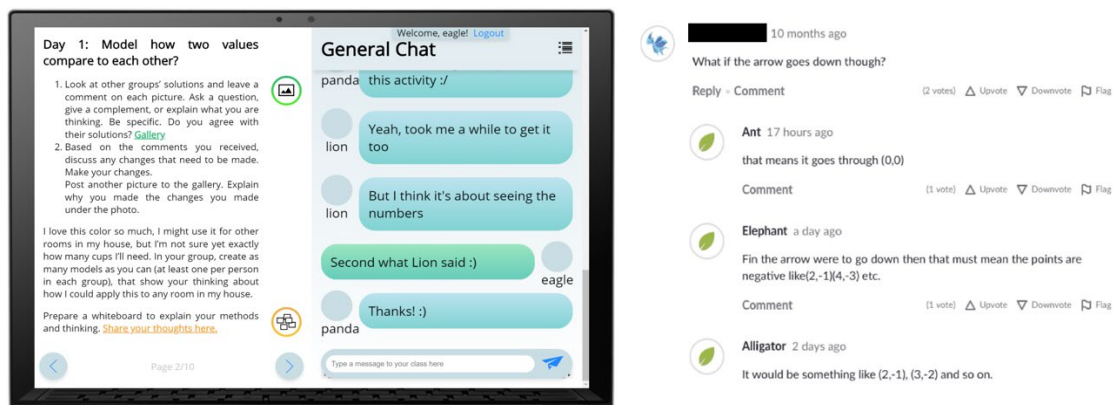


Figure: 1. (left) discussion on the right-hand side of the interactive digital textbook; (right) Khan Academy discussion.

### Student input: Co-design sessions

With the above platforms as our starting point, we conducted a series of co-design workshop sessions with 8th graders to understand learner perceptions of help-giving and how they could inform our approaches for technology and curriculum design. Over seven months, we conducted five after-school two-hour workshops. We followed Sanders' (2003) approach to participatory design, where users' participation reveals their underlying goals and needs. Participants came from different schools within a single school district located in the Southwestern United States and were part of a district leadership program that met regularly after school throughout the year. 87% of learners in the district qualify for free or reduced priced meals. In total, 16 learners participated in the sessions (9 female, 7 male).

To build rapport between learners and researchers, all workshops started with 15 minutes of unstructured social time over food. The goals for the first workshop were to familiarize learners with the project context and goals. Learners interacted with two of the digital contexts (the interactive digital textbook and the teachable agent), and designed achievement badges based on their previous collaboration experiences outside of these sessions, as well as the two technologies they used in the session. The goal for the second and third workshops was to understand how learners conceptualized aspects of technology-based support. In the second workshop, learners participated in a group design activity to brainstorm and create their own intelligent agent within the Khan Academy context, including its appearance, characteristics, and behavior. They were then asked

to draw and describe their agents, as well as to develop a skit depicting interaction with their agents. In the third workshop, we took the Speed Dating approach (Davidoff, Lee, Dey, & Zimmerman, 2007) and presented learners with several scenarios of various help-giving dialogues, enacted by Anki's Cozmo robot ([www.anki.com/en-us/cozmo](http://www.anki.com/en-us/cozmo)). We then had learners write and enact their own dialogues. In the fourth workshop, we further investigated help-giving motivations. Learners played a game where there were opportunities to informally help each other, filled out a self-report questionnaire related to their motivation more generally, and discussed their responses. The goal for the fifth and final workshop was to leverage learners' expertise as users and get their feedback on three preliminary findings and three design ideas. Learners first individually wrote down their thoughts on each item we presented, and then we discussed them as a group.

These sessions resulted in videos, discussion recordings, and paper artifacts. Rather than analyzing each workshop individually, we analyze their results in conjunction to better understand our research questions. Our analysis follows the general inductive method (Thomas, 2006). Several members of the research team initially generated codes for the data. All data was then coded by one of the authors in two distinct passes. To validate the clarity of the coding, another author was handed a set of thirty data points (18.9% of all data) as well as the list of codes and was asked to assign codes to the data. Agreement between both raters was acceptable,  $Kappa=0.692$ . As additional validation, findings were discussed with the learners themselves in Workshop 5 (W5).

Throughout the workshops, learners discussed and demonstrated **motivations for helping others**. Perhaps the most salient reason for helping was **reciprocity**. One should help others because they have helped you before or could help you in the future. For example, when learners developed a script in which an agent tries to convince a learner to help someone else (W3), other learners had the agent appealing to reciprocity: *"They helped you before, so the best thing to do is help them."* Another learner commented on his motivations: *"They always helped you before (...) you're always gonna need help sometime (...) if you help them they might help you."* Along similar lines, learners also expressed the notion of **helping their friends in need**. In W3, when asked for feedback on whether the prompt *"It is a great practice to learn too"* would motivate a learner to answer a question, learners quickly and emphatically replied that it would not. Asked how they would prompt help instead, they proposed *"your friends need help."* Learners also exposed their reasoning for not helping someone as they should **already know the content**. For example, a learner told us about a time when he was aggressive to a request for help in his class: (W3) *"Because we had learned it the year before that, everybody already knew it."* Similarly, learners may also be unwilling to help when they have **already helped several times**. Both groups acknowledged this into their W3 scripts: *"but I already answered it 4 times."* Learners also expressed their lack of time or bad mood as other reasons for not helping.

A second major theme brought up by learners was their **strategy for giving help**. The most striking feature of their strategy was a focus on **empathy and feelings** before actual content. For example, the badges learners developed in W1 highly focused on the social components of help-giving rather than on cognitive ones. Themes such as fighting to bully, being welcoming, and showing etiquette were prevalent across learners' badges. Furthermore, in W2 one of the agents was described as having feelings, and its skit began with the agent automatically detecting that the learner was sad (*"What's wrong?"*) before proceeding with the content explanation. One learner explained the reasoning: *"if you're a strict person giving directions the person you're telling will lose track of you and doze off while you explain it. But if you're friendly, if you are friends with them, you can keep asking if they get it and since they know you they're gonna listen to you better"* (W5). Learners also repeatedly expressed their concern with the **clarity and conciseness of information**. For example, a learner wanted the support to *"give enough information to the point they [learner seeking help] understand"* (W5). Similarly, other learner commented their approach for helping: *"Give them [other student] the key ideas so it helps them better"* (W5) and that we should make sure that *"the information that the system gives is comprehensible and not confusing"* (W5). Finally, there were diverging opinions on **persistence while helping**. When prompted whether they would persist in trying to help someone who needed help, the majority of learners said that they would persist (W5). Learners also expressed **strong reliance on knowledgeable help** (i.e., teachers) especially when they could not help any further. For example, in W5 a learner suggested adding to the textbook app a chatroom with the teacher in case nobody could help you. Another learner suggested that instead of the "Activity recommendation" feature we proposed in W5, we added a "Teacher help" feature. He justified it in this way: *"Every time I ask some of my friends they usually don't understand, so they just ask the teacher."*

## Conclusion

In this paper, we presented results from five co-design sessions that contribute to an understanding of learners' perceptions of and strategies for help-giving by emphasizing learners' focus on helping their peers, their

prioritization of feelings in addition to content, and the need for authoritative sources to confirm the help they are giving. One contribution of our approach is that we present the learners' reports of their perceptions of help-giving behavior and motivations to engage in these behaviors in the classroom. Based on the results from the co-design, we have new insight into how to design curriculum for help-giving across the different contexts. For the interactive digital textbook, it is essential to build on the foundation of a positive classroom community (where learners have bonds of friendship and a mutual history) such that these bonds transfer to the digital setting. Many learners cited previous experiences as their reasons for giving help: Have they helped the person before? Could they in the future? Is the person a friend? They often focused on providing social or emotional support before cognitive. Making both who the learners are helping and their previous relationships salient in the interactive digital textbook may motivate more productive interactions between the learners. Notably, there are different implications for Khan Academy, where the help-seeker may be unknown to the learners. It may be important here to focus on increasing awareness of the help-seeker's performance or existing knowledge, so that learners feel more motivated (e.g., because they can see that the help-seeker has helped others in the past or is genuinely trying to learn the material). Given learners' reliance on more knowledgeable (i.e., teachers) help and connections to their classroom community, bringing learners' peers and teacher into their interactions with other learners on Khan Academy may also be motivating for them. Lastly, we conceptualized the teachable agent as a safe place for learners to practice their help-giving skills. Based on the participatory design results, this may be a good setting for learners to: 1) focus on becoming more confident in their ability to explain in this particular domain, and 2) practice persisting with help in the face of the agent "not understanding." Our findings further suggest that learners may not see the value of the teachable agent, since it is not part of the classroom community, and thus potential benefits should be reinforced by the teacher.

To conclude, we conducted 5 co-design sessions to investigate learners' help-giving motivation and strategies. The results from the sessions will enable the design a CSCL curriculum and technology to support collaborative learning across multiple platforms by facilitating communication and interaction between learners. This paper represents one step towards the ultimate goal of supporting learners in developing their help-giving skills as they move between physical and digital contexts.

## References

- Chase, C. C., Chin, D. B., Opezzo, M. A., & Schwartz, D. L. (2009). Teachable agents and the protégé effect: Increasing the effort towards learning. *18(4)*, 334-352.
- Davidoff, S., Lee, M. K., Dey, A. K., & Zimmerman, J. (2007, September). Rapidly exploring application design through speed dating. In *International Conference on Ubiquitous Computing* (pp. 429-446). Springer, Berlin, Heidelberg.
- Dillenbourg, P., & Jermann, P. (2010). Technology for classroom orchestration. *New science of learning* (pp. 525-552). New York, NY.: Springer.
- Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). *The evolution of research on computer-supported collaborative learning*. Technology-enhanced learning (pp. 3-19). Springer, Dordrecht.
- Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, *38(5)*, 365-379.
- Hiltz, S. R. (1998). *Collaborative Learning in Asynchronous Learning Networks: Building Learning Communities*.
- Lubold, N., Pon-Barry, H., & Walker, E. (2015). Naturalness and rapport in a pitch adaptive learning companion. In 2015 IEEE Workshop on Automatic Speech Recognition and Understanding. (pp. 103-110). (ASRU) IEEE.
- Sanders, E. B. (2003). *Design and the Social Sciences*. (J. Frascara, Ed.)
- Taton, J. A. (2011). *It's School Organized Like a Giant Videogame": Participation Structures Embedded within the Mathematics Content and Curriculum of the Khan Academy*. Working Papers in Educational Linguistics (WPEL) 26.2.
- Thomas, D. R. (2006). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, *27(2)*, 237-246.
- Wu, D., & Hiltz, S. R. (2004). *Predicting learning from asynchronous online discussions*. *Journal of Asynchronous Learning Networks*, *8(2)*, 139-152.

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# School Goes Online With Avatars: Extended Learning in a Secondary School

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**Abstract:** This paper focuses on the initial implications of students' extended activity between virtual and in-presence learning. The study is part of an ongoing project founded in 2018 in a CSCL setting titled "e-PIIm" (Incubator of Immersive Pedagogy for Virtual Reality) taking place in a secondary school in France labelled as pilot in 2016. For this study, some data are selected and qualitatively analysed. The implication of the implementation of the Multi-user Virtual Environment emerge in the field of didactics, student-teacher interactions, and students' corporal and socio-cognitive behaviours; the uses of the MUVE are revealed to be an ongoing transformative learning experience through an extended learning space and institutional change.

## Introduction

For long time, the walls of the classroom and the school were the limited space where students shaped their learning. This "broadcasted mode" gave a central role to teachers and scholastic books. Technology, the multicultural dimension and continuous social and economic change have disrupted and undermined the traditional system: learning environments have multiplied, going online (Tapscott, 2009) in clouds. It is acknowledged that learning technologies do not necessarily involve innovation, rather they are catalysts that, when used well to carry out a communal piece of work or task, allow high engagement and active learning between school and life (Dawley and Dede, 2014) and within virtual communities (Preece, 2001).

One way to extend learning between the classroom and the virtual realm is the use of MUVEs. Made popular by Second Life, the MUVE is an immersive 3D virtual space where people, entering the space via their avatars, meet and interact with one another and with 3D objects in real time. The use of a virtual space in the classroom can introduce changes to how the teacher executes, facilitates and releases the learning through authentic tasks involving 3D object manipulation, creativity and corporal mobility via avatars, which bring change to how the learner acquires, applies and constructs knowledge (Jung & Latchem, 2011). This paper focuses on the initial implications for students' extended activity between virtual and in-presence learning, from the general broad perspective of how technology-supported collaboration can facilitate the sharing and dissemination of knowledge and competencies among community members (Di Blass and Paolini, 2014). The study is part of an ongoing project entitled "e-PIIm" taking place in a pilot secondary school in France (students from 11 to 15 years old). For this study, some data are analysed and initial research results are presented.

## The project: Incubator of Immersive Pedagogy for Virtual Reality

The project "e-PIIm" takes place in a pilot school, in line with the Digital Plan for Education launched by the French government in May 2015 and related to the appropriation of tablets distributed by the academy as part of the "Connected Schools" project. The school set out on the path of digital experimentation in 2016 and is being financially supported by the Digital Education Directorate from 2018 to 2021. The three aims of the project are:

- 1) to propose a scientific study over a period of 4 years (since September 2018). It is about the technological and social conditions of appropriation of virtual reality, in a network of primary and secondary schools;
- 2) to support, on the territory of the academy via a collaborative network, the sharing of knowledge resulting from the joint work of researchers and teachers;
- 3) to create a training guide for trainers or teachers wishing to get involved in this field.

The general project considers Participatory Action Research (Wadsworth, 1998) for an interdisciplinary approach, involving didactics, sociology, psychology and management science. Within this method, participatory and collaborative processes are developed with and the aim of achieving a critical change of practices, through continuous spirals of planning, action, observation, reflection and re-planning (McIntyre, 2008). The research is built on four immersive pedagogy projects developed by the teachers at the school in collaboration with the ITC and research partners: 1) "Interdisciplinary" is an experiment in 3D scriptwriting of lessons (English, Italian, French, History, Mathematics, Technology), on two 5<sup>th</sup>-year classes in which students are asked to build 3D objects in the virtual school and give meaning to them within the framework of a scenario

dealing with the seven new wonders of the world; 2) "*Language and International*" focuses on remote linguistic exchanges between the French students and a class of correspondents, via their avatars who visit and explain the meaning of a virtual exhibition prepared beforehand and showing photos of their favourite places in their city; 3) "*Homework*" is about help with distance work that allows small groups of students to benefit from homework support provided by a school teacher in their home environment at the end of the afternoon; 4) "*Work on SEGPA*": The MUVE is used here for learning in two different trades as well as in general disciplines.

The global strategy of data-gathering, launched back in 2016 and still ongoing, is proposed in a longitudinal approach. A multilevel approach considers the territorial, organisational, collective and individual level. In this way, we view the appropriation of the 3D space from a different, complementary and interdisciplinary perspective, as represented in Figure 1.

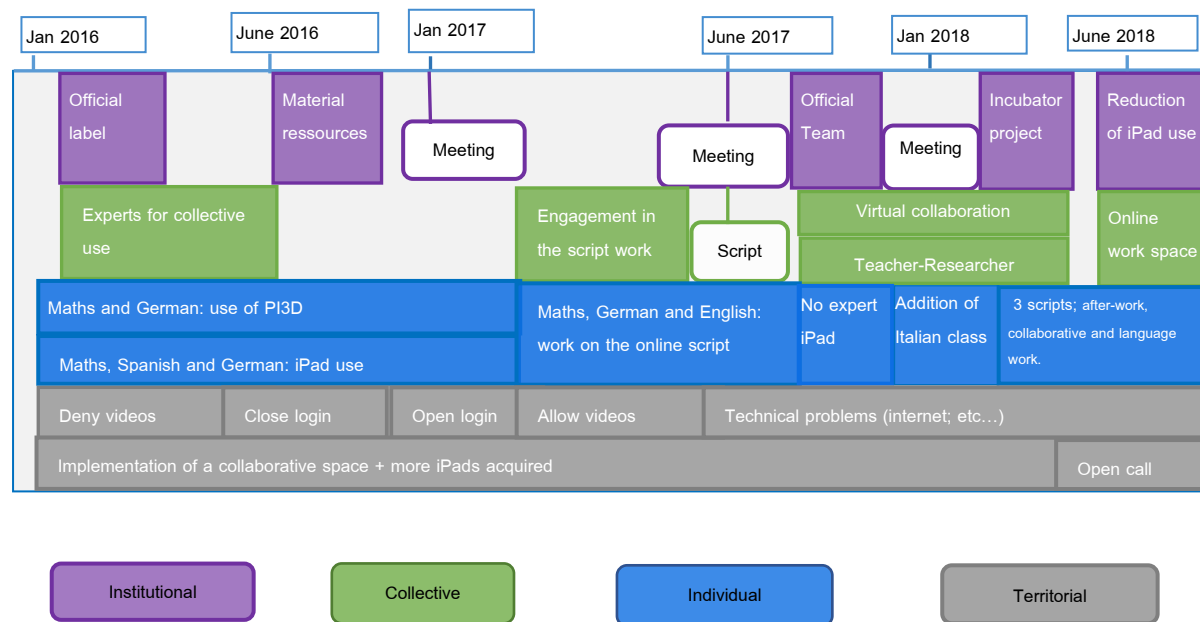


Figure 1. Multilevel approach to data-gathering.

## Methodology

Ethnographic observations (with note-taking and photos), analysis of the virtual space (written text in chat, forum, recording of online activity and online discussion) and collection of practices inside the school (verbal exchanges, report minutes, individual interviews) have been made since January 2016. To organise the data, the NVivo software is used to structure the corpus and encode it with specific dimensions and shared encoding between the researchers' group following a grounded approach.

## The aim of the study

The research questions are: What are the main first direct implications of the project for students' extended activity between virtual and in-presence learning? What indirect implications does the project have for teachers and the school in general?

## Initial analysis of data

For an answer to the research questions of this study about the initial direct implications of the project for students' extended activity between virtual and in-presence learning and the indirect implications of the project for the teachers involved and the school in general, the corpuses of data selected are: five student interviews and direct online and in-classroom observation; nine teacher interviews on different subjects relating to students online and in-classroom activity; two video recordings of meetings between teachers and researchers. An analysis of content and discursive exchanges is applied to data (Bezemer & Kress, 2017). Four dimensions emerged from the selected data: MUVE didactic affordances; MUVE student-teacher interaction; MUVE students' corporal and socio-cognitive behaviour.

## Findings



Regarding the 3D space's affordances for didactic activity, for the teachers, we observed a rise in mental load with an increased permeability between working time and home time for the scripting activity. This time seems counterbalanced by the benefit of being able to make children work with this use of technology. The teachers wonder about the opportunity presented by the introduction of the 3D space in relation to their pedagogical script, linked to the affordances of the technological tools. The understanding of the 3D environment's potential offers new opportunities, as this extract shows: *"When the coordinator told me about avatars, I said to myself, why not? We can exchange objects, and on Skype, it does not always work very well"*. In maths also, the 3D space is interesting to some teachers as it abolishes the physical limitation: *"the skills learned: moving on a map, I extended it to the virtual school, we had only two dimensions"*. For each discipline at the school, the use of the 3D space represents differentiated interests besides the fact that it improves the possibility of situated learning. Students, on their part, stress the evolution of the use of the virtual space, as a girl from 5 class put it: *"We started before the Christmas holidays, but at the beginning we did not go as often as now, when you do not know what to do about it ..."*.

Regarding the effect of the 3D space on student-teacher interaction, linked with the ITC opportunity, teachers suggest that use of the 3D environment improves interaction with students, which can be different, focusing on a new modality of learning. For example: *"In the classroom I move around to advise and help, and it's easier when you have an assistant. On the platform, it is all the more possible because we have the headphones and the microphone, in the classroom it is difficult, there is a lot of noise that can disrupt communication, but in the virtual school not yet"*. The use of 3D helps teachers to interact with students in a new way, with a "silent body", the avatar, which allows idealistic communication without disturbing interferences.

Regarding the effect of the 3D space on the behaviour of the students, the teacher interviews stress the physical implications for their classroom activity. Although the students can be "quieter" in the classroom because they are sitting (*"the students are no longer disturbing the class when they are able to connect"*), paradoxically, students are very active online (*"Children in the space are much more dynamic, there they were very active behind their screen"*). At the same time, the use of the 3D space can also help to support the students in a particular part of the day or of the year, when they are more tired (*"at the end of the year we must also give new motivation to the good students, who begin to get tired, and the students with difficulties..."*). Finally, for the children interviewed, the 3D space represents either a space of creativity, or a space of motivation and resilience used at school as well as at home. The uses of the MUVE when children are at home, helps and support distant exchanges with their teacher in the aid device to homework's in particular. When used to achieve collective tasks in class, it enhances exchanges also, for profiles of very shy children who have difficulty participating.

Regarding the effect of the 3D space on institutional change, during the process and the exchange between teachers, researchers and students, different points are constantly being negotiated, like the right to take pictures of students' faces and the authorisation to destroy 3D objects or virtual documents (*"if we leave the documents in the immersive space, they can be damaged, modified, or deleted, how do we protect them?"*). As a consequence, the script with the MUVE is continually evolving in relation to technical and administrative aspects, linked to the prescriptions of the curriculum and teachers' preferences, like in this teacher's comment: *"... unless the government comes back on those two hours a week, we work together with a maths teacher who guided us to the virtual school: with the avatar it is better to break the ice, offering a nice, warm welcome in a space for discussion"*.

## Discussion

As shown by the initial data analysis, the implementation of the project, and in particular the MUVE technology, have had and still have implication for didactic, student-teacher interaction, students' corporal and cognitive behaviour and institutional change, becoming an ongoing transformative learning experience.

Regarding the 3D space affordances for didactic activity and student-teachers' interaction, we stress how the introduction of technology oblige the teacher and also the student to rethink the traditional model, as widely discussed in the technology. The process of appropriation also includes aspects concerning the mutual influence between the technology and the users (Overdijk & van Diggelen, 2008), with a simultaneous transformation process including the learner and the tool and where the learners are also teachers. The originality of our initial finding lies in the socio-professional and organisational conditions for teachers to develop individually and collectively creative scripts within their professional group

Regarding MUVE students' corporal and cognitive behaviour, the introduction of new digital technologies such as MUVE puts a new non-linguistic, bodily and visually learning dimension at the centre of users' experience, removing language from the dominant vector of the experience. Moreover, teachers are

becoming aware through their experience of the MUVE that extended learning between online and in-presence also implies an embodiment framework as a unifying perspective, considering that all psychological processes are influenced by body morphology, sensory systems, motor systems, and emotions (Glenberg, 2010; Schubert & Semin (2009).

Regarding technology in MUVE institutional change, an educational institution generates tensions between an old system of working and the new one, which needs to be accommodated and assimilated by all of the community involved (Jones & Issroff, 2007). At the same time, the students, teachers and all the administrative staff of the school, supported by the ITC office and also researchers in geographic proximity, need to make sense of the new technology alone and as a group, finding a new opportunity for learning and action.

## Conclusion

The observation and data collected show that this experimentation with a MUVE extends and strongly transforms the learning space by giving teachers, students, parents and the whole educational team the opportunity to exchange, strengthen and build new ways of experiential learning (Jarmon et al., 2009) through projects, involving a wide range of experience (manipulation, social exchange, 3D object creation) from various disciplines. The originality of our work lies in the general application of the MUVE space in the school. We can consider how extended learning is enacted following a multilevel approach, with implications for organisational, collective, individual and territorial transformation. In order for expansive learning to take place, students, teachers and researchers need to be involved in collaborative actions, generating a rich exchange of practices enabling the transformation of the activity. The adoption of the Participatory Action Research, involving the students, the research team, teachers and ITC partners on a daily basis, enables this collective work oriented towards a critical change of practices, through continuous spirals of planning, action, observation, reflection and re-planning. These initial results will be further analysed in the longitudinal appropriation of the 3D MUVE by the school.

## References

- Dawley, L., & Dede, C. (2014). Situated learning in virtual worlds and immersive simulations, in J. M. Spector, M.D. Merrill, J. Elen, & M. D. Bishop (eds), *Handbook of research on educational communications and technology* (4<sup>th</sup> ed., pp. 723-734). New York, NY: Springer.
- Di Blas, N., & Paolini, P. (2014). Multi-User Virtual Environments Fostering Collaboration in Formal Education. *Educational Technology & Society*, 17 (1), 54–69.
- Bezemer, J., & Kress, G. (2017). Young people, facebook, and pedagogy: Recognizing contemporary forms of multimodal text making. *Global Youth in Digital Trajectories* (pp. 22-38). doi:10.4324/9781315303239
- Glenberg, A. (2010). Embodiment as a unifying perspective for psychology. *WIREs Cognitive Sciences*, 1, 586-596.
- Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers & Education*, 53(1), 169-182.
- Jones, A., & Issroff, K. (2007). Learning technologies: Affective and social issues. In G. Conole & M. Oliver (Eds.), *Contemporary perspectives in e-learning research: Themes, methods and impact on practice* (pp. 190–202). London: Routledge.
- Jung, I., & Latchem, C. (2011). A model for education: Extended teaching spaces and extended learning spaces. *British Journal of Educational Technology*, 42(1), 6-18.
- Kukulka-Hulme, A. (2005). Mobile usability and user experience. In A. Kukulka-Hulme & J. Traxler (Eds.), *Mobile Learning: A handbook for educators and trainers* (pp. 45–56). London: Routledge.
- McIntyre A. (2008). *Participatory action research*. Sage, London.
- Overdijk, M., & van Diggelen, W. (2008). Appropriation of a shared workspace: Organizing principles and their application. *International Journal of Computer-Supported Collaborative Learning*, 3(2), 165-192.
- Preece, J. (2001). Sociability and usability in online communities: Determining and measuring success. *Behaviour & Information Technology*, 20(5), 347-356.
- Schubert, T., Semin, G. R. (2009). Embodiment as a Unifying Perspective for Psychology. *Eur. J. Soc. Psychol.*, 39, 1135–1141.
- Tapscott, D. (2009) *Grown up Digital*. New York, NY: McGraw-Hill, Inc.
- Wadsworth, Y. (1998). *What is Participatory Action Research? Action Research International*. Available online: <http://www.scu.edu.au/schools/gcm/ar/ari/p-ywadsworth98.html>

# Moving Between Experience, Data and Explanation: The Role of Participatory GIS Maps in Elementary Science Sensemaking

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**Abstract:** Constructing, sharing, and contesting models of the natural world is central to scientific inquiry (Latour, 1999) yet in K-12 science classrooms, students are rarely engaged in modeling processes of collecting data, authoring varied representational forms, and engaging in science argumentation. Science inquiry also tends to involve faraway locales, distant from students' extensive everyday knowledge of surrounding spaces and places (Barton & Tan, 2009). In this paper, we share findings from the most recent iteration of a larger design-based research project that directly engaged elementary students in modeling a local complex ecological system, the soil ecology underfoot in the schoolyard. We examine how 5th grade students used interactive GIS maps in whole class discussions, moving between their everyday experiences in the schoolyard, the data collection experience, and the classes' aggregated data in reasoning about complex socio-ecological relationships and explanations.

**Keywords:** participatory GIS mapping, elementary science, experiential knowledge

Constructing, sharing, and contesting models of the natural world is central to scientific inquiry (Latour, 1999) yet in K-12 science classrooms, students are rarely engaged in modeling processes of collecting data, authoring varied representational forms, and engaging in science argumentation. By skipping over these modeling practices, students are often left with distorted understandings of the purposes of science inquiry and weaker conceptual understandings of causal systems. Science inquiry also tends to involve faraway locales, distant from students' extensive knowledge of the surrounding spaces, places and people central to their daily experiences. As a result, science is often disconnected from youths' rich daily experiences beyond the classroom walls (Barton & Tan, 2009), limiting what forms of knowledge can be leveraged in science disciplinary learning.

Participatory Geographic Information System (GIS) mapping tools have shown potential in supporting youth integrating their first person experiences in everyday spaces as they reason with complex data about larger socio-political systems and processes (Headrick-Taylor & Hall, 2013; Rubel, Hall-Wieckert & Lim, 2017). Recent research has documented powerful ways in which digital mapping can support both critical conceptual learning and new forms of participation. Yet further research is needed to understand younger students' experiences engaging in participatory GIS mapping and how these digital spatial tools are used by students in collective classroom activity.

In this paper, we examine the most recent iteration of a larger design-based research project that engaged elementary students in participatory GIS mapping of an everyday socio-ecological system, their schoolyard and the soil ecology underfoot (Lanouette, Van Wart & Parikh, 2016). To examine how the interactive maps were used in classroom discussions, we draw on Saxe's framework for understanding cognition as process, with particular concern for how cultural forms come to serve specific functions in collective activity (Saxe, 2012). Using this framework, we focus on how students used the interactive maps as an intermediary form in their whole class discussions as they navigate between their everyday experiences in the schoolyard, their collection of field data, and their aggregated measures to reason about ecological systems (see Figure 1). We ask, how is the GIS map used in children's movement between everyday experiences, data collection experiences, and aggregated data as they construct, share, and contest models of a socio-ecological system?

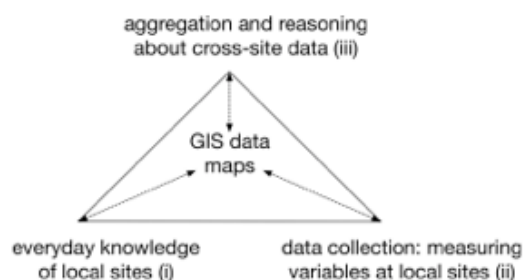


Figure 1. Potential of interactive GIS maps to serve as an intermediary form in collective activity.

## Instructional design and context

This research was conducted in an urban public elementary school (K-5) in the Western United States. In this most recent iteration of the research project, we worked with one fifth grade class of 27 students. The lead author designed and taught an 18-lesson curriculum sequence, focusing students' inquiry on an everyday socio-ecological system, the soil ecology underfoot in the schoolyard. Across these class sessions, 5<sup>th</sup> grade students participated in two rounds of selecting sites for sampling, gathering data out in the schoolyard on both biotic (total invertebrate counts, earthworms, roots) and abiotic (soil moisture, soil compaction, soil color, soil composition) indicators, and collectively creating varied visualizations with the classes' aggregated data (bar charts, two way tables, paper data maps, digital GIS maps).

Throughout the curriculum, students used *Local Ground*, an interactive web-based mapping platform (Van Wart & Parikh, 2013), from early discussions marking potential schoolyard sampling sites to exploring relationships in the aggregated data maps. Three key design principles guided the iterative development of the tool design, including supporting (a) multiple data types, such as drawings, photos, audio recordings, and text notes in conjunction with quantitative data forms, (b) engagement in end-to-end mapping and data processes including designing protocols, analyzing data, and representing findings in varied formats; and (c) collaboration, where youth can collectively author the same map or create multiple variations drawing from the same collective data set.

## Methods

In this analysis, we examined three student-led whole class discussions where 13 student pairs took turns presenting interesting or puzzling patterns in the class-level data using the interactive GIS maps. We selected these lessons because they involved students leading collective discussions about ecological relationships and explanations, with classmates' questions and counterclaims interspersed. As each pair presented, they controlled the *Local Ground* interface using a laptop computer next to a large projected screen (see Figure 3b). Data sources include two video angles of the whole class discussion, screen capture data, and audio recordings.

We engaged in two phases of analysis to examine how students were leveraging their everyday knowledge of the schoolyard and their experiences collecting data as they used the interactive GIS maps to reason about ecological relationships and conjecture possible explanations. In the first phase, we marked all instances of children's everyday knowledge and data collection and transformation experiences as the pairs shared and contested relationships in the data. This coding enabled visualizing not only the frequency of children's uses of these different nodes but more importantly, it illuminated how students were moving between these different nodes as they reasoned about key ecological relationships and processes.

In the second phase, we focused on how students used the maps within pairs' presentations. Findings from an earlier iteration of this design project documented students' shifting between the map, the data, and hybrid blending of the map features and the data (Lanouette, Van Wart & Parikh, 2016). In this analysis, we documented more subtle uses of the interactive maps as they emerged in conversation. For example, as students leveraged the spatial dimensions of the color photo map, we noted how it was used to serve different functions such as enabling children to gather more information about a particular spot (e.g., seeing if there were trees in a location) or to ground a specific recollection, memory, or experience in a location. Similarly, as kids worked with the aggregated data, we noted varied movements *within* the data, from examining just one variable to multiple variables, or focusing on just one site or several sites.

## Findings

We first briefly describe students' experiential knowledge that surfaced as they reasoned about relationships in the data and conjectured possible explanations. We then present one vignette from a larger corpus of microanalytic moments that detail how students used the interactive GIS maps as they moved between different dimensions of their experiential knowledge and the aggregated data.

### Children's experiential knowledge

Children's everyday knowledge of the schoolyard spanned ranged from particular moments in one location (e.g., "I used to pet bees there when I was in third grade) to considering specific locations across time (e.g., "That spot tends to flood in the winter months, when it rains a lot"). Children's knowledge also encompassed multiple modalities, from recalling sounds, smells, and physical pathways of movement to affective feelings rooted in particular places. It included detailed knowledge of the natural environment, such as knowledge of sunlight and shade patterns, areas prone to flooding and plant and animal distributions. Across the three lessons, students in these three lessons drew on their everyday knowledge 57 times, expressed in verbal utterances and accompanying

gestures that further elaborated dimensions of their knowledge (such as movement patterns, particular angles of sunlight, feelings in particular places). Children drew on their experiences collecting and transforming data, including first-person experiences at pairs' own site gathering data as well as general knowledge about data collection tools and processes for using these tools (e.g., soil compaction instruments and procedures for measurement). Children also drew upon their experiences transforming the data, as they moved from field note sheets full of sketches, text notes, and tally marks to symbolized and digital forms where several counts were collapsed into categorical ranges. Across the three lessons, students drew on their data collection and transformation experiences 28 times.

### Interactive GIS map as an intermediary form

In earlier class discussions, students had been noticing a strong relationship between earthworm counts and soil moisture levels in the aggregated data but when Lena and Max presented, they offered a more complex conjecture: high earthworm counts occur in locations with moist soil, shade, and roots. With their initial data map view set to the garden and earthworm data selected (Figure 2a), Lena began talking:

“So I am going to disagree with Mia, sorry. I think it [high earthworm counts at sites] actually has a lot to do with shade and stuff because worms need lots of moist soil and ... shade too. See at the garden (pointing to the garden area), there is lots of shade because there are lots of trees. Now go to the pond (talking to Max, who adjusts the map), and so at the pond, as you can see there is a lot more sunlight (pointing to the sunny pond areas in a sweeping motion) and there is not a single eleven or more worms (pointing to data variables on right side of map) because there is so much sunlight and the soil isn't really moist, most of it is dry so I think shade and soil moisture have a lot to do with worms (see Figure 2b).”

Lena and Max then explain that their second sampling site near the playing fields shows this proposed relationship perfectly, with high earthworm counts, shade, moist soil, and lots of roots (Figure 2c).

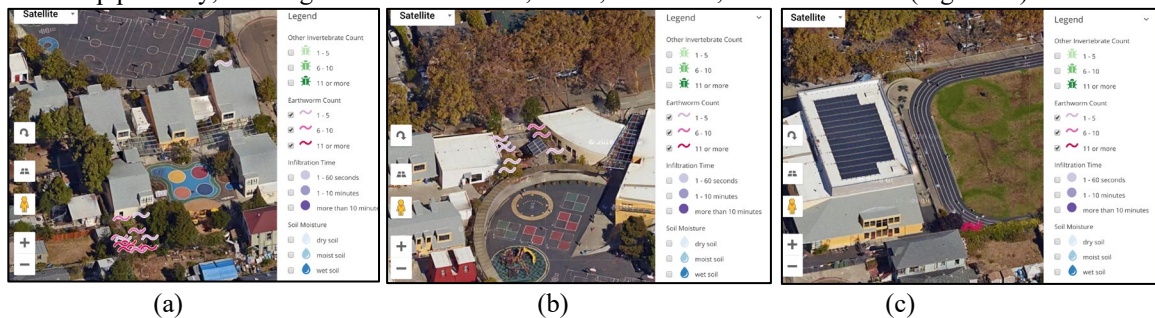


Figure 2. Screen captures of Lena and Max's shifting maps, including the garden (a), pond (b), and playfield (c).

Lena and Max then open up the discussion for questions and comments, with Marcel starting off: “So right now the cherry tree is really bare so there is still a lot of sun there and that and you said that places where there is shade and so it is not providing barely any shade.” Lena replies quickly, adding “Yeah but well, our lavender bush is creating lots of shade.” Lena continues, using extended gestures to clarify her site location, showing how shade cast by the lavender bush by moving her cupped hand back and forth. Lena then turns abruptly to the map and says, “See this one [plant], right here... see, it is super full” moving the pointer stick and then her own hand to land on the site on the large map (see Figure 3a). Max simultaneously moves back to the laptop, zooming in the map to show their site's location and plants into closer view (see Figure 3b).

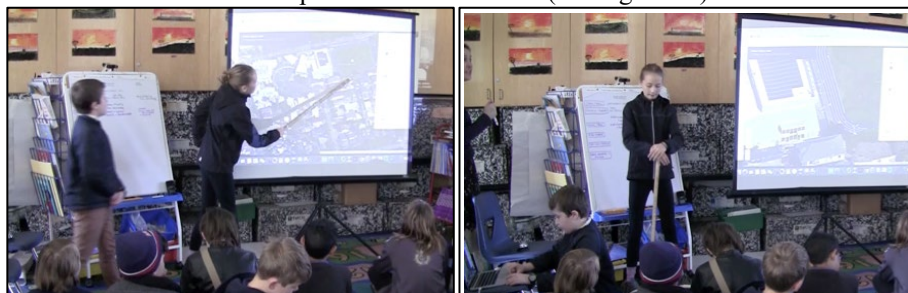


Figure 3. (a) Lena pointing to her sampling site, referencing the shade provided by nearby plants and (b) Max moving to the laptop computer that controls the map, using it to zoom into their exact site.

Another child, Ellis, is then called on by Lena and Max. He uses his group's site data and experience collecting data to refute Lena and Max's earlier proposed relationship. Ellis says: "Well so, I actually kind disagree with this because like, first of all, our group, we basically have the same circumstances as you... we have a lot of shade, we have moist soil, and we have roots down there too and we've only found one worm so far and we are in that tucked away corner in the garden." Ellis then moves up to the laptop, shifting the map view to his garden site, with relevant variables clicked on to include soil moisture and earthworm counts.

Throughout this short exchange, students used different aspects of the map to serve different functions in sharing and contesting potential relationships in the data and plausible explanations for these relationships. Lena and Max begin by showing earthworm counts in the garden and pond area before settling in on their second sampling site along the playing fields, moving back and forth between the spatial aspects of the color map and selected symbolized variables. Two counterclaims are raised, with students drawing on their everyday knowledge of the schoolyard, the data collection experience, and the interactive map in flexible ways. One child, Marcel, questions the likelihood that one variable, shade, was actually a factor at their location, drawing on his everyday knowledge of that space. Lena and Max respond, arguing that several plants at the site provide shade, using extended gestures and the color map to describe the particular site. A second child, Ellis, also contests Lena and Max's conjecture that high earthworm counts are related to soil moisture, shade, and roots. He draws on his own site data gathered in the garden and the first-hand experience of collecting data, changing the map to show his group's site and several symbolized data points.

## Conclusions

Across these class sessions, children used the interactive GIS maps in flexible and inventive ways as they moved between their everyday experiences in the schoolyard, the data collection and transformation experiences, and reasoning about patterns and relationships in their abstracted data. Our findings suggest that by situating elementary students' science inquiry in everyday spaces and engaging them in modeling processes of observation, measurement, and collective discussion using participatory maps supports generative opportunities for learning. Details such as sunlight against a fence, shadows cast by buildings, and children's movement across the schoolyard were accessible and integrated into sharing and considering their peers' proposed relationships and explanations. In reasoning this way, children were able to leverage their vast experiential and everyday ways of knowing in grappling with the complexity of a local socio-ecological system.

## References

- Barton, A. C. & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching*, 46(1), 50-73.
- Lanouette, K., Van Wart, S., & Parikh, T. (June, 2016). Supporting elementary students' science learning through data modeling and interactive mapping in local spaces. In Looi, C.K., Polman, J., Cress, U., & Reimann, P. (Eds.), *Transforming learning, empowering learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 1* (pp.570-577). Singapore: International Society of the Learning Sciences.
- Latour, B. (1999). *Pandora's hope: Essays on the reality of science studies*. London: Cambridge University.
- Rubel, L. H., Hall-Wieckert, M., & Lim, V. Y. (2017). Making Space for Place: Mapping Tools and Practices to Teach for Spatial Justice. *Journal of the Learning Sciences*, 26(4), 643-687.
- Saxe, G & Esmonde, I. (2012). *Cultural development of mathematical ideas: Papua New Guinea studies*. Cambridge University Press.
- Taylor, K. H., & Hall, R. (2013). Counter-mapping the neighborhood on bicycles: Mobilizing youth to reimagine the city. *Technology, Knowledge and Learning*, 18(1-2), 65-93.
- Van Wart, S. & Parikh, T. (2013). Increasing youth and community agency in GIS. *GeoHCI Workshop at CHI*.

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## Young Interpreters: The Situated as Supportive

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**Abstract:** Across the United States schools are largely segregated by race, creating schools that are densely Hispanic and teaching staff that is overwhelming monolingual English speakers. This has created difficulty in home communication in these schools. This study looks at ongoing design-based research efforts to engage bilingual students in helping their teachers become more capable of communicating in Spanish. Through online-delivered challenges teachers and students work together to complete a series of tasks that help teachers learn about communicating across cultures and preparing several communication-aids to help them reach out more frequently. Through a narrative profile analysis, we uncovered the types of influences the five-week intervention can have on teacher's home communication efforts, beliefs in their own ability to develop stronger language skills, and relationships with students, and we trace the implications these efforts have on teacher practice, design iterations, and scaling.

The frequency and types of interactions between teachers and parents have important implications for both students and families. When teachers and school officials reached out to parents regularly, Epstein (1991) reported that parents are more likely to help their students with projects and assignments. The same study concluded that as parent involvement increased, parents were also more likely to feel positive about their children's abilities to succeed in school. Recent meta-analyses arrived at similar conclusions (Castro et al., 2015; Jeynes, 2003).

Communication with parents becomes increasingly complex for teachers when they don't speak the same language. Gandara (2005) described this widespread problem: "Typical respondent comments cited the teacher's inability to speak the parents' language. While teachers acknowledge the value of family and community in the education of these students, many feel unable to call on this critical resource" (p. 10).

It may well be the case that increased training is requisite for making inroads in-home communication efforts with Spanish-speaking families. Gandara (2003) noted that among teachers who taught English Language learners (ELL), 23% of them reported that they had trouble communicating with the parents of ELLs. That number went up to 30% when the teacher had received no or almost no training on communicating with parents of ELLs. These numbers are likely much higher in regular education classrooms, where teachers are much less likely to receive special training for communicating with the families of ELLs.

We report on the efforts to offer online training modules that present a problem-based scenario where teachers and students use their respective skills to build bilingual communication aids designed to enhance school-home communication. In this way, the types of situated skills that students develop in their everyday lives can lend support to teachers trying to communicate with parents.

There is cursory evidence to suggest that students have the resources to help teachers navigate the tensions that can arise between wanting to communicate more with Spanish-speaking families and not having the ability to do so quickly and effectively. Both Valdés (2014) and Orellana (2009) document the social and cognitive benefits as well as particular skills developed by the children of immigrants who grow up translating and interpreting for their parents. Particularly, they highlight young interpreters' skills and abilities to translate effectively, help teachers understand community norms of effective communication, and navigate the power of student-teacher relationships in a way that is mutually enriching.

This paper presents preliminary findings from a design-based research intervention, "Spanish For Lunch" (SFL). This intervention aims to incorporate the Spanish language abilities of students, specifically by involving young interpreters as the principal facilitators of phrase-based Spanish instruction. Our research into the intervention uses qualitative, interview methods to learn about the teachers' experiences using the online resources to structure the challenges and work with their students to help them to both communicate with families and build partnerships with students.

This narrative research study (Seidman, 2013) was guided by these research questions:

1. How does participating in the SFL program aid teachers in developing positive, frequent, and supportive communication with Spanish speaking parents?



2. How does participating in the SFL program strengthen teachers' beliefs and attitudes toward their ability to communicate with Spanish speaking parents?
3. From a teacher's perspective, what type of partnerships form between teachers and students who participate in the SFL program?

In the pilot work from 2018, six 6th-8th grade teachers from both urban-public and urban-charter schools in the western United States selected two to six bilingual students from their classes to collaborate with them on the translation challenges. Student selection was solely at the discretion of the teachers.

The program consisted of five online modules for teachers and an equal number of online videos for students. These online materials guided both groups through five weekly meetings to create different communication aids for a specific home communication task each week (greeting parents, writing a get-know-you-letter, writing positive-template texts, scripting a short-positive phone call, and scripting a parent-teacher conference). After reviewing their respective online materials, the students collaborated with teachers by helping them select and translate a group of phrases that meet the requirements of the challenge each week. During their weekly meetings, teachers and students talk through the question and the guiding question, and then come up with several phrases that answer the question. The students translate these phrases as the teacher writes them down and practices saying each one. The teacher takes a picture of each completed communication aid. Figure 1 shows an example of one of the challenges.

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**Template texts:**  
 What are five positive phrases you would like to text to parents?

Example "Text"

- \_\_\_\_\_ scored 100% on his test.
- \_\_\_\_\_ sacò un cien en su examen.

1)  
 2)  
 3)  
 4)  
 5)

You may wish to use this paper to draft the texts on this paper before transferring them to a larger poster that can be hung up in your classroom.

- Some teachers have also decided to turn some of their templates into cards with compliments or a short message they can mail to parents asking them to call the front office and set up a time to meet with them and a translator.

**Figure 1.** Example from template text challenge.

After completing all five of the challenges the teacher receives a micro-credential, a digital portfolio certificate of completion that can be stored online, as a certificate of their completion. The schematics of the program are displayed in Figure 2.



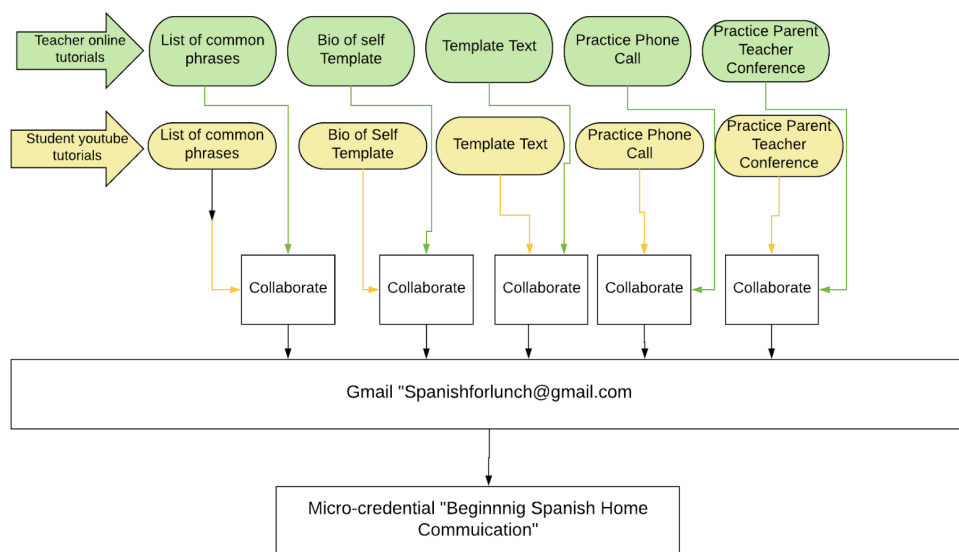


Figure 2. Program workflow.

Before we began the intervention, we held a 45-minute semi-structured interview with all six teachers. The purpose of this interview was to gather information about the teachers' attitudes and perceptions toward home communication and partnerships with students. During the second and third interviews, also semi-structured 45-minute interviews, we gathered stories and anecdotes from teacher's experiences using the program materials, meeting with students, and using their communication aids to reach out to parents. These interviews took place during week three of the intervention and within one week of the end of the training. Figure 3 shows the timeline for each of the phrases of the intervention.

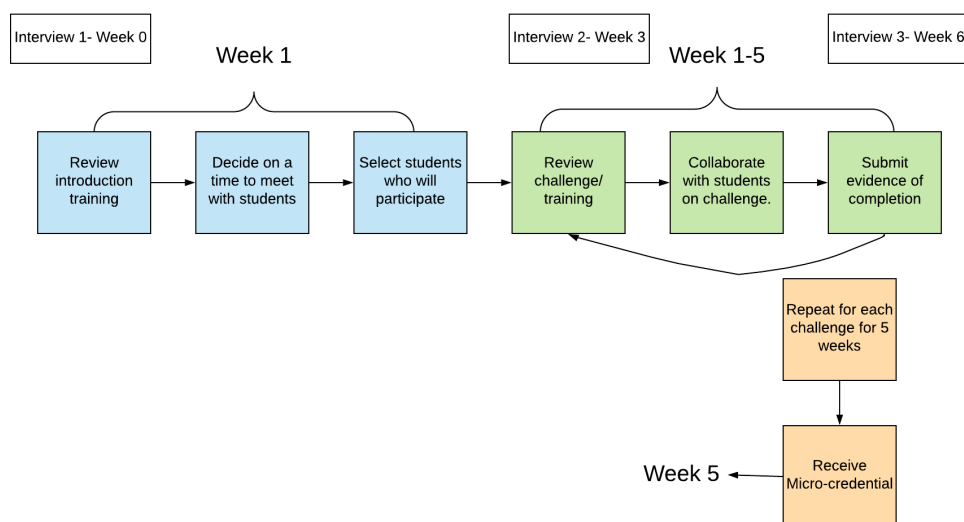


Figure 3. Timeline of interviews and challenges.

We created narrative profiles of each of the teachers' experience using the Seidman (2013) process. This included creating a transcript of all of the teacher's relevant comments related to their experience, and then eliminating experiences that seemed non-essential. This was repeated again to produce the final narratives. We sought to uncover what elements of the program helped teachers reach out more, develop the capacities they wanted to develop, and form partnerships with their students. Specifically, we looked closely at the way that the teachers describe the development of the program. For example, we wanted to see how the teacher described his/her communication with families in interviews one, two, and three to see if there is a narrative of growth to be uncovered.

We found that the program did not have a significant impact on teachers' communication attempts across all five teachers, but those teachers who reached out most, we encouraged by their growth. Additionally, we found that teachers Spanish did not improve significantly, but their belief that these kinds of activities could be very beneficial was a recurrent theme. Specifically, the teachers felt that they were able to focus on the kinds of phrases that they needed to know, and learn them in a hands-on-environment. They were also encouraged by the patience of the students as they coached them through pronunciation and spelling. Finally, we found that all of the teachers reported that working with students strengthen their relationships with them by establishing complementary roles, sharing cultural values, and sharing personal experiences.

Finally, we found that several teachers discussed changes that they were considering making to their teaching practice based on the experiences in working with students. For example teachers talked about more frequently providing places for students to act as teachers in the classroom, focusing on examples where the teachers had made mistakes, modeling making mistakes in front of students, and exemplifying life-long learning by try to develop new language skills.

## References

- Epstein, J. L., & Dauber, S. L. (1991). School programs and teacher practices of parent involvement in inner-city elementary and middle schools. *The Elementary School Journal*, 91(3), 289-305.
- Castro, M., Expósito-Casas, E., López-Martín, E., Lizasoain, L., Navarro-Asencio, E., & Gaviria, J. L. (2015). Parental involvement on student academic achievement: A meta-analysis. *Educational Research Review*, 14, 33-46.
- Jeynes, W. H. (2003). A meta-analysis: The effects of parental involvement on minority children's academic achievement. *Education and Urban Society*, 35(2), 202-218.
- Gandara, P., Maxwell-Jolly, J., & Driscoll, A. (2005). Listening to Teachers of English Language Learners: A Survey of California Teachers' Challenges, Experiences, and Professional Development Needs. *Policy Analysis for California Education, PACE (NJI)*.
- Gandara, P., Rumberger, R., Maxwell-Jolly, J., & Callahan, R. (2003). English Learners in California Schools: Unequal resources, 'Unequal outcomes. *Education Policy Analysis Archives*, 11, 36.
- Orellana, M. F. (2009). *Translating childhoods: Immigrant youth, language, and culture*. New Brunswick, NJ: Rutgers University Press.
- Seidman, I. (2013). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. New York, NY: Teachers College Press.
- Valdés, G. (2014). *Expanding definitions of giftedness: The case of young interpreters from immigrant communities*. New York: Routledge.

# Collaboration Script Appropriation in a Science Class

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**Abstract:** This paper presents how a collaboration script informed by the Funnel Model was appropriated by a class of students in a secondary science class lesson. Based on the script, a class of 33 tenth grade students enacted four stages of a technology-supported collaborative learning activity: individual construction, intra-group construction, inter-group rating, and intra-group refining. Quantitative and qualitative analyses of students' behaviors and perceptions were conducted to identify and explain how students appropriated the collaboration script.

## Introduction

Collaboration script is an important topic in the field of computer-supported collaborative learning (CSCL) (Fischer, Kollar, Stegmann, & Wecker, 2013; Yun & Kim, 2015). While collaborative learning when aptly designed and enacted has been shown to be helpful for students' higher-order thinking (Lazarou, Sutherland, & Erduran, 2016), students may not be substantively engaged in the process of sharing, communication or negotiation. The embedded collaboration script can help to provide a structured collaborative learning scenario, such as associating group learners with specific tasks, roles, and resources, or designing an interactive structure for group learning (Tsovaltzi, Puhl, Judele, & Weinberger, 2014). Many researches focus on scripting individual and collective regulatory processes (Borge, Ong, & Rosé, 2018; Wang, Kollar, & Stegmann, 2017), learners' appropriation (perception, understanding and embodiment) of the script was also an important factor influencing their collaboration learning (Tchounikine, 2016). In this context, we worked with a school teacher to implement a collaborative learning lesson, and studied how each group appropriated the collaboration script.

We propose a script based on Funnel Model that is a pedagogical model guiding for collective knowledge improvement (Chen, Wen, & Looi, 2012; Wen, Looi, & Chen, 2011). This model abstracts the process of group interactions into three stages: "brainstorm", "rise above", and "advance." We developed an online system called AppleTree to tightly embody Funnel Model (Chen, Looi, Wen, & Xie, 2013) in the system design. In this study, we focus on investigating: 1. Whether and how was the use of AppleTree system with the collaboration script helpful for improving students' conceptual knowledge learning? 2. How did the students appropriate the collaboration script and what factors affected their appropriation of the script?

## Research design

We employed design-based research to design and implement collaborative learning activities using AppleTree for secondary grade ten class with 33 students in Singapore. These students studied physics phenomena over three weeks (one lesson per week and each lesson was a cycle of the design-based research) using the AppleTree system. All the 33 students were heterogeneously grouped by the teacher according to their previous test scores on Science. There were nine groups of 3-4. The data analyzed in this paper were from lesson 3 on the topic of electromagnetic induction phenomenon. In this lesson, students in each group first conducted their own hands-on experiment to observe the induced current flowed in a solenoid over time when a magnet fell through it. Each student in groups needed to sketch a current-time graph based on what she observed in the experiment. To deepen the students' understanding on electromagnetic induction phenomenon, the teacher provided students opportunities to inquire and explain the phenomena that they observed on the AppleTree system. The purpose of collaborative learning is to integrate the conceptual knowledge of group and class members to facilitate complete and reasonable explanations. Below are the details of students' activities.

Stage 1: Every student was asked to provide explanations to elaborate the current-time graph on their group space in AppleTree system.

Stage 2: After each member of a group provided at least one explanation, they negotiated, challenged and revised their explanations (Figure 1).

Stage 3: Students went to the workspace of other groups to review their group artefacts and provide comments. Students were asked not only to rate others' explanations, but also to provide comments for

others to improve. In this lesson, the teacher asked group 2 to visit group 1; group 3 to visit group 2, and so on.

Stage 4: All the students returned to their own group to further revise and refine their own group's artefact based on the feedbacks provided by others.

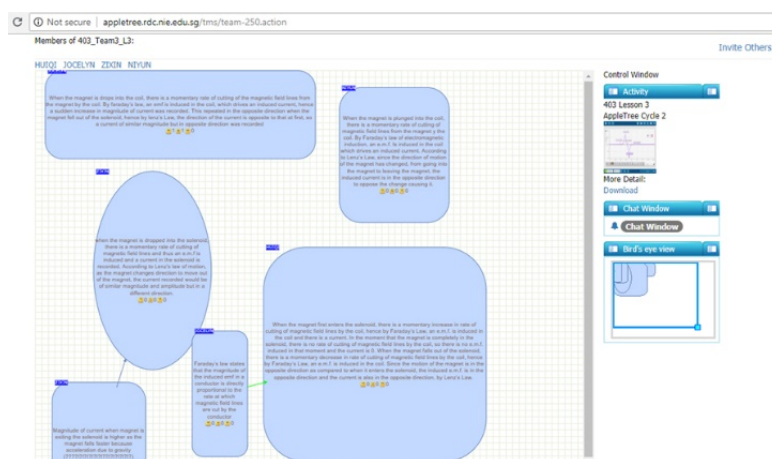


Figure 1. The interface of stage 2.

### Coding scheme for analyzing students' revision behavior

The first author analyzed all of students' revisions several times and created open codes. Then, these open codes were clustered as primary themes. Third, the obtained themes were validated again by checking the data against the themes and were merged and modified. The final coding scheme is shown in Table 1.

Table 1: The coding scheme for students' revision of explanations

Post	Add (+)	Link	Modification Content	Delete (-)
• Explanation	• Knowledge support	• Partial modification	• Post	
• Data	• Emotional support	• Completely modification	• Link	
• Reasoning	• Knowledge against			
• Irrelevant content	• Query			

### Coding scheme for analyzing students' comments

The coding scheme adapted from Lu & Law (2012)'s studies was used to code students' comments. Content analysis was conducted to examine the categories of comments (e.g., identifying problems or providing suggestions). The unit of content analysis in this study was a comment. The first and third authors independently coded all the comments, with an inter-rater reliability of 0.736 (Cohen's Kappa).

### Pre-test and post-test design

Pretest and posttest used the same text paper, which contained 4 questions, one point for each question. The test questions were closely related to the knowledge points in this lesson.

### Data collection and analysis

The data collected in this study included 1) students' pre-test and post-test scores on their scientific knowledge of the concepts; 2) all group artifacts generated on AppleTree and; 3) students' post-intervention interview data. We echo with Tchounikine (2016) that learners would appropriate the script and its technology both as individuals and as a group. "With respect to appropriation, we do not see individual and collective perspective as incoherent." (Tchounikine, 2016, p.366). Therefore, in this study, we investigated how students appropriated a collaboration script as a group based on their learning process data. Meanwhile, we required individual students to reflect on their experiences of collaborative learning based on two guiding questions in the post-

intervention interview: 1. What did you do at each stage of collaborative learning activity? 2. What factors may affect the revision of your explanations at each stage of collaborative learning activity?

## Findings

### The improvement of conceptual knowledge.

Descriptive statistics and the Wilcoxon signed Ranks test was used to detect differences between pretest and posttest. The results showed that the students' post-test score ( $M=3.70$ ,  $SD=0.83$ ,  $Z=-4.647$ ,  $df=32$ ,  $p<0.001$ ) was significantly higher than the pre-test score ( $M=2.58$ ,  $SD=0.529$ ,  $Z=-4.647$ ,  $df=32$ ,  $p<0.001$ ).

### The observable behaviors of the script appropriation

All the groups were engaged in the activity, but not all the groups followed all the stages. We calculated the number of explanations posted by students as a group at stages 1, 2, and 4 respectively. All the groups, except for group 2, revised their group artifacts and contributed new ideas after the intra-group discussion. Only group 7 and group 8 contributed new postings at stage 4. For those groups who did not generate new postings, they revised their existing postings. Students revised group artefacts 56 times in stage 2 and 4 (see Figure 2).

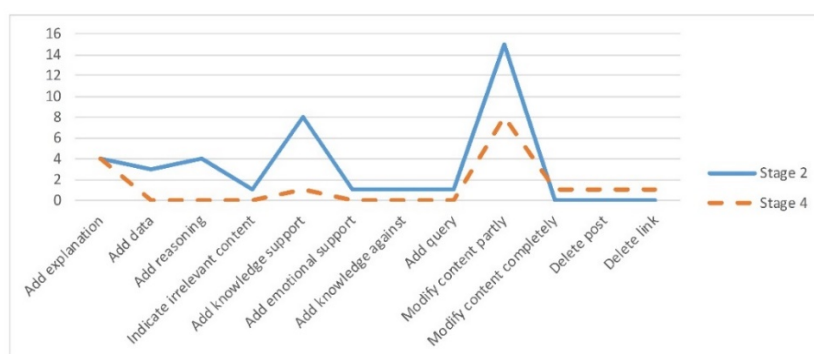


Figure 2. The number of changes in stage 2 and stage 4.

All the groups provided comments for others but the quality of comments was uneven. A total of 79 comments were provided in stage 3, see Table 2. Students provided more comments related to “Identifying problems” and “Positive”. Comments related to “Editing language” were rare, and negative comments did not appear.

Table 2: The number of comments (by type)

	Categories	Example	Number
Cognitive	Identifying problems	“Why does the direction change?”	31
	Providing suggestions	“Talk about different direction of currents.”	11
	Providing explanations	“It becomes zero cos there is no more cutting of magnetic field lines!”	2
	Editing language	“Wrong SIN spelling.”	1
Affective	Negative	“You did not even do it!”	0
	Positive	“Very detailed explanation.”, “Good explanation.”	38

Note. 4 of 79 comments were double-coded as belonging to two categories.

### The perception of the collaboration script

Students' reflections on collaborative learning experiences in the post-interview were analyzed. In stage 1, students independently expressed their ideas and input them into the AppleTree platform directly until the end of this stage. Each group member gave only one or two explanations in this stage. In stage 2, students mainly revised their own explanations. They only gave a suggestion for revision rather than revised the explanation directly. In stage 3, students actively commented on other group's explanation and brought good explanations back to their own group. In stage 4, students carefully read the comments given by other group members. But, some factors hindered students' revision of their explanations, such as students' understanding of the scientific conceptual knowledge, and the limited time of this stage.

## Discussion and conclusion

This study elaborates how students appropriate the collaboration script based on the empirical data from students' behaviors and perception, as well as explores out the factors that may affect students' appropriation of collaboration script. Firstly, the findings show that students' conceptual knowledge influences their appreciation of collaboration script. As far as science is concerned, students need to judge the validity of explanations or comments in the process of deleting, revising and integrating. If students cannot judge the validity of the conceptual knowledge, they will find difficult to complete the task in stage 2 and 4. Secondly, time is an important factor influencing students' appropriation of collaboration script. As shown in the study, even if the students had been well aware of the collaborative learning process, they did not have enough time to further refine their explanations. Thirdly, students' appropriation of collaboration script may be influenced by other factors such as culture. In the Asian culture, it is usually considered not polite to point out others' mistakes directly. It is observed that even if there was inconsistency among students' explanations within the group, students did not take the initiative to revise other group members' explanations, but they would modify the postings that originally posted by themselves if necessary. Nevertheless, this may be also because the students were still in the early stage of collaboration, so they still lacked sufficient group-awareness. A future longitudinal study will be conducted to further explore it. The current study provides insights on the factors that need to be considered when designing and implementing collaboration script for school students.

## References

- Borge, M., Ong, Y. S., Rosé, C. P. (2018). Learning to monitor and regulate collective thinking processes. *Internal Journal of Computer-Supported Collaborative Learning*, 13(1), 61-92.
- Chen, W., Looi, C. K., Wen, Y., & Xie, W. (2013). AppleTree: An assessment oriented framework for collaboration and argumentation. In N. Rummel, M. Kapur, M. Nathan & S. Puntambekar (Eds.), *Proceedings of Computer Supported Collaborative Learning (CSCL) 2013 (Part 2, pp. 6-9)*. Madison, USA: International Society of the Learning Sciences.
- Chen, W., Wen, Y., Looi, C.K. (2012). Technology enhanced pedagogical innovation in second language learning. *Global Chinese Journal for Computers in Education*, 8(1/2), 122-133.
- Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist*, 48(1), 56-66.
- Lazarou, D., Sutherland, R., & Erduran, S. (2016). Argumentation in science education as a systemic activity: An activity-theoretical perspective. *International Journal of Educational Research*, 79, 150-166.
- Lu, J., & Law, N. (2012). Online peer assessment: Effects of cognitive and affective feedback. *Instructional Science*, 40(2), 257-275.
- Tchounikine, P. (2016). Contribution to a theory of CSCL scripts: taking into account the appropriation of scripts by learners. *Internal Journal of Computer-Supported Collaborative Learning*, 11(3), 349-369.
- Tsovaltzi, D., Puhl, T., Judele, R., & Weinberger, A. (2014). Group awareness support and argumentation scripts for individual preparation of arguments in Facebook. *Computers & Education*, 76, 108-118.
- Wen, Y., Looi, C. K., & Chen, W. L. (2011). Towards a model for rapid collaborative knowledge improvement in classroom language learning. In H. Spada, G. Stahl, N. Miyake & N. Law (Eds.), *Proceedings of Computer Supported Collaborative Learning (CSCL) 2011 (Part 2, pp. 836-840)*. Hong Kong, China: International Society of the Learning Sciences.
- Wang, X., Kollar, I., & Stegmann, K. (2017). Adaptable scripting to foster regulation processes and skills in computer-supported collaborative learning. *Internal Journal of Computer-Supported Collaborative Learning*, 12(2), 153-172.
- Yun, S. M., & Kim, H. B. (2015). Changes in students' participation and small group norms in scientific argumentation. *Research in Science Education*, 45(3), 465-484.

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# Understanding the Connections of Collaborative Problem Solving Skills in a Simulation-based Task Through Network Analysis

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**Abstract:** As one of the identified key 21st century skills, collaborative problem solving (CPS) attracted attention from both education research and the assessment industry. Studies and assessments were developed to conceptualize and to measure CPS skills. Most studies operationalized different dimensions of CPS skills as discrete measures even though they may be interweaving in the construct. In this study we went beyond the separate measures on the different dimensions and focused on the connections among these skills. Using log data of 20,947 events on actions and chats from 43 teams, we studied how different dimensions of CPS skills were connected as reflected in problem solving. CPS skill networks were constructed to capture the co-occurrence of the skills in turns during collaboration. The results showed that teams with high and low performance had significantly different CPS network structures.

## Background

Competencies such as collaborative problem solving (CPS) are considered increasingly important for career and academic success in the 21<sup>st</sup> century. As individuals move through school and into the workforce, they will be expected to work with others to make decisions, solve complex problems, and generate novel ideas, and many times in contexts in which team members are not in the same physical location. The awareness of these changes has motivated interest in education and assessment industries in developing and assessing skills such as CPS. A number of recent efforts have been put forth that seek to conceptualize CPS and create assessments for CPS (e.g., Andrews et al., 2017; Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, 2015; Liu, von Davier, Hao, Kyllonen, & Zapata-Rivera, 2015; OECD, 2013) However, most projects operationalize different dimensions of CPS skills as discrete measures, and the connections among CPS skills are rarely considered.

Epistemic frame theory (Shaffer, 2004) suggests that communities can be characterized by not only the possession of knowledge, skills, value and practices, but more importantly the associations among these different elements and the configurations of them. For example, two communities with similar levels on their knowledge and skills, may have very different perceptions of how different dimensions of knowledge and skills are related to each other, and how these are related to values and practices. In the current study, we drew ideas from the epistemic frame theory, and focused on understanding how CPS skills are connected to each other. We constructed networks of CPS skills for individuals solving a simulation-based task collaboratively. The goal was to characterize the CPS skill networks and to compare the structural features of the networks for teams with different performance levels.

## Method

### Participants

Eight community college and university instructors and their corresponding engineering and electronics classes participated in the study. A total of 129 students were randomly assembled into groups of three for each class (43 teams). Of those who reported their gender (2% were unreported), 81% were males and 17% were females. Of those who reported their race (2% were unreported), 51% were White, 7% were Black or African American, 6% were Asian, 2% were American Indian or Alaska Native, 10% reported being more than one race, and 2% reported Other. For ethnicity, 22% of the sample who chose to provide demographic information reported being Hispanic. The ages of participants ranged from 16 to 60 with an average age of 24.

### Task

Students were asked to complete a simulation-based task on electronics concepts called the Three-Resistor Activity (see Figure 1). Each student in a team of three worked on a separate computer that ran a simulation of a portion of an electronic circuit composed of three resistors connected to form a series circuit. Each of the three resistors was controlled by a different teammate. Each team member had the goal of reaching a specified goal voltage across their resistor. However, since each resistor was connected in series, any changes that one teammate made on their resistor value to obtain their own goal voltage would affect the current through the circuit and

therefore the voltage drop across each teammates' resistor. Therefore, students needed to communicate via a chat box and coordinate their actions to reach the goal voltages across each resistor in the series. The task included four levels of increasing difficulty. In higher levels of the task, students were additionally asked to work together to determine the unknown resistance and voltage of an external, fourth resistor in the series that none of the teammates could control. As students worked together to solve the problems, all of their relevant actions and discourse (e.g., measurements, resistor changes, calculations, answer submissions, text chats) were logged to a database and used for our subsequent analyses.

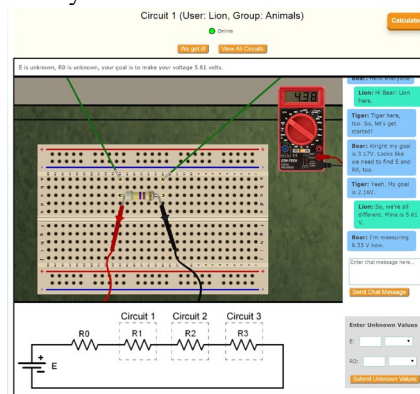


Figure 1. Screenshot of Three-Resistor Activity.

## CPS ontology

A CPS ontology was developed to conceptualize the CPS construct. Ontologies are similar to concept maps and provide a theory-driven representation of targeted skills and their relationships and link them to observable behaviors in a task that would provide evidence of the skills. The CPS ontology includes nine high-level CPS skills. Four skills correspond to the social dimension of CPS (i.e., maintaining communication, sharing information, establishing shared understanding, negotiating) and five skills correspond to the cognitive dimension of CPS (i.e., exploring and understanding, representing and formulating, planning, executing, monitoring). *Maintaining communication* includes content irrelevant social communication whereas *sharing information* refers to content relevant information shared in the service of solving the problem. *Establishing shared understanding* corresponds to communication used to learn the perspective of others and ensure that what has been said was understood. *Negotiating* refers to communication used to identify conflicts in ideas among teammates and resolve conflicts that may exist. In the cognitive dimension, *exploring and understanding* corresponds to actions taken to explore the task environment and build a mental representation for components of the problem. *Representing and formulating* refers to communication used to represent the problem and formulate hypotheses. *Planning* includes communication around developing a strategy for solving the problem. *Executing* includes actions taken to carry out a plan and communication used to carry out a plan. *Monitoring* corresponds to actions and communication used to monitor progress toward a goal and monitor the organization of the team. For more in depth discussion of the CPS ontology, see Andrews-Todd and Forsyth (in press).

## Qualitative coding

Two raters coded the content of students' discourse and their actions for nine CPS skills outlined in the CPS ontology. Executing and monitoring were shown in both actions and chats and were thus split into two separate action and chat skills. This created 11 total skills for the qualitative coding (i.e., *maintaining communication (SMC)*, *sharing information (SSI)*, *establishing shared understanding (SPT)*, *negotiating (SN)*, *exploring and understanding (CEU)*, *representing and formulating (CRF)*, *planning (CP)*, *executing actions (CE)*, *executing chats (CEC)*, *monitoring actions (CM)*, and *monitoring chats (CMC)*). Raters coded the log data at the level of each log file event, with each event receiving only one code. Inter-rater reliability between two raters was calculated on a sample of 20 percent of the data that was double coded and was found to be high (Kappa = .84). There were a total of 20,947 log file events, which were coded for the presence of one of the 11 CPS skills.

## Analyses

To explore connections among the CPS skills, we built co-occurrence networks of the CPS skills. We defined each turn for an individual as a series uninterrupted chats or actions, and considered the co-occurrence of the CPS skills in each turn. For each team, we scanned the records containing events from all team members, and built the aggregated CPS skill network for the team. In these networks, the nodes represent CPS skills, the links represent



the co-occurrence of the CPS skills in the turns, and link weights represent the frequencies of the co-occurrence. To characterize the constructed CPS skill networks, we used six well-adopted network measures (Newman, 2003; Wasserman & Faust, 1994). *Density* captures the number of existing links divided by the number of possible links. *Weighted density* is the sum of link weights divided by the number of possible links. *Centralization* (Freeman, 1979) captures the extent to which the number of links connected to nodes vary across all nodes in the network. Further, *Maximum Component Size* is the size of the biggest connected component in the network. *Connectedness* is the number of dyads (a set of two nodes) with existing direct connections or indirect connections through other nodes divided by the total number of dyads. Lastly, *Maximum Degree* is calculated as the maximum number of links connected to a single node.

For each team, we calculated the above measures to characterize the CPS skill networks. To compare the network measures of teams with different performance levels, we considered two measures of team performance. In the Three-Resistor Activity, each team had the opportunity to complete up to four levels. We used the number of successfully completed levels and the number of levels attempted as two separated measures of team performance. For further analysis, we dichotomized the two performance measures using the medians as the cut point to yield low and high performing subgroups. Multiple independent sample t-tests with Bonferroni correction were conducted on the network measures for subgroup comparisons.

## Results

All 43 teams attempted to solve at least one level, but were not all successful. Among all teams, 20 attempted all four levels, seven attempted three levels, eight attempted two levels, and eight attempted just one level. Nine teams successfully completed all four levels, 12 completed three levels, five completed two levels, eight completed one level, and nine did not complete any levels successfully. For the dichotomization, we used the medians of 2 and 3 for the number of successful levels and the number of levels attempted, respectively. Teams with values higher than the medians were coded as high (H), and teams with values lower or equal to the medians as were coded as low (L). Examples of CPS skill networks from two teams with high and low performance are shown in Figure 2. For each network, the size of the nodes indicates the frequencies of the CPS skills presented in the team's chats and actions, and the thickness of the links indicates the frequencies of the co-occurrence of the CPS skills in turns. Visually, the high performing team network in Figure 2 (a) has not only bigger nodes but also more and thicker links than the low performing team network in Figure 2 (b).



(a) Attempted 4 levels, solved 3

(b) Attempted 1 level, solved 0

Figure 2. Example networks from a high performing team and a low performing team.

Using number of levels successfully completed, high performing teams ( $M = 854.43$ ,  $SD = 328.56$ ,  $N = 21$ ) demonstrated higher frequencies of CPS skills than low performing teams ( $M = 369.45$ ,  $SD = 198.47$ ,  $N = 22$ ),  $t(33) = 5.83$ ,  $p < .001$ . When measured by the number of levels attempted, CPS skills frequencies of the high performing teams ( $M = 824.95$ ,  $SD = 322.66$ ,  $N = 20$ ) were also significantly higher than low performing teams ( $M = 416.17$ ,  $SD = 281.85$ ,  $N = 23$ ),  $t(38) = 4.39$ ,  $p < .001$ . However, higher frequencies of CPS skills did not necessarily indicate more links in the network. In fact, the correlation between CPS skill frequencies and network density was 0.57. We next compared the CPS skill network statistics for the high and low performing teams using independent sample t-tests (adjusted  $\alpha = .05/6 = .0083$ ), and the results are summarized in Table 2. When using number of levels successfully completed, we found that high and low performing teams differed in most network measures except centralization. The differences in *Density*, *Weighted Density*, *Maximum Component Size*, *Connectedness* and *Maximum Degree* all showed that the CPS skill networks for the high performing teams were better connected and had more coverage than the low performing teams. The lack of significant results for centralization indicates that both high and low performing teams did not show preferences towards connecting certain CPS skills with others. Instead, the connections among the CPS skills were evenly distributed with no CPS skills more central than others. When using number of levels attempted, only weighted density was significantly different for high and low performing teams.

Table 2: Comparisons of teams with H/L performance

	By Number of Successful Levels			By Number of Levels Attempted		
	M <sub>H</sub> (n=21)	M <sub>L</sub> (n=22)	<i>t-test</i>	M <sub>H</sub> (n=20)	M <sub>L</sub> (n=23)	<i>t-test</i>
<i>Density</i>	0.45	0.30	$t = 3.62, df = 41, p = .0008$	0.43	0.32	$t = 2.62, df = 41, p = .012$
<i>Weighted Density</i>	1.64	0.79	$t = 4.59, df = 38, p < .0001$	1.58	0.87	$t = 3.57, df = 41, p = .0009$
<i>Centralization</i>	0.43	0.43	$t = -0.05, df = 40, p = .958$	0.44	0.42	$t = 0.61, df = 41, p = .547$
<i>Maximum Component Size</i>	10.10	8.77	$t = 2.95, df = 39, p = .005$	10.00	8.91	$t = 2.37, df = 40, p = .023$
<i>Connectedness</i>	0.85	0.65	$t = 3.18, df = 41, p = .003$	0.83	0.67	$t = 2.49, df = 41, p = .017$
<i>Maximum Degree</i>	7.95	6.50	$t = 2.79, df = 41, p = .008$	7.90	6.61	$t = 2.44, df = 41, p = .019$

## Discussion and future directions

In this study, we constructed CPS skill networks from log data on team actions and chats during collaborative problem solving. The results showed that high and low performing teams significantly differed not only on the frequencies of the CPS skills displayed, but also on how the skills were connected with each other. This study makes contributions to the measurement of CPS skills by demonstrating a new way of assessing and understanding CPS skills: through the exploration of connections among CPS skills. For future directions, different approaches to constructing the CPS skill networks will be explored. This study used the co-occurrence of skills in the same turn, and focused on the connections of skills represented in the chat and actions of individual team members. Alternatively, the moving window approach (Siebert-Evenstone et al., 2017) captures the evidence of the connections displayed during the interactions among team members. We intend to identify the connections using this alternative approach and explore the similarities and differences of the resulting networks.

## References

- Andrews-Todd, J., & Forsyth, C. M. (in press). Exploring social and cognitive dimensions of collaborative problem solving in an open online simulation-based task. *Computers in Human Behavior*. <https://doi.org/10.1016/j.chb.2018.10.025>
- Andrews, J. J., Kerr, D., Mislevy, R. J., von Davier, A., Hao, J., & Liu, L. (2017). Modeling Collaborative Interaction Patterns in a Simulation-Based Task. *Journal of Educational Measurement*, 54(1), 54–69. <https://doi.org/10.1111/jedm.12132>
- Freeman, L. (1979). Centrality in Social Networks I: Conceptual Clarification. *Social Networks*, 1, 215–239.
- Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A framework for teachable collaborative problem solving skills. In P. Griffin & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 37–56). New York: Springer.
- Liu, L., von Davier, A. A., Hao, J., Kyllonen, P., & Zapata-Rivera, D. (2015). A tough nut to crack: Measuring collaborative problem solving. In Y. Rosen, S. Ferrara, & M. Mosharraf (Eds.), *Handbook of research on computational tools for real-world skill development* (pp. 344–359). Hershey, PA: IGI-Global.
- Newman, M. E. J. (2003). The structure and function of complex networks. *SIAM Review*, 45, 167–256.
- OECD. (2013). *Pisa 2015 Draft Collaborative Problem Solving Framework March 2013*. OECD Publishing.
- Shaffer, D. W. (2004). Epistemic Frames and Islands of Expertise: Learning from Infusion Experiences. *Proceedings of the Sixth International Conference of the Learning Sciences*, 473–480.
- Siebert-Evenstone, A., Arastoopour Irgens, G., Collier, W., Swiecki, Z., Ruis, A. R., & Shaffer, D. W. (2017). In Search of Conversational Grain Size: Modelling Semantic Structure Using Moving Stanza Windows. *Journal of Learning Analytics*, 4(3), 123–139. <https://doi.org/10.18608/jla.2017.43.7>
- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge University Press, Cambridge.

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# Video Annotation for Content-Focused Coaching

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**Abstract:** We implemented an innovative online mathematics professional learning model designed to create high-impact growth opportunities for teachers in rural school districts. As a part of this model, classroom teachers were partnered with coaches with whom they worked on content-focused coaching cycles. Within a coaching cycle, teachers and coaches met to plan a mathematics lesson, the teacher video recorded the lesson, the coach and teacher both annotated the lesson video, and finally the two met to debrief the lesson verbally. We report on the process of video annotations. Data analysis focused on identifying the type of response within an annotation as well as the extent to which the teacher or coach noticed students' mathematical thinking. We contend that the annotation process afforded opportunities for direct suggestions to teachers that may not have otherwise occurred. Findings indicate annotations were predominantly focused on mathematics content goals and classroom discourse practices.

## Conceptual background, context, and significance

Teachers in rural areas face constraints in terms of accessing the expertise and resources required for high-quality professional learning experiences, often because of lack of proximity to such resources as institutions of higher education and critical masses of teachers required to collectively reflect on problems of practice (Howley & Howley, 2005). Rural contexts are thus ideal sites for online professional development, which can be offered at a distance and can engage geographically dispersed participants in collaborative learning experiences (Francis & Jacobsen, 2013). The innovative online professional learning experiences in our project focus on the development of teacher capacity to enact ambitious, responsive instruction espoused in recent US educational policy documents (CCSSI, 2010). Recognizing the critical need to prepare all teachers to implement rigorous instruction, especially teachers who are not geographically proximate to face-to-face trainings or coaching resources, we engaged participants in online courses, online demonstration lessons, and online video coaching over the last two years. In the process, we created experiences that match, if not exceed, what is possible in face-to-face settings. The project is based in two geographically diverse locations in the US to explore the scalability of the model to other under-resourced contexts.

In this paper, we focus on online coaching, particularly the use of video annotations to stimulate the coaching interactions. The use of coaching to foster teacher learning and improve student achievement has become an increasingly popular strategy for schools, districts, and states in the US (Heinke, 2013). Prior studies have shown that coaching can improve both teaching and student learning (Sailors & Price, 2015; Kraft, Blazar, & Hogan, 2018). However, coaching activities vary widely, impacting the effectiveness of coaching and posing problems for researchers and professional developers alike (Gibbons & Cobb, 2016). Content-focused coaching is a specific model for guiding coaching activities that aims to support teacher learning by focusing on the mathematical goals of the lesson, and how students might engage with those goals (West & Staub, 2003). In content-focused coaching, the coach accepts equal accountability for generating effective student learning (West & Staub, 2003).

To facilitate online content-focused coaching, we used video conferencing software (Zoom), and video capturing/annotating software (Swivl). The online video coaching was purposely designed with features analogous to West and Staub's (2003) face-to-face content-focused coaching cycle. First, the teacher and coach met via Zoom to plan the lesson; second, the teacher video recorded the lesson implementation using Swivl; third, the teacher and coach separately viewed and annotated the video of the enacted lesson; and finally, the coach and teacher met via Zoom to reflect on the lesson, using the annotations to anchor their discussion. The purpose of this study was to better understand the content of the annotations and the interactions of the coach and teacher in the online space. Specifically, we were interested in understanding the discursive moves and content of the annotations from both the coach and teacher. We posed the following research questions:

1. What was the focus of the annotations (e.g., non-mathematical aspects of classroom practice, teacher discourse moves, student strategies, mathematical goals of the lesson)?

2. What were the discursive moves coaches and teachers used when annotating video of a mathematics lesson?

## Method

Using a cohort model, we engaged 16 teachers in an intensive two-year professional development model focused on supporting teachers to engage in ambitious, responsive instruction. The teachers taught in grades five through eight (ten to 14 years-old), specifically in mathematics, and worked in rural locations that made it difficult to engage in face-to-face coaching.

## Data collection

The unit of analysis was coach-teacher pairs, with each coach-teacher pair completing two or three coaching cycles annually. For the purposes of this paper, we focus specifically on data from the annotations the coach and teacher produced as they initially reviewed the lesson video and made comments. To make the annotations in Swivl, the coach and teacher each viewed the lesson video in the Swivl software platform. They then stopped the video at moments they saw as relevant to the coaching cycle, which were automatically time-stamped by the software. The coach or teacher would then annotate the moments with their thoughts and reflections. They were given the following prompt:

Add your comments, questions, and thoughts to the video segment in Swivl at any points in the video that might be interesting to discuss further. For example, were there any moments that surprised you? (i.e., misconceptions that emerged, strategies that you did not anticipate, struggles/challenges, or any “Ah-ha” moments) Were there particular instances that showed evidence of student thinking? Is there something that you see as you watch the lesson that relates to the goal you set for this coaching cycle?

For each of the nine coaching pairs, we analyzed the written annotations from three coaching cycles. This involved annotations from five different coaches and nine different teachers. Figure 1 shows an example of an annotation, with Bishop as the coach and Cole as teacher (both are pseudonyms), making comments on the video of a lesson Cole taught.

00:22:34	Jun 01, 2017	Cole	---Can we leave the answer in radical form?---
00:25:52	Jun 04, 2017	Bishop	Great introductory discussion about why we might want to leave the result in radical form and why sometimes the rounded form is good enough.
00:26:21	Jun 04, 2017	Bishop	I wonder what the students might have noticed if before you introduced the formula you had focused the students on how they might be able to find the lengths of the two legs of the right triangle without drawing the triangle. “Suppose you did not have a coordinate plane to draw the triangle in questions 1. Could you have found the lengths of 4 and 5 by reasoning with the two ordered pairs only? Can you explain how?” We could even ask students to turn and talk about how they might be able to do this prior to sharing with the entire class.

Figure 1. Sample of annotations.

## Data analysis

Data analysis focused on identifying the coaches’ and teachers’ discursive moves and nature of comments in the annotations. Initially, each annotation was assigned a *Category Code* based the nature of the comment. These codes (i.e. Marking an Event, Question, Suggestion, Interpretation/Explanation, and Evaluation) were intended to capture the essence of the annotation. We then developed a codebook to analyze the discourse moves and content of the annotations. The codebook is based on research on content-focused coaching (West & Staub, 2003) as well as open codes, based on initial constant comparison analysis (Corbin & Strauss, 2003). The codebook contains first level codes and second level codes for four different categories: Coach Discursive Moves, Teacher Discursive Moves, Goals of Lesson, Content/Design of Lesson. Figure 2 provides an excerpt of the Coach Discursive Moves of the codebook.

Features of Coaching Discursive Moves (HOW Coaching)		
First Level	Second Level	Description
Invitational	Elicitation/Pressing	Eliciting a response; broad initial questions;
	Other	Other Comment
Direct Assistance	Suggesting	Offering an alternative point of view or suggesting

	Explaining	Provide and interpretation or rationale of an event, interaction, or mathematical idea
	Other	Other comment
Describing	Account of Practice General	Provides an objective account of a scenario or practice without reference to a specific event

Figure 2. Excerpt of Codebook, Coaching Discursive Moves Section.

From this codebook, each annotation received a *Discursive Code* that was either a Coach Discursive Move or a Teacher Discursive Move and a *Content Code* that related to the Goals of Lesson or Content/Design of Lesson. Two researchers each independently coded each annotation, assigning at least one Category Code, one Discursive Code, and one Content Code for each annotation and then met to compare and reconcile codes.

## Findings

Examining the annotations across the various coaches and teachers, coaches wrote approximately 60% of the annotations and teachers 40%. The first focus of the research was to identify the Category Code coaches and teachers used when annotating video of mathematics lessons. Of the five Category Codes (i.e. Mark, Question, Suggestion, Interpretation/Explanation, and Evaluation), *Marking* was the most common for both the coaches and teachers. Marking included comments that pointed to a specific account of practice deemed relevant by the teacher or coach, meaning they highlighted a particular action or verbalization of someone in the video by using a timestamp to draw attention to that action. As an example, one teacher wrote, “Student explained the pictures of the shapes and their angles in Part A.” Most annotations coded as *Mark* were also coded with another Category Code, such as *Interpretation/Explanation* or *Evaluation*, as the Category Codes were not mutually exclusive. Although these were the most common category codes, annotations that received this code commonly received another code as well. As an example, one teacher wrote, “I’m handing out the papers and placing them down on the desk in hopes of keeping their focus on the front - hoping they are not distracted by the formula on the top of the back of the paper. I don’t usually hand out papers this way. :)” In this example, the teacher *Marked* the moment, stating that she was handing out the papers; however, she then went on to *Interpret/Explain* that she usually does not pass out papers this way and hopes it is not distracting. With these additional comments, this annotation was coded as both *Marking* and *Interpretation/Explanation* (the discursive code was *Describe: Account of Practice Specific*, meaning a detailed review of an event).

With respect to the other Category Codes interestingly, *Evaluative* comments were distributed almost equally between coaches and teachers. As an example of an *Evaluative* comment, one coach wrote, “Great introductory discussion about why we might want to leave the result in radical form and why sometimes the rounded form is good enough.” The *Evaluative* codes were used when there some type of positive or negative judgement about something in the lesson. The code for *Questions* was used when either the coach or teacher wrote a direct question to the other person or wrote a question to his or herself as something to consider at a later point, and this code was the least frequently applied.

The Discursive Moves that were most common (those coming from the codebook, Figure 2, and relating to the type of speech from the coach and teacher) included Direct Assistance from the coaches and Describing Accounts of Practice from the teachers. The coach commonly included phrases that provided suggestions to the teacher on how they may rethink their instructional moves or on how they may consider pedagogy in the future. Many of these suggestions began with “I wonder...” and included language about what could or should be done in a similar situation in the future or in the next lesson. In contrast, the teachers most commonly described what they were doing in the video as they wrote out their annotations.

With respect to the Content Codes, Math Content Goals and Discourse were the most common topics for discussion. As an example, one teacher was working on a goal of supporting students to understand formulas. For the annotation, the coach wrote, “Perhaps rewriting the distance formula as the square root of delta x squared plus delta y squared, might have helped some students makes more sense of the formula at this point.” In this example, the coach focuses on the mathematics content goals of the lesson and provides a specific suggestion related to the mathematics. Discourse was another common topic of focus in the annotations. Discourse refers to verbal interactions among the teacher and students. As an example, one coach annotated the following, “George states that *every angle can make a straight line*. This statement is quite ambiguous but is a start to the conversation. I wonder what would have happened if you followed this up with *George says that every angle can make a straight line. What does he mean by this? Do you agree or disagree?*” In this example, the coach comments on how the teacher started a conversation and then provides a specific question the teacher could have asked. It was common that the coach and teacher wrote comments that were aimed at improving classroom discourse, which was a focus of the professional development project.

## Implications and conclusion

The coaches and teachers focused most of their annotations on the mathematical content and discourse moves, reflecting the content-focused coaching model and the focus of the professional development project. The annotations provided an opportunity for the coaches and teachers to indicate how they were interpreting the enactment of the mathematical goals and how teachers were facilitating those goals. This is typical of face-to-face coaching interactions, when the coach and teacher can explore artifacts together in person. In the absence of that opportunity, the annotations provided a means for the coach and teacher to independently mark crucial moments, which could then be used to anchor the post-lesson Zoom discussion. Though classroom management was sometimes a focus of the annotations, most of the annotations were more in line with content-focused coaching. Importantly, the annotations also focused on classroom discourse moves, and many of these annotations were non-evaluative, instead describing objective accounts of the episode.

These findings draw attention to the possible affordances of the annotation process for supporting teachers to pay attention to students' mathematical thinking, an important aspect of effective mathematics instruction (Jacobs, Lamb, & Philipp, 2010). We contend that the process of watching a video and typing specific comments about the video through a content-focused coaching model (West & Staub, 2003) may support teachers in thinking more about the specifics of mathematics as compared to having a general conversation about a lesson, as may occur with an interview or other type of interaction. Therefore, we consider the Swivl online annotation platform as a possible medium to elicit math-specific comments that may support teachers' development and understanding about pedagogy and content. The data show that the online annotation platform allows for new types of interactions between the teacher, coach, and their learning environment, which may afford new knowledge of collaborative online technologies for supporting teacher learning. We recognize additional analysis would be necessary to support claims about the benefits of annotation, but this study gives rise to the possibility of these types of affordances of annotation technology.

## References

- Common Core State Standards Initiative (CCSSI). 2010. Common Core State Standards for Mathematics. Washington, DC: National Governors Association and the Council of Chief State School Officers.
- Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: Sage.
- Francis, K., & Jacobsen, M. (2013). Synchronous online collaborative professional development for elementary mathematics teachers. *International Review of Research in Open and Distance Learning*, 14, 319–343.
- Gibbons, L. K., & Cobb, P. (2016). Content-focused coaching: Five key practices. *The Elementary School Journal*, 117(2), 237-260.
- Heinke, S. F. (2013). Coaching discourse supporting teachers' professional learning. *The Elementary School Journal*, 113(3), 409-433.
- Howley, A., & Howley, C. (2005). High-quality teaching: Providing for rural teachers' professional development. *The Rural Educator*, 26(2), 1-5.
- Jacobs, V. R., Lamb, L. L. C., & Philipp, R. A. (2010). Professional Noticing of Children's Mathematical Thinking. *Journal for Research in Mathematics Education*, 41(2), 169–202.
- Kraft, M. A., Blazar, D., & Hogan, D. (2018). The effect of teacher coaching on instruction and achievement: A meta-analysis of the causal evidence. *Review of Educational Research*, 88(4), 547-588.
- Matsumura, L. C., Garnier, H. E., & Spybrook, J. (2013). Literacy coaching to improve student reading achievement: A multi-level mediation model. *Learning and Instruction*, 25, 35-48.
- Sailors, M., & Price, L. (2015). Support for the improvement of practices through intensive coaching (SIPIC). *Teaching and Teacher Education*, 45, 115-127.
- Star, J. R., & Strickland, S. K. (2008). *Learning to observe: Using video to improve preservice mathematics teachers' ability to notice*. *Journal of Mathematics Teacher Education*, 11, 107-125.
- West, L., & Staub, F.C. (2003). *Content-focused coaching: Transforming mathematics lessons*. Portsmouth, NH: Heinemann.
- West, L., & Cameron, A. (2013). *Agents of change: How content coaching transforms teaching and learning*. Portsmouth, NH: Heinemann.

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# Negotiating Uncertainty to Develop a Joint Deepening Focus in Knowledge Building Discourse

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**Abstract:** In open-ended and creative knowledge building communities, students engage in socially shared reasoning and discursive interaction to develop deep understanding of authentic problems related to the real world. Regulating a shared deepening focus in sustained knowledge building involves negotiating uncertainty as a space for potential idea generation and improvement. The research explores socio-cognitive and discourse practices in a class of fourth-graders studying light, whereby a shared space of epistemic objects is shaped, challenged and adapted leading to deeper conceptual explanations of the optical phenomena. Qualitative analysis of talk-in-interaction, online students notes and teacher's journal showed patterns of cognitive embodiment and uncertainty-oriented discursive practices to explain shared regulation of progressive knowledge building.

## Introduction

In knowledge building communities, members engage in sustained knowledge building discourse by which they constantly improve and advance shared understandings. Students are required to take individual as well as collective responsibility for continually advancing the community's knowledge while identifying deeper problems and challenges (Scardamalia & Bereiter, 2014; Chan & van Aalst, 2018). As a critical component, researchers need to better understand how students develop a joint deepening focus to sustain their knowledge building discourse over time (Tao, Zhang & Huang, 2015). Building on existing research on socially shared regulation (Järvelä & Hadwin, 2013) and collective structuration of collaborative knowledge building (Zhang et al., 2018), this study intends to make a deeper dive to produce a micro-analytic view of the socio-cognitive and discursive practices by which members generate ideas mediated by embodied artifacts and monitor knowledge uncertainty to deepen their understanding.

The regulation of collaborative knowledge building is socially distributed and embedded, as it involves the creation and adaptation of ideational artifacts (theories, hypotheses, proofs, etc.) in the contexts in which knowledge building actions and interactions unfold. Shared regulation of knowledge building connects with Winn's (2003) framework of embodiment, embeddedness and adaptation, which theorizes learning as a mutual interaction with the students' intelligible environment in which their ideas are embedded. Ideational artifacts embody perception-based representations of the idiosyncratic view students hold of the real world (e.g. analogies, physical perceptions, sensory imagery), of how students see and understand the investigated problem. As these artifacts get progressively scrutinized, negotiated and adapted, students' knowledge advances. Their regulatory function lies in their unbounded capacity to generate questions (Cetina, 2001), trigger puzzlement thus affording opportunities for clarifications and negotiation of understanding. Underpinning knowledge advancement is an intentional and imaginative quest for sources of uncertainty about existing ideas (Ford & Forman, 2015) in dialogue with other peers. We interpret uncertainty as a space for idea generation and improvement embedded in knowledge building discourse, and shared regulation involves the monitoring and adaptation of this space in which embodied knowledge is challenged for deeper understanding. By engaging in dialogic discourse students unveil, negotiate and resolve uncertainty as they seek increasingly sophisticated understandings. This study examines how uncertainty-oriented discourse around embodied knowledge can characterize student regulation of a shared problem space in a 4<sup>th</sup> grade science class adopting knowledge building principles.

## Method

The study analyzes the inquiry work of a class of 22 Grade 4 students aged 9-to-10 years old at the Dr. Eric Jackman Institute of Child Study Laboratory School in Toronto. Students engaged in the exploration of optical phenomena during a three-month period based on a knowledge building approach. This included the use of Knowledge Forum (Scardamalia & Bereiter, 2014), an online tool for recording ideas, theories and other inquiry activity in problem-based views (i.e. workspaces). The teacher acted as facilitator and co-learner throughout the inquiry work. He supported collective regulation of knowledge building by scaffolding students' progressive discourse both during face-to-face meetings and online. He encouraged students to formulate initial questions, write notes and carry on research and experiments to refine their theories and deepen their understanding. Prior

to this inquiry students had already used Knowledge Forum in grade 1 when they studied how animals' fur reflects or absorbs light depending on its color. Reviewing their online notes written at that time marked the onset of the light inquiry during the first whole class talk (see also Zhang & Sun, 2011).

To characterize the regulation of uncertainty in knowledge building discourse, we carried on a qualitative analysis of a set of data including audio recording of whole classroom discussions, small group dialogues and experiments. The analysis was extended to online artifacts in Knowledge Forum and records in the teacher's reflection journal. We applied a whole-to-part inductive approach (Derry et al., 2010) to first develop a macro representation of the whole inquiry and then zoom on some of the most meaningful excerpts of conversational episodes to unpack the conversational flow and analyze discursive features. At this lower grain of analysis, we progressively identified patterns associated with the concepts of embodied, embedded knowledge, and dialogic discourse practices of seeking and resolving uncertainty.

## Findings

Students investigated the topic of light and its interaction with objects through various activities such as participating in small group and whole class discussions, searching for authoritative sources and carrying on self-designed experiments. Their inquiry work evolved throughout the three months leading to the creation of seven views in Knowledge Forum, each containing notes focused on newly identified or deeper problems of understanding related to optics. Three salient patterns were identified from the data analysis showing how the community developed and deepened its joint focus to sustain knowledge building over time.

### Initiating a shared area of inquiry with embodied experiences and artifacts

During the whole class kick-off meeting, the teacher showed a view in an old database of Knowledge Forum created by the students in 1<sup>st</sup> grade. The view titled "Adaptive Weirdos" collected notes about how animals adapt to light. One note in particular containing a theory about grey fur reflecting light generated an interesting discussion around light and color reflection during which students contributed explanations using examples from their direct experience with the real world. The teacher reported, for example, that a student "made a connection to the black streaks worn by football players." The fact that it was snowing outside during the discussion occasioned a new emerging interest about the connection between snow and white in relation to light. As reported in the teacher's journal, "We asked the question if there was a reason why snow was white". The online notes were collected in a new view that the teacher created and called "Grey Fur and White Snow" in symbolic reference to the former theme in grade 1 and the emergent topic of color reflection. Bringing to the students' attention the existence of several notes in Knowledge Forum about "how black and white interact with heat", the teacher proposed this sub-topic as a new problem of understanding. Students started offering theories on whether black attracts heat or light bringing in examples of various objects.

The initial stage of problem inquiry was characterized by the development of ideas and explanations embodied in figures of speech and analogies (Table 1). By defining physical properties or explaining abstract concepts, these figurative arguments were used as a means to enter the problem space and get hold of an idea as "to solve a problem quickly" (Dunbar, 2000, p. 54).

Table 1: Examples of building knowledge using embodied experiences

Students discourse moves	Description of embodied knowledge
"Light is cold like the light reflected from the moon"	A figure of speech based on the student's direct perception of the moon light
"Black is like magnet, it absorbs heat"	An analogy explaining absorption as an attraction force
"What does black does with the light - absorbs like a sponge?"	Another figure of speech suggesting the idea of black as a porous material
"The moon is greyish white and we said that snow reflects light because it is white"	An implicit analogy suggesting that the moon reflects light like snow because of its greyish white color
"Cold in the night because the moon is sort of like mirror since heat travels from sun to moon and then to earth – a lot of heat is lost in travel"	A simile – the moon being like a mirror – followed by a visual imagery conveying the idea that heat is a physical entity losing intensity across space

Another example of embodied reasoning was the use of visual imagery in the form of perception-based and "intuitive functional explanations" (Hakkarainen, 2003):



Student I can see ... the moon is kinda colder than the sun, it would get colder... if you went on to the moon with a space suit you wouldn't die, but if you went onto the sun with a space suit you would die.

The production of embodied ideational artifacts and the use of objects to think with provided an initial and yet incomplete or, at times, misconceived view of the phenomena in the real world. However, it appeared to have an important function in maintaining a shared focus by triggering curiosity and promoting further questioning. Underpinning subsequent steps of progressive inquiry was an intentional and purposeful search for uncertainty as a space within which these objects of knowledge could be refined and sharpened.

### Seeking and negotiating uncertainty as a space for deepening understanding

After framing the initial questions and developing early explanations, students pursued their inquiry to find evidence, refine their ideas, and overcome misconceptions. Although their goal was to improve their theories, their emerging and transitional focus was on seeking uncertainty (gaps and problems) in those initial explanations, spotting something that could not be accounted for by their current theory, or introducing counter-hypotheses. Doubt and uncertainty created a space for further deepening their understanding.

Regulation of uncertainty involved the practice of questioning and challenging others' claims. Doing so required participants to direct attention and react coherently to one another's argument as shown in the turn sequence that follows, which occurred a few weeks after the discussion about light and heat absorption:

Student 1 You're saying that you need lights to um, to for the carpet to be green. But if it's green it does not um ah it's not like it changes color or anything.

Student 2 Well, it's without the lights; black through your eye is still green on the ground. You don't need the lights for it to be green. You need the light for it to be green to you, to your eyes.

Student 3 Well, you don't need the light to make the carpet green, you just need the lights to see that the carpet is green.

Student 1 Exactly, so how come everyone is saying that you need green light to make this carpet green (...).

In this episode students deepened their focus on light and color. In the first turn of the sequence the speaker paraphrased another member's claim, "You're saying that..." before noticing an anomaly in it, introduced by the discourse marker "But if...". In the subsequent two turns students 2 and 3 tried to address the puzzlement and refined the initial idea – they clarify that light is not as much needed for the carpet to *be* green rather to *appear* green to one's eyes – thus giving a stronger evidence for negotiating understanding. Student 1 wrapped up the sequence reiterating the former contradiction, as a way to validate that the explanation offered by students 2 and 3 was now satisfactory. Likewise, students purposefully gave voice to uncertainty in their own ideas challenging part of the content as in the following turn:

Student If you, if this room was totally black, the carpet would still be green, the floor would still be that color but you wouldn't see it because there's no light to bounce off of it so you couldn't see the color. [Name] are you understanding, does that make any sense to you? Because it's not like a green light bounces off it so we can all see it, it's the lights that's um. *But how come you can't see it? Then how come when the lights are off...?*

Here the student first displayed how she understood the colors as being an intrinsic characteristic of objects, independent of the ability of seeing them when light is on. While articulating this explanation though, she raised uncertainties, monitoring her own understanding, as reflected in the last two questions.

### Addressing uncertainty through socially embedded practices of inquiry

As uncertainty became a shared and accepted focus among peers, it encouraged adaptation of initial ideas by directing a greater attention to the chain of reasoning behind students' theories and by finding more refined grounds for their ideas. Carrying on experiments was one of the ways to respond to uncertainty. Theories about reflection and absorption of light and heat, for instance, were further tested through an experiment in the schoolyard to observe differences in how snow melted on a white and a black panel. Likewise, to address suspicion

about having green color contained in light, a student stood up, went to the chalkboard and drew a prism. Pointing to the ceiling light he explained that when the light shines through the prism it splits up into different colors thus helping his peers understand that light is made up of different colors.

## Discussion

The present investigation sheds light on the role that imagery, uncertainty, and adaptation play in sustaining and regulating a joint deepening focus in collective inquiry. Findings illustrate that the use of embodied cognition is a central characteristic that shapes knowledge building discourse. Students developed, monitored and refined their understanding of abstract concepts such as light reflection and absorption by leveraging objects and experiences from the real world. Embodied representations of conceptual thinking served to maintain a shared focus in the moment-to-moment interaction and beyond through the online discussion in Knowledge Forum. Furthermore, students were encouraged to think and speak imaginatively and to dare exposing doubts or formulating tentative explanations in their knowledge advancement efforts. If learning is not about memorizing authoritative ideas or treating scientific knowledge as definitive conclusions (Ford & Forman, 2015), teaching should support dialogic discursive practices that promote uncertainty as a collaborative space for monitoring understanding, sparking further questions and prompting discernment through appropriate scaffolds during class and online dialogues. A deeper analysis of classroom videos, online notes and teacher's journal is under way to further understand how patterns of shared regulation evolve from shorter to longer timescales of activity.

## References

- Cetina, K. K. (2001). Objectual practice. In T. Schatzki, K. K. Cetina & E. von Savigny (Eds.), *The practice turn in contemporary theory* (pp. 175-188). London: Routledge.
- Chan, C. K. K., & van Aalst, J. (2018). Knowledge building: Theory, design, and analysis. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), *International Handbook of the Learning Sciences* (pp. 295-307). New York, N.Y.: Routledge.
- Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., ... Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences*, 19(1), 3-53.
- Dunbar, K. (2000). How scientists think in the real world: Implications for science education. *Journal of Applied Developmental Psychology*, 21(1), 49-58.
- Ford, M. J., & Forman, E. A. (2015). Uncertainty and scientific progress in classroom dialogue. In L. B. Resnick & C. S. C. Asterhan (Eds.), *Socializing intelligence through academic talk and dialogue* (pp. 143-156). Washington, DC: AERA.
- Hakkarainen, K. (2003). Progressive inquiry in a computer-supported biology class. *Journal of Research in Science Teaching*, 40(10), 1072-1088.
- Järvelä, S., & Hadwin, A. F. (2013). New Frontiers: Regulating Learning in CSCL. *Educational Psychologist*, 48(1), 25-39.
- Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. *Cambridge handbook of the learning sciences*, 397-417.
- Tao, D., Zhang, J., & Huang, Y. (2015). How did a grade 5 community formulate progressive, collective goals to sustain knowledge building over a whole school year? In O. Lindwall & S. Ludvigsen (Eds.), *Proceedings of the 11<sup>th</sup> International Conference on Computer Supported Collaborative Learning (CSCL2015)*. International Society of the Learning Sciences.
- Winn, W. (2003). Learning in artificial environments: Embodiment, embeddedness and dynamic adaptation. *Technology, Instruction, Cognition and Learning*, 1(1), 87-114.
- Zhang, J., & Sun, Y. (2011). Reading for idea advancement in a grade 4 knowledge building community. *Instructional Science*, 39(4), 429-452.
- Zhang, J., Tao, D., Chen, M.-H., Sun, Y., Judson, D., & Naqvi, S. (2018). Co-Organizing the Collective Journey of Inquiry with Idea Thread Mapper. *Journal of the Learning Sciences*, 27(3), 390-430.

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# Foundations of Community in an Online, Asynchronous Professional Development Website

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**Abstract:** Having a sense of community can support teacher growth in face-to-face professional development, but teachers in online, asynchronous professional development might not feel a sense of community, given their isolation, both physically and temporally. To be successful, the learning must be enacted (in classrooms), but the community is ephemeral. To investigate whether participants on one large online teacher professional development (OTPD) site were hampered in forming community, or overcame these barriers, this study interviewed members of the PD site to get at their sense of community. Using grounded theory, the transcripts of the interviews were coded to reveal members' perceptions of community in this online space. Results suggest that most consider themselves as part of the community, and, importantly, see this as a space in which to share material resources. The results have implications for understanding and augmenting the role of OTPD in supporting professional learning.

## Objectives

Having a sense of community has been heralded as a cornerstone to success in face-to-face and online learning environments (e.g., Supovitz, 2002). Although most scholars agree that community formation is beneficial, the definition of community and what it looks like varies across contexts. This study examines how elementary school teachers view community within the *Everyday Mathematics* Virtual Learning Community (VLC), a National Science Foundation-funded site with approximately 50,000 members. Specifically, we investigate 1) whether members think there is a community within the VLC and 2) why they think a community does or does not exist. Understanding users' perceptions of community has the potential to inform strategies to strengthen the community not only within the VLC but also within similar online teacher professional development (OTPD) sites (e.g., the Teaching Channel, Math Forum).

## Theoretical framework

Teacher PD has the goal of improving practice and student outcomes. Because sustained engagement with professional development appears to be key to achieving this outcome (e.g., Heck et al., 2008; Yoon et al., 2007), substantial work has been devoted to exploring the importance of developing community in online settings to prevent drop-outs (e.g., Liu et al., 2009). A sense of community also helps raise course satisfaction (Drouin, 2008), aids learning (Rovai, 2002), strengthens cooperation (Hur & Hara, 2007), and increases feelings of belonging (Besser & Donahue, 1996). With this in mind, having a sense of community in OTPD may support the kinds of persistent engagement that can make PD most effective.

Garrison, Anderson, and Archer's (2000) Community of Inquiry (CoI) theory explains the components necessary to create a successful community-based educational experience via the interaction of social presence (e.g., open communication and group cohesion), cognitive presence (e.g., cognitive exploration and application of new ideas), and teaching presence (e.g., organization and discourse facilitation). All three elements work together to determine the content, set the climate, and support discourse.

Although varied, definitions of online communities typically incorporate elements of the CoI theory and particularly focus on the strength of members' relationships (e.g., Haythornthwaite & Wellman, 1998). For example, Rheingold (1993) described the necessity of online communities to offer social network capital, knowledge capital, and communion to be true communities. When defining what community looks like in learning settings, there are also common threads across theoretical and empirical accounts (e.g., Hill, 1996; Lave & Wenger, 1991). For example, Rovai (2002) defined learning communities as having members who "believe that they matter ... to the group; that they have duties and obligations to each other ...; and that they possess a shared faith that members' educational needs will be met through their commitment to shared goals" (p. 4).

When online learning communities for teachers lack these features, the result can be a lack of

participation and interest in the community, despite the perception that the community offers valuable resources (Barab et al., 2001). Nevertheless, many emerging OTPD communities are being built primarily to provide professional learning resources and experiences to teachers across the nation in an asynchronous, come-as-you-can setting. This context challenges the focused, collaborative tenets of community described above. To imagine how such new communities can be successful, it is important to understand how teachers themselves perceive community. What kinds of embedded supports are needed for teachers to invest in a community, particularly one focused on teachers individually learning to enact new practices in the classroom? How can OTPD sites provide a sense of community in an asynchronous space? This study's purpose is to uncover which research-based tenets of community are particularly important for OTPD community development as well which tenets are excluded from current definitions of online and learning communities and are therefore unique to OTPD sites.

## Methods and data sources

### Sample

Forty-one participants, all of whom were VLC members, volunteered to be interviewed for this study: 29 participants were classroom teachers, 7 were instructional coaches or curriculum coordinators, and 5 were classroom teachers and instructional coaches. Two teachers did not answer questions pertaining to community, leaving 27 classroom teacher participants and 39 total participants. Each participant was compensated \$100.

### Data source: Participant interviews

We used a semi-structured interview protocol to understand how and why participants used the VLC as well as their perceptions of whether (and how) the site contributed to their professional learning and to a sense of community. Two of the authors conducted the interviews, and most interviews lasted approximately 35 minutes. The key question about community was worded as follows: "The C in VLC is for Community. Does it feel like a community to you? Why or why not?" Answers to these questions serve as the basis for our analyses.

### Coding

We looked for emerging themes using grounded-theory (Corbin & Strauss, 2008) and created codes that captured participants' thoughts about whether the VLC was a community, and why. Two authors independently coded 24% of the data. We achieved high reliability (Cohen's  $\kappa = .97$ ). Disagreements were discussed and reconciled. Most participants clearly stated either that the VLC felt like a community or that it did not. However, a few stated that the VLC both did and did not feel like a community. Those participants were coded under both categories, and their reasons for both were documented.

### Reasons the VLC feels like a community.

We developed four codes to capture the participants' reasons that the VLC felt like a community: Togetherness, Sharing Resources, Familiarity, and Discussions.

We coded participants' comments as Togetherness when they discussed how members of the VLC have shared experiences or understanding of the rewards and challenges of the profession. Many participants discussed leaning on each other for validation and support, and particularly appreciated being able to rely on other members for curricular planning support, thus reducing their overall workload. Additionally, some participants commented on how they experienced elements of a shared culture. Reflecting on this, one participant noted, "We're coming together, and it is a unified effort towards teaching math well. I think people are on there because they want to be, so in that sense, it's a community. And I think there's a genuine feeling that these [videos] are to be helpful, so we're all gathered around a common idea."

We coded Sharing Resources when the participants indicated that they thought of the VLC as a community because its foundation is built on sharing resources. These comments highlighted how resources came from a variety of people, and some emphasized the bottom-up nature of resource development. One participant expressed the sentiment of many, "There's a lot of resources on here... There's so much free sharing, you know? "

When participants mentioned that they either knew, or felt like they knew, other members on the VLC, we coded these comments as Familiarity. Participants reported that a sense of familiarity made them feel connected and gave them a sense of belonging, allowing them to envision implementing suggestions and resources more freely. In recounting the progression of becoming more familiar with the other members, one participant said, "You know, there's even some people on the groups that are responding, and you don't know who they are, and you can't picture them, but you already have an idea of their voice."

We coded Discussions when participants mentioned dialogue with others and question-and-answer interactions about the content. One participant said, "People are open to help each other out or, like in the

discussion groups, people will check back and there are posts all week about ‘Well, there was this mistake here—I’m confused’ or ‘Is anyone else feeling the same?’ Perhaps there is a technology question or something. So, yes I would say it’s definitely like a community.”

### Reasons the VLC does not feel like a community.

We developed three codes that captured participants’ reasons that the VLC did not feel like a community: Lacking Familiarity, Isolation, and No Discussion.

We coded Lacking Familiarity when participants remarked about not knowing anyone who was posting resources or not knowing the teachers in the videos. We also used this code when participants reported that they didn’t feel like their classrooms were represented and that it was difficult to relate to the other members’ experiences. As one participant noted, “When I look at other people’s videos, I have no clue as to where the other teachers are... I’m in an urban setting... In the VLC videos, a lot of times the children are well behaved. I think, are they in an urban setting? ... When I see a video... a majority of the students are Caucasian.”

We coded Isolation when participants reported that they felt anonymous and did not feel like they belonged. Some observed that VLC members seemed to work independently and were focused on their own goals. This was not always met with despair, as one participant offered, “I know what a community is, but... I feel anonymous. In fact, sometimes you might want that, I don’t know. You know, I can go in, I can go out.”

We coded No Discussion when participants pointed out that the discussions were not robust or there was a lack of conversation. Some noted that the discussions were impersonal and lacked insight. One participant described this issue when she said, “The one thing that I would say is that there is not a lot of people that post about their experiences. It would be nice to see more people saying... oh, I did this, and for this lesson, I did that.”

## **Results**

### **The VLC as a community**

The majority of participants indicated that the VLC felt like a community: 70% of teachers, 66% of coaches, and 80% of the teacher-coaches stated that the VLC was a community. 7% of teachers, 17% of coaches, and 20% of teacher-coaches believed the VLC both did and did not feel like a community. 23% of teachers, 17% of coaches did not think there was a community on the VLC. A  $\chi^2$  test revealed no statistical difference across roles.

### **Reasons the VLC feels like a community**

Participants most frequently cited Togetherness (41% of participants) as the reason that participants felt the VLC was a community. They also frequently mentioned Sharing Resources (26%) and Discussions (20%), but only 13% of all participants noted that they felt Familiarity with other VLC members.

### **Reasons the VLC does not feel like a community**

Few participants noted that the VLC did not feel like a community. When they did, 13% cited Isolation; 10% cited No Discussion; and 5% cited Lacking Familiarity. Interestingly, users who felt like there was not a community within the VLC cited the same aspects of what a community *should* look like by those who said a community existed. For example, both those who reported community and those who did not discussed knowing the other users (Familiarity vs. Lacking Familiarity) and having the same goals (Togetherness vs. Isolation).

## **Discussion and scholarly significance**

For OTPD to work effectively, site developers must understand how learning and engagement develop within it, which implicitly requires examining how community forms and grows. This study shows that the members of one widely used OTPD platform—the VLC—currently feel a strong sense of community for a variety of reasons, some of which coincide with the literature on online professional development (e.g., Togetherness) and others that are more unique (e.g., Sharing of Resources). By devising a coding scheme to capture participants’ feelings of community, we have provided a clearer picture of what makes teachers feel (and not feel) a sense of community.

This research has implications for theory and practice. Theoretically, this study contributes to understanding the types of behavior required for sustained engagement in professional development by demonstrating that engagement—but not necessarily collaboration—promotes community. Additionally, the definitions that emerged from this study emphasize the necessity of the three components of the CoI model: social presence, cognitive presence, and teaching presence.

Practically, this study led to the design and implementation of site-related innovations to boost interactive dialogue and community-building among VLC members. For example, the VLC now emails members when others respond to their posted commentary; other online communities could develop similar features. More

broadly, this study suggests that research on online communities may need to focus less on whether teachers' online activities rise to the definition of community established in off-line learning communities (such as shared tasks and a sense of closeness to each other) and more on how teachers define and create communities online through shared features, ideas, and resources, even in spaces where teachers have different goals and are unknown to each other. Perhaps it is possible that online teacher learning communities (like other online communities) can be powerful and effective without being overtly connected or collaborative. The reasons for feeling connected, which emerged from the comments made during the interviews, suggest that video resources on an online site can connect teacher-learners with ideas for enactment in their own classrooms. More generally, OTPD sites can capitalize on all of the reasons that participants provided, and amplifying the presence of these same reasons within any flourishing OTPD has the potential to make its community even stronger.

Because we know that fostering a sense of community is a key ingredient of successful online teacher professional development (Lock, 2006), paying attention to why teachers feel a lack of community can also point to avenues for productive changes, including attending to resources that are likely to increase feelings of belonging. Listening to users' perceptions of community in this setting and creating an environment that incorporates those perceptions has the potential to increase teachers' usage of OTPD sites, learning from the sites, and feelings of support within their profession.

## References

- Barab, S., MaKinster, J. G., Moore, J., Cunningham, D., & the I.L.F. Design Team. (2001). Designing and building an online community: The struggle to support sociability in the Inquiry Learning Forum. *Educational Technology Research and Development, 49*(4), 71-96.
- Besser, H., & Donahue, S. E. (1996). Distance independent education. *Journal of the American Society for Information Science, 47*, 799-883.
- Corbin J. M., & Strauss, A. L. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3<sup>rd</sup> ed.). Los Angeles: Sage.
- Drouin, M.A. (2008). The relationship between students' perceived sense of community and satisfaction, achievement, and retention in an online course. *Quarterly Review of Distance Education, 9*, 267-284.
- Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education, 2*, 87-105.
- Haythornthwaite, C., & Wellman, B. (1998). Work, friendship, and media use for information exchange in a networked organization. *Journal of the American Society for Information Science, 49*, 1101-1114.
- Heck, D. J., Banilower, E. R., Weiss, I. R., & Rosenberg, S. L. (2008). Studying the effects of professional development. *Journal for Research in Mathematics Education, 39*, 113-152.
- Hill, J.L. (1996). Psychological sense of community: Suggestions for future research. *Journal of Community Psychology, 24*, 431-438.
- Hur, J. W., & Hara, N. (2007). Factors cultivating sustainable online communities for K-12 teacher professional development. *Journal of Educational Computing Research, 36*, 245-268.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Liu, S. Y., Gomez, J., & Cherng-Jyh, Y. (2009). Community college online course retention and final grade: Predictability of social presence. *Journal of Interactive Online Learning, 8*, 165-182.
- Rheingold, H. (1993). *The virtual community: Homesteading on the electronic frontier*. Reading, MA.: Addison-Wesley.
- Rovai, A. P. (2002). Building sense of community at a distance. *International Review of Research in Open and Distance Learning, 3*, 1-16.
- Supovitz, J. A. (2002). Developing communities of instructional practice. *Teachers College Record, 104*, 1591-1626.
- Trust, T., Krutka, D. G., & Carpenter, J. P. (2016). "Together we are better": Professional learning networks for teachers. *Computers & Education, 102*, 15-34.
- Yoon, K. S., Duncan, T., Lee, S. W.-Y., Scarloss, B., & Shapley, K. L. (2007). *Reviewing the evidence on how teacher professional development affects student achievement*. Issues & answers. REL 2007-No. 033. Regional Educational Laboratory Southwest. Regional Educational Laboratory Southwest.

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# Exploring Teaching and Course Assistants' Interventions with Groups during Collaborative Problem-Solving

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**Abstract:** This study explores the task-related interventions of a teaching assistant and three course assistants with six small groups during collaborative problem-solving activities in undergraduate engineering classrooms. Results indicated that the majority of the interventions were not preceded by monitoring the group activity and were initiated by asking the groups a general question about their activity or progress on the task. The majority of the interventions were dominated by feedback moves which suggests that the teachers were using direct instruction strategies more than dialogic strategies when intervening with the groups' work.

## Introduction

The role of the teacher in orchestrating collaborative problem solving activities in face-to-face STEM classrooms has received increasing attention in recent years (Gillies, in press). Research suggests that teachers must implement strategies that can facilitate student interactions and positively impact the group progress towards the goal of solving the task during these activities (Kaendler et al., 2015). Few empirical studies focused on the strategies that teachers use during collaborative problem-solving activities to intervene with group work. Similarly, studies that take place in higher education STEM classrooms and examine the intervention strategies that are implemented by graduate teaching assistants (TAs) and sometimes more advanced undergraduate students are equally limited. This study addresses this gap in the literature by exploring the interventions of a graduate teaching assistant and three undergraduate course assistants (CAs) with groups during collaborative problem-solving undergraduate engineering discussion sessions.

Effective teachers' interventions in group work are characterized by being contingent on any difficulties that the group is facing, but without taking away the need for students to co-construct knowledge as they solve the task (e.g., Hofmann & Mercer, 2016). In order for such interventions to occur, teachers must avoid immediately using authoritative or directive strategies (e.g., giving solution procedures). Instead, teachers must monitor the group activity to diagnose the difficulties that are blocking the group members from engaging in high quality interactions or making progress on the task (Kaendler et al. 2015). Then, teachers can initiate the intervention by asking the group members to describe what they are thinking about and actively listen to their thoughts and discussions (Hofmann & Mercer, 2016). This gives teachers the opportunity to further understand the group members' difficulties and be helpful without immediately evaluating their ideas or providing answers (Chiu, 2004). Also, teachers must implement follow-up strategies to facilitate the group work. These strategies can be direct instruction strategies such as telling the group the solution processes or giving the group hints. They can help the group in solving the task or focusing the group's attention on certain concepts or aspects of the task (Chiu, 2004). They can also be dialogic strategies such as asking questions to probe and explore the group's understanding of the task and pushing the group members to clarify and elaborate on their ideas. These strategies can engage group members in thinking together and can encourage silent group members to participate in the discussion (Hofmann & Mercer, 2016; Webb et al., in press).

Although we know a little about how teachers intervene in group work, we do not yet know how these interventions look like in actual collaborative problem-solving higher education STEM classrooms that are orchestrated by teaching assistants. This study explores the interventions of a teaching assistant and three course assistants (CAs) with six small groups during collaborative problem-solving undergraduate engineering discussion sessions. The study set out to answer the following research questions:

- 1) What were the initiating and follow-up moves that the teachers used when engaging in task-related interventions with groups?
- 2) What was the nature of the strategies that the teachers implemented during these interventions?

## Methods

A qualitative exploratory design is used in this study, which is a part of a multi-year design-based implementation research project that aims to develop tools to support collaborative problem solving in undergraduate engineering courses.

## Participants

Participants were one TA (Austin), three CAs (Tom, Jim, Ted), and 20 undergraduate engineering students (13 males and 7 females). The TA was a graduate engineering student and the CAs were undergraduate engineering students who had taken this engineering course in previous semesters. The TA and the CAs had no prior teaching experience when they started teaching the discussion sessions and had not attended any professional development on teaching in a collaborative problem-solving classroom. However, the faculty member responsible for the course met weekly with all the TAs to provide some framing for the learning and teaching goals of each weeks' task.

## Data collection

The data for this study was collected during two 50-minute discussion sessions that were a required part of an introductory engineering course at a large Midwestern university. Both discussion sessions took place in a laboratory classroom. In the first discussion session, four groups of undergraduate students, the TA (Austin), and the two CAs (Tom & Jim) were recorded using ceiling mounted cameras and lapel, table or hanging microphones. Similar recordings were collected in the second discussion session, from two groups of undergraduate students, the TA (Austin), and the two CAs (Tom & Ted). During both discussion sessions, students worked in small groups to solve the same ill-structured, authentic engineering task that was designed using the guidelines developed by Shehab et al. (2017). Students worked on 11-inch tablets with software built specifically for this project. Each student had one tablet; tablets of students in the same group were synchronized, so that members of each group worked on and contributed to the same document.

## Data analysis

The videos were transcribed and analyzed. The analysis focused on the task-related intervention episodes that were initiated by the TA or one of the CAs. An intervention episode began when the TA or CA joined a group and ended when the TA or CA left this group. The TA or CA's activity was examined to identify if the TA or CA appeared to purposefully observe a group's activity before intervening. When this occurred, the researcher assumed that the TA or CA monitored the group activity. To evaluate interrater reliability, two researchers coded the TA or CA activity that preceded the intervention episodes of two of the six groups. Cohen's kappa was .90. Disagreements were discussed to reach agreement.

Two emergent coding schemes were used to identify the initiating move that occurred at the beginning of an intervention episode and the follow up moves that occurred during an intervention episode. The *initiating moves coding scheme* (see Table 1) was applied to the initiating turn by TA or CA. The *follow up moves coding scheme* (see Table 2) was applied to each follow up turn by the TA or CA that came after the initiating turn in the same intervention episode. To evaluate interrater reliability, two researchers coded all initiating and follow up turns of the intervention episodes of two of the six groups. Cohen's kappa was .90 for the initiating moves and .80 for the follow up moves. Disagreements were discussed to reach agreement. For the purpose of this analysis, the coded follow-up turns were categorized as moves that can be associated with *giving feedback* to group members (provided a simple answer, provided an elaborated answer, evaluated/judged, provided explicit tips/hints, provided an explanation or elaboration, and instructed student or group), and *prompting for a response* from the group members (repeated/revoiced, invited students to speak, explored students' understanding, challenged student idea, and encouraged students to collaborate).

Table 1: Initiating moves coding scheme

Code	Definition	Example
Asked a general question	The TA/CA asked a question that was related to the group's activity or progress on the task	"What are you guys doing?"
Asked a specific task-related question	The TA/CA asked a question that was related to a specific step necessary to solve the task	"So, have you calculated the shear force?"
Commented on collaboration	The TA/CA commented on the collaborative process of the group or the collaborative behavior of a group member	"I notice you're not working with your group, how are you doing?"
Commented on the group's work	The TA/CA commented on the quality of the group or student's work	"Interesting work Marco!"
Instructed group	TA/CA instructed one or more students to do or not to do something	"Now you put down what you do to solve for it."
Other	Inaudible talk	



**Table 2: Follow-up moves coding scheme**

Provided a simple answer	The TA/CA answered a student's question without any additional elaboration or explanation	<i>Student: "Is that talking about the shear or the normal force?"</i> <i>TA: "Shear force"</i>
Provided an elaborated answer	The TA/CA answered a student's question with additional elaboration or explanation	<i>Student: "Do we only get one of each?"</i> <i>TA: "Yes, so those are all the objects that you're working with. You put one of each of those on one of the shelves."</i>
Evaluated/Judges	The TA/CA evaluated or judged the group work	<i>TA: "No, what you guys did here is wrong"</i>
Provided explicit tips/hints	The TA/CA explicitly presented hints or tips on how to solve the problem	<i>TA: "Just put the books in the middle of the shelf and you are on the right track"</i>
Provided an explanation or elaboration	TA/CA explained or elaborated on certain concepts or problem-solving procedures	<i>"So for this case since we have zero axial or zero forces, it does not really matter"</i>
Instructed student or group	TA/CA instructed one or more students to do or not to do something	<i>"Okay so can all of you go to page three? I can explain this to all of you. And then just put your tablets down"</i>
Reacted to a student's statement	TA/CA simply accepted, confirmed, or rejected students' statements or made neutral statements	<i>Student: "So the shelf is held on the left and right side"</i> <i>TA: "Right, the shelf is held on the left and right side"</i>
Asked a student to clarify or repeat idea	TA/CA asks a question to clarify something related to what the student was saying	<i>Student: "So we are going to find the distribution that fails"</i> <i>TA: "Huh? say again"</i>
Repeated/ Revoiced	TA/CA repeated/revoiced a student idea to give the student a space to follow-up	<i>Student: "We put everything in the middle and now we're going to calculate it"</i> <i>TA: "You are calculating it, okay."</i>
Invited students to speak	TA/CA invited one or more students to speak up to share ideas/thoughts/reasoning	<i>"So what do you guys think?"</i>
Explored students' understanding	TA/CA prompted students to say more about a certain concept or problem solving procedure	<i>TA: "If I cut it just to the right of that 62 newtons going down it, what would it be?"</i>
Challenged student idea	TA/CA challenged student's idea by asking a question or providing a counter argument that prompts student's thinking	<i>Student: "So this distribution will fail"</i> <i>TA: "Are you sure about that?"</i>
Encouraged students to collaborate	The TA/CA encouraged students to communicate/talk/discuss ideas with each other	<i>"Just discuss how you want to go about the problem and the assumptions that you want to make"</i>
Other	Inaudible or unintelligible	
No follow up moves	The TA/CA left the group without making any follow up moves besides the initiating move	

## Results

The total number of task-related TA or CA intervention episodes was 29. Nineteen episodes were not preceded by monitoring the group activity; ten episodes were preceded by monitoring. Fifteen of the 19 episodes that were not preceded by monitoring the group activity were initiated by asking the group a general question. Of the 10 episodes that were preceded by monitoring, six were initiated by asking the group a general question and four were initiated by asking the group a specific task-related question. The 29 TA or CA intervention episodes included a total of 229 follow-up turns. Figure 1 shows the number of turns that were coded as moves that can be associated with giving feedback to group members and with prompting the group members for a response. Of the 29 episodes, Figure 2 shows the number of episodes that included only giving feedback moves, only prompting moves, a mixture of both, and only other or no follow-up moves.

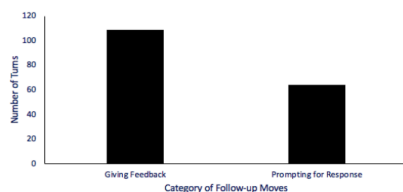


Figure 1. Number of Turns per Category of Follow-up Moves.

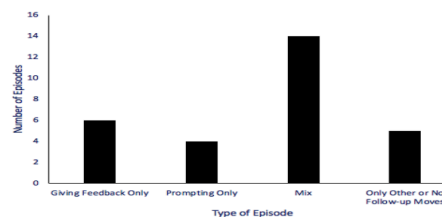


Figure 2. Type of Episodes.

## Conclusions and implications

This study examined the task-related intervention episodes of one TA and three CAs with six small groups in two collaborative problem-solving undergraduate engineering discussion sessions. Results indicate that the majority (19 out of 29) of the intervention episodes were not preceded by monitoring the group activity. This suggests that the teachers did not diagnose the difficulties that may have been blocking the group members from engaging in high quality interactions or making progress on the task. Rather, TAs and CAs intervened to check on the groups' progress on the task as part of doing their job in managing the classroom. The fact that 15 of the 19 episodes that were not preceded by monitoring were initiated by asking the group a general question supports this claim. However, all 10 episodes that were preceded by monitoring the group activity were initiated by asking the group a question. This suggests that the teachers may have avoided intervening immediately with the groups' work before getting a sense of the students' thoughts and progress on the task.

Figure 1 shows that the number of follow-up moves that are associated with giving feedback to the group members are greater than the number of follow-up moves that are associated with prompting the group members for response. Figure 2 shows that the majority of the episodes (20 episodes) either included only giving feedback moves or a mix of giving feedback and prompting moves. Further examination of the sequence of turns of episodes that included a mix of giving feedback and prompting moves, indicated that even when the teachers prompted students for a response to explore their thinking or share their ideas, at some point during the intervention the teachers switched to answering students' questions, explaining the solution processes or giving the group tips that can help in solving the task. This suggests that the teachers tended to use direct instruction strategies more than dialogic strategies when intervening with the groups' work. Implementing these strategies kept the teachers in control of the problem-solving process and may have taken away the need for students to co-construct knowledge as they solved the task. Further analysis is needed to understand the impact of these strategies on variables, such as the quality of student interactions and progress on the task, that can influence what students learn during a collaborative problem-solving activity. In addition, further analysis of data that was collected from other discussion sessions that were taught by the same and different teachers is needed to better understand the differences in the interventions across the teachers and across the groups.

## References

- Chiu, M. M. (2004). Adapting teacher interventions to student needs during cooperative learning: How to improve student problem solving and time on-task? *American Educational Research Journal*, 41, 365-399.
- Gillies, R. M. (in press). Promoting academically productive student dialogue during collaborative learning. *International Journal of Educational Research*.
- Hofmann, R., & Mercer, N. (2016). Teacher interventions in small group work in secondary mathematics and science lessons. *Language and Education*, 30(5), 400-416.
- Kaendler, C., Wiedmann, M., Rummel, N., & Spada, H. (2015). Teacher competencies for the implementation of collaborative learning in the classroom: a framework and research review. *Educational Psychology Review*, 27(3), 505-536.
- Shehab, S., Mercier, E., Kersh, M., Juarez, G., & Zhao, H. (2017). Designing tasks for engineering problem solving. In *Proceedings of the 12th International Conference on Computer Supported Collaborative Learning*. Philadelphia, PA: International Society of the Learning Sciences.
- Webb, N. M., Franke, M. L., Ing, M., Turrou, A. C., Johnson, N. C., & Zimmerman, J. (in press). Teacher practices that promote productive dialogue and learning in mathematics classrooms. *International Journal of Educational Research*.

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# Students' Funds of Knowledge and Knowledge Creation During STEM Learning in a Computer-Supported Makerspace

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**Abstract:** Despite increased research attention to novel design and making environments, often referred to as “makerspaces”, students’ funds of knowledge and knowledge creation are still a fairly unexplored issue in these contexts. To address this gap, we draw from sociocultural theorizing, with a specific interest in the notions of funds of knowledge and knowledge creation. We ask: how do the students’ funds of knowledge mediate their knowledge creation during STEM learning in a novel computer-supported makerspace? Our findings indicate three forms of knowledge creation during STEM learning: “horizontal knowledge creation”, “vertical knowledge creation”, and “extended knowledge creation”. Our work joins with the line of research focused on complex intersection between students’ funds of knowledge and schooled knowledge in a third space. It makes visible how a novel computer-supported makerspace makes available a repertoire of digital, material and social resources that can advance the emergence of creative third spaces.

## Introduction

Digital learning tools and technologically enhanced learning environments often referred to as “makerspaces” have aroused recent educational interest (Honey and Kanter, 2013; Halverson and Sheridan, 2014; Kafai, Fields and Searle, 2014, Peppler, Halverson and Kafai, 2016, Kumpulainen, Kajamaa and Rajala, 2018). Makerspaces account for interest-driven engagement in hands-on creative activities with a range of tools and artefacts. Despite the growing importance and popularity of these learning environments, how students’ use their funds of knowledge and create knowledge in these contexts is still fairly unexplored. To address this research gap, we investigate students’ funds of knowledge and knowledge creation in a novel computer-supported makerspace, the FUSE Studio, which is a choice-based digital infrastructure for STEM (i.e., Science, Technology, Engineering and Mathematics) learning (Stevens and Jona, 2017). It is located within a school context and provides digital tools and other material means for mediating between school and the out-of-school lives of the participating students. Ideally, the students can make their implicit funds of knowledge explicit and expand these in innovative learning processes by constructing novel solutions to the STEM challenges during the design and making activities. This thus provides an intriguing context for the investigation of students’ funds of knowledge and knowledge creation during STEM learning. Drawing from sociocultural theorizing, we ask: How do students’ funds of knowledge mediate their knowledge creation during STEM learning activities in a novel computer-supported makerspace? To answer this research question, we draw on the theoretical notions of funds of knowledge (e.g. Moll, Amanti, Neff and Gonzales, 1992; Vélez-Ibáñez and Greenberg, 1992; Barton and Tan, 2009; Esteban-Guitart, Maria Serra and Llopart, 2018) and knowledge creation (e.g. Nonaka and Takeuchi, 1995; Paavola, Lipponen and Hakkarainen, 2004; Hakkarainen, 2009; Ritella and Hakkarainen, 2012).

## Conceptual background

“Funds of knowledge” refers to a student’s multiple cultural resources that stem from their life worlds in and out of school. Earlier studies applying the funds of knowledge approach have largely focused on promotion of inclusive educational practices, highlighting that pedagogical practices built upon students’ funds of knowledge can generate positive consequences for their learning and participation in the classroom, potentially leading to improved educational quality (e.g. Moll et al., 1992; Vélez- Ibáñez and Greenberg, 1992; Gonzales, Moll and Amanti, 2005; Barton and Tan, 2009). Recent research has shown that classroom interaction plays a crucial role in mediating students’ opportunities to draw upon their funds of knowledge and productively connect this knowledge to their academic learning (Rodriguez, 2013; Esteban-Guitart et al., 2018; Silseth and Erstad, 2018). Research also shows how new digital tools and online spaces can support students’ sense making and meaning-making and coherence between the students’ funds of knowledge across school and out-of-school contexts (e.g. Kamberlis and Wehunt, 2012; Lantz-Anderson, Vigmo and Bowen, 2013; Kumpulainen et al., 2014). Recently, studies have explored students’ funds of knowledge in STEM education of non-dominant groups’ mathematics learning (Civil, 2016) and to understand math, science and engineering concepts, at the secondary and post-

secondary level (Verdin, Godwin and Capobianco, 2016). However, at present little is known how students' funds of knowledge mediate their knowledge creation in novel, computer-supported makerspaces that differ from regular classroom contexts with teacher-centered classroom practices. Our study is based on Vygotsky's sociocultural idea of conceptual (signs, language) and material (artefact/tool) mediation of human action (Vygotsky, 1978, see also Ritella and Hakkarainen, 2012). We stress tensions, questions and questioning as important mediators, mediating the student's interaction and innovative learning and knowledge advancement. We view knowledge creation as a non-linear process, drawing from the funds of knowledge of the participants, always embedded in practices and mediated by language and tools (Vygotsky, 1978). Further, the explication of students' funds of knowledge is considered central in the genesis of students' creative processes (Nonaka and Takeuchi, 1995). In our case, in the technologically enhanced design and making activities, following Nonaka and Takeuchi (1995), we view knowledge as created through a continuous dialogue between tacit and explicit knowledge, in our study the tacit referring to the student's funds of knowledge and the digital tools and other material means and the collaborative interaction seen as enabling the articulation of tacit knowledge, and mediating the transfer between the tacit and the explicit knowledge.

## Empirical study

The context of this study is a city-run comprehensive school with 535 students and 28 teachers at the primary level. The school strives for student-centredness and stresses design and digital learning, which is aimed at enhancing students' creative problem-solving skills across the curriculum. In 2016, as a response to the new national core curriculum requirements, the school introduced the FUSE Studio ([www.fusestudio.net](http://www.fusestudio.net)) as one of its elective courses. The FUSE Studio is a technological and pedagogical infrastructure that provides digital tools (computers, 3D printers) and other materials (e.g., foam rubber, a marble, tape and scissors) for science, technology, engineering and mathematics (STEM) learning. In the FUSE Studio, students are free to select which 'challenges' to pursue, who with (or alone) and when to move on. The challenges level up within sequences, following the basic logic of video game design principles. Each challenge is designed to engage students in different STEM topics and skill sets. A *Solar Roller* challenge, where the students build a toy car and try to move it by charging it with power from the lamp, as an example. The challenges are accompanied by computers, 3D printers and other materials, as well as instructions on how to process the challenges. The core idea is to promote young learners' STEM learning and to cultivate STEM ideas and practices among those who are not already affiliated with them, and by so doing broadening the access to participation in STEM learning. The assessment of a student's participation and learning does not include grading, but is carried out by utilizing photos, video or other digital artifacts and the student's own documentation (Stevens and Jona, 2017).

## Methodology

Our primary data comprise 111 hours of transcribed video recordings and field notes of groups of students (N = 94) aged between 9 and 12 years old and their facilitator-teachers carrying out making and design activities in the FUSE Studio. The video recordings were collected intermittently over a period of one academic year. The data come from three groups of students and their teachers who participated in the FUSE Studio elective course. Due to the elective nature of the course, the groups consisted of students from several classes. Group 1 consisted of 32 students (22 boys and 10 girls), Group 2 consisted of 30 students (19 boys and 11 girls) and Group 3 consisted of 32 students (19 boys and 13 girls). Each group was supported by two to four teachers and teaching assistants. At the beginning of the first semester, each group had one 45-minute FUSE session a week. Later in the semester, each session was extended to 60 minutes. All relevant parts of the video data and field notes of students' and teachers' collaborative interaction in the design and making environment were transcribed. Our analytic approach can be defined as abductive, involving repeated iterations between theory and data. Our analysis focused on the interaction taking place between the students and their teachers in their making activities. Our analysis proceeded from inductive analysis of the discursive acts in the student's interactions (Jordan and Henderson, 1995) in which the student's explicated their funds of knowledge. We depicted episodes where the students' funds of knowledge were either supported or overrun by the peers and/or the teachers. For this, we first engaged in close and iterative readings of all the interview data and started to extract funds of knowledge from the data. On this basis, the students out-of-school and school experiences were given codes, and connections were then looked among codes, and the codes were then progressively clustered in emerging main themes. With the aim of deepening our analysis of the students' funds of knowledge, and to investigate it in relation to their knowledge creation that emerged in the students' collaborative interaction, we then focused on further analyzing the parts of the transcripts in which the students experienced challenges and success during their STEM activities. Our interaction analysis proceeded to the tracing of the main forms (or patterns) of student's knowledge creation from the depicted interaction

episodes. Moreover, inspired by the approach on knowledge creation developed by organization scholars, Nonaka and Takeuchi, (1995), we developed a typology of forms of knowledge creation which gave evidence of how the students' funds of knowledge mediated knowledge creation, moving across different domains of STEM practice—everyday life, school, and STEM disciplines (see also Civil, 2016).

## Findings

Our study revealed three forms of knowledge creation in the students' design and making activity in the FUSE Studio. *Horizontal knowledge creation* refers to the bottom-up and student-driven nature of knowledge creation during which the students actively explicated their funds of knowledge to others in their making activity. For example, the students enthusiastically interacted and instructed one another, and their funds of knowledge were recognized and taken into account, by their peers and / or the teacher. This often reframed the activity, extending the original FUSE maker challenges. While drawing on their everyday experiences, the potential of the FUSE Studio to contribute to knowledge creation between school and out-of-school was effectively realized. Here, the students relied on their personal funds of knowledge that potentially contributed to their creation of new knowledge and STEM learning. *Vertical knowledge creation* refers to the top-down directed nature of knowledge creation in which there was little room for the students' funds of knowledge. The students' funds of knowledge remained implicit and were not explicated in ongoing interactions. For example, the students drew from their existing knowledge without questioning or reconceptualizing the FUSE challenges or the teacher's instructions. The students' activity was focused on STEM learning, however, the FUSE studio then privileged a traditional classroom interaction through which students followed authorized instructions given from the outset with little recognition of their personal funds of knowledge. This created multiple tensions between the students and their teachers. *Extended knowledge creation* refers to hybridized forms of knowledge creation in which the students' funds of knowledge hybridized with and advanced schooled knowledge and practice. In these episodes, the students' funds of knowledge created extended possibilities for their knowledge creation and STEM learning. The students stepped beyond the horizontal and vertical knowledge creation and applied knowledge in creative ways while working on the FUSE maker challenges. We illustrate how this process may lead to creative processes (see also Sefton-Green et al., 2011), as well as to the development of the student's "conceptual artifacts", which are symbolic in nature and enhance the student's learning activity (Paavola et al., 2004).

## Potential significance of the work

Our findings highlight the importance of not only the students bringing in their funds of knowledge into the design and making activity, but also how creative processes emerge when the students' personal funds of knowledge are explicated and hybridized with schooled knowledge, advancing their knowledge in ongoing collaborative interactions. In the FUSE Studio, the students creatively explicated their funds of knowledge in the collaborative interaction, and also broke away from the situation and the instructions. In some cases, extended, innovative and unexpected ways of working and solutions on the FUSE challenges emerged. However, often times the students quite mechanically carried out vertical knowledge creation, in other words, strictly followed the structures and instructions of the FUSE Studio and/or facilitating teachers. Our work joins with the line of research focused on complex intersection between students' funds of knowledge and schooled knowledge in a third space (see also Moje et al., 2004; Gutiérrez, 2008; Barton and Tan, 2009). The study makes visible how a novel computer-supported makerspace, in our case, the FUSE Studio makes available a repertoire of digital, material and social resources that can advance the emergence of creative third spaces. Widening of the understanding of the different forms of students' knowledge creation can provide valuable lessons and guide knowledge advancement and transformation of school contexts, yet due to the tensions, this presents a challenging endeavor.

## References

- Barton, A. and Tan, E. (2009). Funds of knowledge, discourses and hybrid space. *Journal of Research in Science Teaching*, 46(1), 50–73.
- Civil, M. (2016). STEM learning research through a funds of knowledge lens. *Cultural Studies in Science Education*, 11, 41–59.
- Esteban-Guitart, M., Maria Serra, J. and Llopart, M. (2018). The Role of the Study Group in the Funds of Knowledge Approach. *Mind, Culture, and Activity*, 25(3), 216-228.
- González, N., Moll, L. C., and Amanti, C. (2005). *Funds of Knowledge: theorizing practices in households, communities, and classroom*. Mahwah, NJ: Lawrence Erlbaum.
- Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly*, 43, 148–164.

- Hakkarainen, K. (2009). A knowledge-practice perspective on technology-mediated learning. *Computer-Supported Collaborative Learning*, 4, 213-231.
- Halverson, E. R. and Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), 495-504.
- Honey, M. and Kanter, D. (Eds.) (2013). *Design, make, play: Growing the next generation of STEM innovators*. New York: Routledge.
- Jordan, B. and Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39-103.
- Kafai, Y., Fields, D., and Searle, K. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review*, 84(4), 532-556.
- Kamberelis, G., and Wehunt, M. D. (2012). Hybrid discourse practice and science learning. *Cultural Studies of Science Education*, 7(3), 505-534.
- Kumpulainen, K., Lipponen, L., Hilppö, J., and Mikkola, A. (2014). Building on the positive in children's lives: a co-participatory study on the social construction of children's sense of agency. *Early Child Development and Care*, 184(2), 211-229.
- Kumpulainen, K., Kajamaa, A., and Rajala, A., (2018). Understanding educational change: Agency-structure dynamics in a novel design and making environment. *Digital Education Review*, 33, 26-38.
- Lantz-Andersson, A., Vigmo, S., and Bowen, R. (2013). Crossing boundaries in Facebook: Students' framing of language learning activities as extended spaces. *International Journal of Computer-Supported Collaborative Learning*, 8(3), 293-312.
- Moje, E. B., Ciechanowski, K.M, Kramer, K., Ellis, L., Carrillo, R. and Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and Discourse. *Reading Research Quarterly*, 39(1), 38-70.
- Moll, L. C., Amanti, K., Neff, D., and Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice*, 31(2), 132-141.
- Nonaka, I., and Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.
- Paavola, S., Lipponen, L., and Hakkarainen, K. (2004). Models of innovative knowledge communities and three metaphors of learning. *Review of Educational Research*, 74(4), 557-576.
- Peppler, K., Halverson, E., and Kafai, Y. B. (Eds.). (2016). *Makeology: Makerspaces as learning environments* (Vol. 1). New York: Routledge.
- Ritella, G. and Hakkarainen, K. (2012). Instrumental genesis in technology-mediated learning: From double stimulation to expansive knowledge practices. *International Journal of Computer-Supported Collaborative Learning*, 7(2), 239-258.
- Rodriguez, G. M. (2013). Power and agency in education: Exploring the pedagogical dimensions of Funds of Knowledge. *Review of Research in Education*, 37(1), 87-120.
- Sefton-Green, J., Thomson, P., Jones, K., and Breslin, L. (Eds.). (2011). *The Routledge international handbook of creative learning*. London: Routledge.
- Silseth, K., and Erstad, O. (2018). Connecting to the outside: Cultural resources teachers use when contextualizing instruction. *Learning, Culture and Social Interaction*. Published online before print, February 2018, <https://doi.org/10.1016/j.lcsi.2017.12.002>
- Stevens, R., and Jona, K. (2017). Program design. FUSE Studio -website. Retrieved May 20, 2017 from <https://www.fusestudio.net/program-design>
- Vélez-Ibáñez, C. G., and Greenberg, J. B. (1992). Formation and transformation of funds of knowledge among U.S.-Mexican households. *Anthropology and Education Quarterly*, 23(4), 313-335.
- Verdin, D., Godwin, A., and Capobianco, B. (2016). Systematic review of the funds of knowledge framework in STEM education. *School of Engineering Education Graduate Series*, 59(6), 26-48.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher mental processes*. Cambridge, MA: Harvard University Press.

# Children's Interactive Strategies around Digital Technology in a Collaborative Learning Environment

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**Abstract:** The current study examines how children develop different interactional strategies around digital technology as they get enculturated within a community of design learners. Using a comparative case study of a single case we discuss how a student progresses from individual to collective interactional strategies, over a period of time, as she collaborates around digital technology in a small design group. We then discuss the social affordances of technology and its importance in developing technology integration models.

## Technology integration in collaborative learning

The introduction of screen-based technologies has led to improvements in developing both academic and 21<sup>st</sup> century skills and hence many schools have quickly adopted one computer per student initiatives in a classroom (Freeman et al., 2017; Swallow, 2017). However, the mere addition of technology in learning environments is not a sufficient condition to ensure improvements in learning outcomes, since technology presents trade-offs that interact with individual and group processes (Jeong & Hmelo-Silver, 2016; Kirkwood & Price, 2014; Lim & Chai, 2008). Our previous work suggests that digital technology affords different kinds of interactions in collaborative learning environment that are especially problematic in developing shared understanding among young children (Toprani, Yan, & Borge, 2016). These findings led us to further unpack the results on a time scale to understand if these processes are impacted by continued participation within a community of learners. Towards this goal, the current study aims at identifying the interactional strategies that students use around digital technology as a part of learning design, over a period of time, and subsequently analyzing their development within the larger culture of design practices.

Technology has been efficiently used to widen the scope of learning by providing more competent tools to learn with, however, it's potential to bring about a shift from traditional instructional approach to a student-centered instructional approach fostering higher-order thinking processes are preliminarily developed (Kirkwood & Price, 2014). There is a need for developing technology integration models that approach the process from a nested, systemic perspective where the role of technology is studied in relation to factors like curriculum, teaching pedagogies, learner's needs, and the learning goals (Veletsianos, 2016). We conceptualize collaboration as a nested process between individuals, small groups, and the larger classroom community. During this process participants are engaging in higher-order thinking: developing a joint understanding about the idea, collectively critiquing the idea, discussing alternative perspectives, evaluating its feasibility, and negotiating solutions so as to create new knowledge (Stahl, 2006). Studies that look at collaboration from a nested, knowledge-building perspective have found technology to have a more ambiguous and distributed impact on learning because of the interplay of a number of factors (Jeong & Hmelo-Silver, 2016; Toprani et al., 2016). Hence, in the current study we intend to explore *How student's strategies around digital technology change as they become a part of the community of design learners?* To take a systemic perspective, we explore these ideas in relation to one student's process of getting enculturated within the afterschool club over a period of two years. We view enculturation as a process that supports not only the acquisition of knowledge but also development of judgements around its application (Tishman, Jay, Perkins, 1993). We track the development of a student, "Catherine", who was a part of the afterschool club for more than two years (four semesters). We identify the collaborative strategies she developed around digital technology in relation to her continued participation at the club. The study is designed from the student's vantage point to understand technology's affordances within a sociotechnical system i.e. what the technology offers and how the students develop social processes to make use of it. We observe Catherine's interactional strategies over a period of two years, within the larger framework of the afterschool club's cultural practices to understand how her interactional strategies change.

## Context and data selection

The current study is situated within an afterschool club, developed to promote design thinking among 8-12 years old students, in North East United States. The club is conducted weekly and each session is 75 minutes long where students work on design projects in teams of three or four. The goal of the club is to help students go through different design stages of questioning, planning, creating, and finally evaluating their design prototype against the initial client requirements. As a part of this project, Catherine, joined the club as a 4<sup>th</sup> grader and returned to the

club every semester starting Fall 2015, until Spring 2017 (i.e. four semesters). Her case provides a unique perspective to understand how student’s collaborative strategies develop as they get enculturated through the club activities and experiences. Catherine, in her first semester was grouped with three other students of her age: Kathy, Eric, and Aron. They worked on creating a garden for a fictional client named Fred. In Spring 2017, Catherine was grouped with the same members Eric and Aron, and the fourth member was changed to Marcos. In this semester they were again creating a butterfly garden for Fred with a different set of requirements. In both the semesters students would create a Lego plan of their design and then recreate the same design in Minecraft, incorporating minor revisions.

We selected Catherine, because she has been in the club the longest without missing any semesters. We compared Catherine’s collaborative strategies around digital technology across three semesters i.e. Fall 2015 (FA15) and Spring 2016 (SP16), when she was a novice to the design club’s culture, and Spring 2017 (SP17), when she was enculturated in the design club based on her participation for four semesters. By systematically reviewing video data and curriculum plan we selected one comparable lesson for each of the three time points. Across the three semesters, we selected the first lesson when they started designing with digital technologies.

## Methods

Three lessons were analyzed using interaction analysis approach (Jordan & Henderson, 1995) to build a comparative case study (Glaser & Strauss, 1973) and shed light on how the collaborative interaction strategies changed across the three time points within the cultural practices of the club. The case studies were developed by analyzing talk among the group members with a focus on the strategies used by Catherine. We began by reviewing the lessons in their entirety and then gathering critical instances representing collaborative interactions among the team members. An instance was started when two or more members interacted with each other within the context of their design project and ended when the discussion was either terminated or interjected by the beginning of a new topic. We gathered 28 instances from FA15, 22 instances from SP16, and 24 instances from SP17 for further analysis of strategies. We then created Content Logs of these instances, followed by a detailed analysis of the transcripts in order to understand the strategies. These strategies were interpreted from the data by the first author, audited by the second author and then reviewed by the third author to look for biases and inconsistencies. The analysis draws from Ciolek and Kendon’s (1980) and Streeck’s (2013) work on spatial organization of talk and artifacts, facilitating collective learning processes.


## Findings

The three cases presented below contrast between the interactional strategies used by Catherine when she had no exposure to the design club’s culture and after she participated in the club for almost four semesters. The three cases present a trajectory of change from using individualistic interactional strategies, to using more inclusive and collective interactional strategies, as she got enculturated into the design club over a period of time.

### FA15: Individualistic strategies around shared technology

When Catherine was a club novice, she largely controlled the arrangement of the artifacts. Catherine and Kathy, while collaborating together, shared a laptop and Catherine controlled access to the screen, while Kathy was left in a position of asking for access. Table 1 represents the spatial arrangement of artifacts and the position of the participants from the 11<sup>th</sup> lesson in FA15. In line 314 Kathy made a move to press some keys on the laptop and in 317, since her attempt failed, she tried to instruct Catherine of where she wanted to go in the shared Minecraft server. Although Catherine gave Kathy the autonomy to guide her in Minecraft, when Kathy asked her to focus on the fence instead of the biking trail, she redirected her attention to a decision Eric made earlier in the group about the fence, and continued working on the biking trail. The given instance and the arrangement of the artifacts

Table 1: Catherine’s Individualistic Strategies around shared technology, FA15 (New participant)

	<p>314 Kathy: Can I control ((pressing some keys on the laptop))          315 Cath: Ehh.. wait watch out Kathy          316 Cath: Tell me what to do because you are the one who ‘tells me what to do’          317 Kathy: Go there, there, there          318 Cath: Should I just do the biking trail?          319 Kathy: We need umm more fence because we have a very skinny          320 Cath: Well Eric wants it to be that way so let’s first ((continues doing the biking trail))</p>
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in the group provide evidence for Catherine’s individualistic approach. All the artifacts were placed in her



transactional space (Ciolek & Kendon, 1980) i.e. space that was easily accessible to her and Kathy's entry into the space was controlled by her (315). Kathy and Eric's position made the spatial arrangement more problematic for collaboration because the three students had no shared transactional space, physically or virtually, to initiate a conversation. Although they were in a shared Minecraft server, they didn't know where the other person was and what they were doing. This kind of a spatial arrangement of the participants and the artifacts in the group creates a tension in the process of developing shared meaning (Streeck, 2013). This tension was verbalized towards the end of the lesson when Catherine, Kathy, and Eric got into an argument about having a magical fairyland in their design, which was added by Catherine without Eric's knowledge and Kathy's complete understanding of the idea.

### SP16: Individualistic strategies around individual technology

By SP16 Catherine had limited exposure to the club's culture and was still a novice, collaborating with the same group of students from FA15. In the 4<sup>th</sup> lesson of this semester, they were building a haunted house in Minecraft and they all had individual laptops to work on. Table 2 represents the spatial arrangement of artifacts and the position of the participants. In line 665 Catherine tried to control what Kathy could touch in Minecraft world, using her own laptop. Catherine asked Kathy if they should fill up a structure in Minecraft (669). When Kathy expressed that she liked it the way it was (670) Catherine disregarded her opinion and stated that it wasn't very important. She asked other team members if it belonged to their design (671) and later in the session deleted the structure. These interactional strategies, with individual laptops, continued to look similar to the FA15 strategies. The arrangement of the laptops and the position of the participants continued to be problematic for developing intersubjectivity (Ciolek & Kendon, 1980; Streeck, 2013). Kathy and Catherine's screen arrangement, and their spatial positioning provided them with no transactional space to reference what they were doing in Minecraft.

Table 2: Catherine's Individualistic Strategies around individual laptops, Spring 2016 (New participant)

	<p>665 Cath: Hey Kathy do not touch the chest. One good thing. Kathy where are you?          666 Kathy: I am right here.          667 Cath: I am coming.          668 Cath: What's this?          669 Cath: Should we fill it? Should we fill it?          670 Kathy: Ohk.. Actually I like it.          671 Cath: eh I think it's not important. I don't think it's important. Let's ask anybody if they built it.</p>
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### SP17: Collective strategies around individual technology

Table 3. Catherine's Collective Strategies around Individual laptops, Spring 2017 (Experienced participant)

<p>(a)</p>	<p>(b)</p>	<p>330 Cath: Guys is this big enough ((fence she was building in Minecraft)) what I am building, is this big enough?          331 Aron: No cover..cover the entire area that          332 Marc: We have to leave the water there          333 Aron: No too much water          334 Marc: Until she finishes the fence          335 Cath: Is this fine? How big it is so far?          336 Marc: Where are you?          337 Cath: Are we making it a square, or a rectangle?          338 Marc: Rectangle. Ya that's pretty big. Outline the water</p>
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By SP17, Catherine had four semesters of experience at the design club and was working with other students with similar amount of experience. Catherine's interactions provided more opportunities for collective meaning making. Table 3 represents the spatial arrangement of artifacts and the position of the participants. In line 330, Catherine stopped half way through creating the fence that demarcated their building area in Minecraft, and asked Marcos and Aron if it looked alright to them. Initiating a discussion among the members, in line 331 and 338 Aron and Marcos respectively verbalized their alternative perspectives as a response to her question. Her follow-up questions (335, 337) gave all of them an opportunity to engage in collective information synthesis by trying to jointly understand the group's design and iterating on it (Borge, Ong, & Rose, 2018). These interactions in relation to the arrangement of the artifacts in the group provide evidence for Catherine's collective approach. Arranging the artifacts in the shared transactional space, giving every member equal opportunity to access them, is seen to

be favorable for collective interactions (Ciolek & Kendon, 1980). The transactional space was maintained in the virtual Minecraft environment by asking each other their locations, and physically turning their screens around to show what they were building (see picture b).

## Discussion

The crucial change that emerged in the interactional strategies used by Catherine, from the instances analyzed across FA15, SP16, and SP17, was a shift from an individualistic interactional approach to a collective interactional approach while designing in her small-group. Collaboration is a social process of developing shared meaning within a small group (Stahl, 2006). Catherine's interactional strategies, mediated through the group's artifacts (digital technology in this case) played an important role in developing shared understanding among the members about their design projects. The existence of shared transactional space in SP17 ensured more efficient communication among the members compared to FA15 and SP16. This connects to Streeck's (2013) discussion of how intersubjectivity develops around embodied interactions between participants. The movement of artifacts contributes to the development of meaning making as the participants experience a single object together and build off of each other's experiences to expand on their ideas. As Catherine got enculturated in the design club, she manipulated the artifacts in ways that promoted collective interactions. Streeck (2013) considers these approaches as being central to the development of intersubjectivity, which in turn is influential in developing a shared understanding in collaborative teams (Stahl, 2006). Different technologies have different social affordances for supporting discourse-based learning and imbibing collaborative cultural practices among children (Kirschner et al., 2004; Toprani et al., 2016). This knowledge is crucial in orchestrating technology-enhanced learning environments to help designers and instructors integrate technology to benefit learning systemically, rather than influencing its parts (Prieto et al., 2011).

## References

- Bartlett, L., & Vavrus, F. (2017). Comparative case studies: An innovative approach. *Nordic Journal of Comparative and International Education (NJCIE)*, 1(1), 5-17.
- Borge, M., Ong, Y. S., & Rosé, C. P. (2018). Learning to monitor and regulate collective thinking processes. *International Journal of Computer-Supported Collaborative Learning*, 13(1), 61-92.
- Ciolek, T. M., & Kendon, A. (1980). Environment and the spatial arrangement of conversational encounters. *Sociological Inquiry*, 50(3-4), 237-271.
- Freeman, A., Adams Becker, S., Cummins, M., Davis, A., & Giesinger, C. (2017) NMC/CoSN Horizon Report: 2017 K–12 Edition. Austin, Texas: The New Media Consortium.
- Glaser, B., & Strauss, A. (1973) *The discovery of grounded theory: Strategies of qualitative research*. London: Wiedenfeld and Nicholson.
- Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help?. *Educational Psychologist*, 51, 247-265.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, 4(1), 39-103.
- Kirkwood, A., & Price, L. (2014). Technology-enhanced learning and teaching in higher education: what is 'enhanced' and how do we know? A critical literature review. *Learning, media and technology*, 39, 6-36
- Kirschner, P., Strijbos, J. W., Kreijns, K., & Beers, P. J. (2004). Designing electronic collaborative learning environments. *Educational technology research and development*, 52(3), 47-66.
- Lim, C. P., & Chai, C. S. (2008). Teachers' pedagogical beliefs and their planning and conduct of computer-mediated classroom lessons. *British Journal of Educational Technology*, 39(5), 807-828.
- Prieto, L. P., Dlab, M., Gutiérrez, I., Abdulwahed, M., & Balid, W. (2011). Orchestrating technology enhanced learning: a literature review and a conceptual framework. *International Journal of Technology Enhanced Learning*, 3(6), 583-598.
- Stahl, G. (2006). *Group cognition*. London: The MIT Press.
- Streeck, J. (2013). Interaction and the living body. *Journal of Pragmatics*, 46(1), 69-90.
- Tishman, S., Jay, E., & Perkins, D. N. (1993). Teaching thinking dispositions: From transmission to enculturation. *Theory into practice*, 32(3), 147-153.
- Toprani, D., Yan, S., & Borge, M. (2016, October). A comparative analysis of the collaboration process across different technologies. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education* (pp. 66-69). ACM.
- Veletsianos, G. (2016). The defining characteristics of emerging technologies and emerging practices in digital education In George Veletsianos (Ed) *Emergence and innovation in digital learning: Foundations and applications*, (pp. 3-16). Edmonton: AU Press.

# Examining the Educative Value of Person-To-Person Knowledge Sharing on Social Media: The Case of YouTube as a Site of CSCL?

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**Abstract:** This conceptual paper examines the educative potential of social media as a platform for everyday on-demand computer-supported collaborative informal learning. We propose three dimensions: reliability, learnability and critical-construction, as a framework for investigating collaborative learning within naturally occurring social media. We use YouTube as a focal case. Our review of literature on YouTube as a space for informal peer learning suggests that post-video deliberative comments hold much promise as precursors for co-construction of knowledge. However, questions remain concerning the veracity of user-contributed videos, and the adequacy of this medium for different learning goals. Nonetheless, investigating the educative value of non-formal person-to-person knowledge sharing on social media can be an important direction for CSCL research in its aim to support learners in formal environments for future life-long learning and civic engagement.

## Introduction

In this conceptual paper, we examine the educative value of person-to-person knowledge sharing on social media, and propose how it can be a productive line of inquiry in the CSCL community. Web 2.0 offers a platform for both social and informal learning by providing support for user-generated content with features of social networking sites (Duffy, 2008). Interaction with these social spaces is based upon a discovery of new materials in a self-directed mode which is aimed to satisfy different learners with a variety of informal learning goals. A unique feature of learning with social media is that it is mostly motivated by an intrinsic need which is followed by intentional but also by an opportunistic search for information. Though this may start as a solitary endeavor, once the information is located, it can be supported by a collective shared knowledge and shared literacy.

This duality: motivated by a particular authentic need but also supported by a social learning space, offers an opportunity for the CSCL community to better understand how knowledge that is created and shared as part of everyday life routines might contribute to theoretical dimensions of collaborative learning (Dyosi & Hattingh, 2018; Ludvigsen, Cress, Law, Rosé, & Stahl, 2016). More specifically, by unfolding informal collective learning with YouTube as a focal case, we aim to contribute to a deeper understanding of opportunities for collaborative learning. This study is intended to question the social nature of collaboration in such environments (Asterhan & Bouton, 2017; Asterhan & Schwarz, 2007; Kimmerle, Moskaliuk, Oeberst, & Cress, 2015; Cress, Stahl, Ludvigsen & Law, 2015), with the goal of articulating principles that distinguish what constitutes person-to-person knowledge sharing versus collaborative learning, and when and how it is possible to generate situations that constitute collaborative learning.

In the following sections, we review literature on YouTube as a space for informal peer learning. Following, we propose, and apply to YouTube, a framework to evaluate the educative value of social media.

## YouTube as a focal case for educative social media

A widespread example of informal learning from the Web 2.0 is YouTube, launched in 2005 to enable any subscribed member to create, upload, and share a wide range of content ranging from homemade video to movie scenes. Yet, YouTube is not merely the second-most popular platform in the world for broadcasting content, but an emblem of emerging participatory culture, which plays a central role in learning on demand that is embedded within social interaction in the form of commenting, seeking and providing information (Tan, 2013). Within this context, the transformation in learners' consumption and participatory practices may alter what and how learning occurs. This social epistemological nature of YouTube facilitates both joint interaction with group members and interaction with broader communities such as citizen science, which might create a need for unanticipated and unexpected learning of new science knowledge and skills (Polman & Hope, 2014).

YouTube is designed as a content sharing site which is mostly based on videos that are used for informal learning tasks and entertainment. The instructional videos on YouTube can be classified through three following main types of learning: First is *procedural learning* that has a motor, visual or auditory components, such as specific troubleshooting of printer jam clearance (Rodriguez, 2002); laptop memory replacement; handheld device assembly (Watson, Butterfield, Curran, & Craig, 2010); learning of technique-based musical objectives (Waldron, 2013); or medical education, i.e., how to step by step perform a lumbar puncture procedure (Rössler, Lahner,

Schebesta, Chiari, & Plöchl, 2012). People are able to develop their procedural motor skills by performing the actions while watching the sequences in motion with actual objects and tools. A second type of learning on YouTube is *informational learning*, such as where to visit when touring a destination, what to pack. A widespread example is when people search for health-related information issues such as immunizations or H1N1 Influenza Pandemic. The rarest form of YouTube learning is the third type, *procedural conceptual learning*, which focuses on how to perform intellectual skills, for example how to analyze risk, how to decide between alternatives based on multiple criteria, or how to decide which statistical analysis is appropriate and how to interpret analysis results.

Although more than 72 hours of videos are uploaded to YouTube every minute, numerous studies have documented severe quality deficits in the information provided, stating that some of the videos' information quality "pose a grave threat" (Rössler et al., 2012, pp. 657). This threat is heightened by the unlimited ability of users to upload open-ended materials which can then be further shared. This suggests that awareness of information accuracy is key in this context (Stadler & Bromme, 2007). However, the content management features such as YouTube channels, a playlist, and measures to assess popularity, enable users to organize, source, and share videos. It thus becomes important for researchers to investigate the nuances and practices in peer interaction and learning in YouTube as a collective knowledge sharing platform. With this aim in mind, we propose three dimensions for examining the educative value of YouTube as a focal social media platform.

## Dimensions in the educative value of YouTube

We propose three dimensions: reliability, learnability and critical co-construction, as a framework for examining whether and how informal learning unfolds in YouTube, and whether it can be considered a CSCL environment.

*The Reliability dimension.* In order for YouTube instructional videos to have educative value the information and procedures that appear in them need to be reliable. Although the question of who determines or sanctions knowledge and procedures is charged, here, we define reliability as information that accords with the consensus in leading scientific journals or central professional organizations (Krippendorff, 2008). The question is what means are available to YouTube users in evaluating the veracity of the content that is uploaded? YouTube includes a number of features that can be considered with respect to this question. These include various measures to assess popularity (i.e., popularity rankings, number of views), the ability to upload an unlimited number of videos, and to post comments, which may further encourage users' discussions and interactions. Some evidence uncovers that these affordances of collective and individual social engagement, support information evaluation and sourcing within social media spaces. For instance, Azer (2012) who evaluated YouTube as a medium for learning anatomy, stated that although only 27% of videos were useful for teaching and learning purposes, the useful videos had a viewership per day on average double that of non-useful videos (38 vs. 16 average viewership/day). Similar results were suggested by Pandey et al. (2010) who evaluated YouTube as a source of information on the H1N1 influenza pandemic. Their findings point out that 61.5% of videos had accurate information about the disease, while the information that was contributed by CDC had the highest viewership share. Duncan, Yarwood-Ross and Haigh (2013) evaluated 100 YouTube channels to assess the quality of clinical skills videos. They found evidence that quality is recognized by the viewers and approval is expressed through the 'like' button on the YouTube site. In this sense, user-to-user to content interactions (i.e., sharing, popularity rankings) creates a collective literacy in information evaluation.

*The Learnability dimension.* This dimension examines whether and how the form and content of the video mediates learning, and to what degree. It also offers a way to compare the different types of learning discussed above (e.g., procedural versus informational), in terms of what strategies are more effective for each type of learning. As mentioned above, procedural learning is the most popular type of learning with YouTube instructional videos. Some evidence shows that learning with this medium is driven by perceived usefulness and expectations that learning through YouTube would improve their understanding of "how to do something" (Lee & Lehto, 2013). Interestingly, Dyosi and Hattingh (2018) reported that children who watched how-to-YouTube-videos did not realize that they were actually learning and acquiring skills, underlining that informal learning with YouTube can be incidental and unintentional. Unfortunately, there is not much direct evidence in the literature concerning the efficacy of learning with YouTube and similar social media. Although, there is some evidence through self-reports in subscribers' text comments on the posted video that suggests that knowledge and skills were acquired (Hattingh, 2017). One area for future research is to develop specialized methods to elicit evidence of learning from social media that goes beyond self-report measures.

*The degree of critical co-construction and interdependence dimension.* This dimension represents the degree of interaction and interdependence among consumers of the shared media, and between the consumers and the subscribers who create and share the media (Cress et al., 2015). This is the dimension that is most critical to the CSCL community, and for determining whether the learning context can be considered a CSCL environment. YouTube and similar social media might generate situations that make collaborative learning possible, and as

such, there is a great potential for learning. Though the structure of social media is designed to support sharing of knowledge and ideas, the process of critical evaluation, refinement or improvement of ideas is not guaranteed, and consequently, there is no guarantee that collective knowledge construction will take place. For example, Asterhan and Bouton (2017) investigated secondary-school students' interactions with social media, and found that their communication was mainly characterized by peer-to-peer exchange of information and knowledge sources, and not by in-depth, peer-guided, knowledge co-construction. They further argue that the notion of *knowledge sharing* is a more accurate depiction of this type of social knowledge-based activities than co-construction or collaborative learning.

Online knowledge sharing is a well-known construct in communication, business management and information sciences (John, 2013). Knowledge sharing refers to activities in which individuals make their own internally stored knowledge and/or external knowledge sources that they have at their disposal accessible to others. In the majority of cases, there is no direct reward for making one's knowledge available. Knowledge sharing requires time and effort to assemble and share online, and involves letting someone else have something that you have, often without knowing who benefits from this knowledge. Despite its pro-social value, Asterhan and Bouton (2017) caution about the educative value of online knowledge sharing, because the ease with which one can consume knowledge that is produced by others, forfeits important individual learning activities (e.g., summarizing, highlighting and integrating information) that are essential for skill development and knowledge growth. They posit that the lack of these pivotal attributes can be explained by the discrepancy between the underlying values that characterize social networking versus formal learning environments, such as promoting pro-social behavior versus assessment and evaluation based on individual performance.

In the Asterhan and Bouton study the most common platform studied was WhatsApp, other studies that evaluated YouTube suggest that it may offer more potential for deliberation and knowledge co-construction. For instance, studying comments on videos concerning climate change, Shapiro and Park (2018) reveal that though there were no moderators to guide the interaction, an argumentative discourse took place. Interestingly, though the post-video comments were not necessarily related to the corresponding video's content, the argumentative communication was supported by users who posted some scientific evidence, and by other subscribers who questioned that evidence by providing counter claims and citing academic sources. Another potential avenue for co-construction in YouTube is through interaction between those that post the videos and their audience. Hattingh (2017) describes how, in a subsequent video post, the presenter referred back to questions he got from subscribers and explained concepts with which they had struggled. Deschamps (2014), proposed that those comments present an opportunity for users to "transform the narrative by presenting new information... by challenging arguments, relaying new ideas, offering counterfactuals or by attempting to re-frame the discussion" (pp. 345).

Some studies have analyzed *coherence* in video-related comments on YouTube. Coherence refers to connections between ideas that appear in different individuals' comments (Bou-Franch, Lorenzo-Dus, & Blitvich, 2012). Bou-Franch and her colleagues (2012) analyzed two samples of 150 consecutive comments and found that the comments included many coherence-forming linguistic devices. This suggests a degree of attention to the content of one another's comments that can be a productive pre-cursor to the type of critical co-construction that is essential to transformative CSCL interactions. However, such coherence was produced by a minority of users, so it is not clear what impact such processes might have on the majority of users.

### **Is there an educative value?**

While most CSCL studies deal with learning within specially designed environments to support collaborative learning, the current conceptual paper concerns the landscape of spontaneous and non-formal interactions that emerge as part of the social epistemological nature of YouTube. These everyday, self-regulated, informal learning opportunities that are driven by an authentic need, offer, as shown above, precursors for collaborative learning through deliberation in the post-video comments. There are a number of open research questions to explore. First, the educative value of YouTube hinges on the reliability of its content. While ranking markers for the video itself seem to pose a fairly good indicator of reliability, such formalized and aggregating ranking markers do not exist for in-comment reactions to other comments. Thus, the reliability of the post-video deliberation, and the ability to gauge reliability need further research. In addition, aside from self-reports, there is a paucity of measures for documenting evidence of learning, especially for procedural conceptual learning, which has received little, if any, attention in the study of social media. We see this line of research as an important goal for the CSCL community, because a key role for contemporary formal education is to prepare learners for future civic participation (Gratton, 2010). Therefore, knowing how to design intentional learning environments that support future public use of informal networked learning-on-demand platforms will be central to fulfilling this role.

### **References**



- Akgun, T., Karabay, C. Y., Kocabay, G., Kalayci, A., Oduncu, V., Guler, A., ... Kirma, C. (2014). Learning electrocardiogram on YouTube: How useful is it? *Journal of Electrocardiology*, 47(1), 113–117.
- Asterhan, C. S. C., & Schwarz, B. B. (2007). The effects of monological and dialogical argumentation on concept learning in evolutionary theory. *Journal of Educational Psychology*, 99(3), 626–639.
- Asterhan, C. S. C., & Bouton, E. (2017). Teenage peer-to-peer knowledge sharing through social network sites in secondary schools. *Computers and Education*, 110, 16–34.
- Azer, S. A. (2012). Can “YouTube” help students in learning surface anatomy? *Surgical and Radiologic Anatomy*, 34(5), 465–468.
- Bou-Franch, P., Lorenzo-Dus, N., & Blitvich, P. G. C. (2012). Social interaction in YouTube text-based polylogues: A study of coherence. *Journal of Computer-Mediated Communication*, 17(4), 501–521.
- Cress, U., Stahl, G., Ludvigsen, S., & Law, N. (2015). The core features of cscl: Social situation, collaborative knowledge processes and their design. *International Journal of Computer-Supported Collaborative Learning*, 10(2), 109–116.
- Deschamps, R. (2014). What potential for you tube as a policy deliberation tool? commenter reactions to videos about the keystone XL oil pipeline. *Policy and Internet*, 6(4), 341–359.
- Duffy, P. (2008). Engaging the YouTube Google-Eyed Generation: Strategies for Using Web 2.0 in Teaching and Learning. *The Electronic Journal of E-Learning*, 6(2), 119–130.
- Duncan, I., Yarwood-Ross, L., & Haigh, C. (2013). YouTube as a source of clinical skills education. *Nurse Education Today*, 33(12), 1576–1580.
- Dyosi, N., & Hattingh, M. J. (2018). Understanding the extent of and factors involved in the use of YouTube as an Informal Learning Tool by 11- to 13-year-old children Theoretical Underpinning : Social Cognitive Theory, 1–10.
- Gratton, L. (2010). The future of work. *Business Strategy Review*, 21(3), 16–23.
- Hattingh, M. (2017). A Preliminary Investigation of the Appropriateness of YouTube as an Informal Learning Platform for Pre-teens, 101–110.
- John, N. A. (2013). Sharing and Web 2.0: The emergence of a keyword. *New Media and Society*, 15, 167–182.
- Kimmerle, J., Moskaliuk, J., Oeberst, A., & Cress, U. (2015). Learning and collective knowledge construction with social media: A process-oriented perspective. *Educational Psychologist*, 50(2), 120–137.
- Krippendorff, K. (2008). Reliability. *The International Encyclopedia of Communication*. Retrieved from <https://onlinelibrary.wiley.com/doi/abs/10.1002/9781405186407.wbiecr029>
- Kruse, N. B., & Veblen, K. K. (2012). Music teaching and learning online: Considering YouTube instructional videos. *Journal of Music, Technology and Education*, 5(1), 77–87.
- Lee, D. Y., & Lehto, M. R. (2013). User acceptance of YouTube for procedural learning: An extension of the Technology Acceptance Model. *Computers and Education*, 61(1), 193–208.
- Ludvigsen, S., Cress, U., Law, N., Rosé, C. P., & Stahl, G. (2016). Future-looking conversations in CSCL. *International Journal of Computer-Supported Collaborative Learning*, 11(3), 255–262.
- Pandey, A., Patni, N., Singh, M., Sood, A., & Singh, G. (2010). YouTube As a Source of Information on the H1N1 Influenza Pandemic. *American Journal of Preventive Medicine*, 38(3), e1–e3.
- Rodriguez, M. A. (2002). Development of diagrammatic procedural instructions for performing complex one-time tasks. *International Journal of Human-Computer Interaction*, 14(3–4), 405–422.
- Rössler, B., Lahner, D., Schebesta, K., Chiari, A., & Plöchl, W. (2012). Medical information on the Internet: Quality assessment of lumbar puncture and neuroaxial block techniques on YouTube. *Clinical Neurology and Neurosurgery*, 114(6), 655–658.
- Shapiro, M. A., & Park, H. W. (2018). Climate Change and YouTube: Deliberation Potential in Post-video Discussions. *Environmental Communication*, 12(1), 115–131.
- Shifman, L. (2012). An anatomy of a youtube meme. *New Media and Society*, 14(2), 187–203.
- Stadtler, M., & Bromme, R. (2007). Dealing with multiple documents on the WWW: The role of metacognition in the formation of documents models. *International Journal of Computer-Supported Collaborative Learning*, 2(2–3), 191–210.
- Waldron, J. (2013). User-generated content, YouTube and participatory culture on the Web: Music learning and teaching in two contrasting online communities. *Music Education Research*, 15(3), 257–274.
- Watson, G., Butterfield, J., Curran, R., & Craig, C. (2010). Do dynamic work instructions provide an advantage over static instructions in a small scale assembly task? *Learning and Instruction*, 20(1), 84–93.

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# Designing Epistemic Scaffolding in CSCL

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**Abstract:** In this paper, we propose an epistemic scaffolding framework to understand the support for epistemic change in computer supported collaborative learning (CSCL). Two types of epistemic scaffolding are differentiated based on existing literature and educational practices, namely, implicit and explicit epistemic scaffolding. Implicit epistemic scaffolding refers to the support (including tool, activities, resources, etc.) that has epistemic implications but is not made obvious to learners. Explicit epistemic scaffolding refers to the support that intentionally makes epistemic ideas explicit to learners to promote their epistemic understanding. Many of the CSCL environments have been designed with epistemic underpinnings, which could serve as implicit epistemic scaffolds. We propose that embedding explicit epistemic scaffolds in CSCL environments that are designed with implicit epistemic scaffolds is a promising way to maximize the power of support for epistemic growth.

## Introduction

Epistemic cognition is a field that studies individual's epistemic related thinking, including understanding of the nature of knowledge, process of knowing, and achievement to epistemic ends (Chinn, et al., 2014; Hofer, 2016). The importance of promoting sophisticated epistemic cognition has been acknowledged by a growing number of researchers (Greene, et al., 2016; Sinatra & Chinn, 2011). Sophisticated epistemic cognition is not only an important educational goal itself, but also an important predictor of students' learning (Chinn, et al., 2011; Elby, et al., 2016). In recent decades, much progress has been made in understanding the nature of epistemic cognition, and its relation to other constructs (Chinn et al., 2011; Hofer & Pintrich, 1997; Khine, 2008), relatively less is known about the ways in which growth towards epistemic sophistication can be promoted (Brownlee, et al., 2001; Kienhues, et al., 2016). In this paper, we attempt to propose an epistemic scaffolding framework to understand the support for epistemic change. By *epistemic scaffolding*, we mean the support that could enable learners to achieve a higher level of epistemic sophistication. It encompasses both the supports for promoting the sophistication of tacit epistemic understanding (e.g., how people actually work on knowledge) and explicit epistemic understanding (e.g., how people talk about the nature of knowledge). In this paper, we will primarily focus on the epistemic scaffolding in science.

Even though the term epistemic scaffolding has not been mentioned often in the previous literature, it has been employed intentionally or unintentionally in some educational designs, theories, and technologies. Sandoval and Reiser's (2004) study is an example of explicitly using the term "epistemic scaffold" to refer to the support used to help students understand the epistemic aspects of inquiry. There are also some other studies and efforts that tried to support students' epistemic understanding (Carey, et al., 1989; Smith, et al., 2000), however, there has been little examination of the nature and pattern of epistemic scaffolding. In this paper, we differentiate two types of epistemic scaffolding, namely, implicit and explicit epistemic scaffolding, and discuss how they could be combined to maximize the power of support for epistemic change in CSCL.

## Epistemic scaffolding

Scaffolding, in the traditional sense, is used to refer to the assistance provided by a more capable individual (e.g., tutor) to a learner to accomplish tasks that would be otherwise out of reach. The discrepancies between what an individual's actual competences are for accomplishing tasks alone and his/her potential competence for accomplishing the task with assistance is defined as the zone of proximal development (ZPD) (Vygotsky, 1978). ZPD defines the lower and upper bounds of developmental levels, and how providing support within these levels may promote learning. Researchers have identified few features that are essential for scaffolding (Puntambekar & Hubscher, 2005), including shared understanding, ongoing diagnosis, calibrated support, and fading.

The notion of scaffolding has evolved in the past decades, and the original notion does not adequately explain learning in complex learning environments. Especially in today's classroom, students are interacting not only with human agents such as teachers and peers, but also with increasingly complex tools and artifacts, from instructional materials in papers form, to computers and software, each embedded in a host of activities. The scaffolder is no longer the more capable person; rather, scaffolding is *distributed* among teachers, peers, activities, software, and resources, etc. (Puntambekar & Kolodner, 2005; Tabak, 2004).

Different forms of scaffolding have been designed to help students accomplish complex tasks. For example, soft and hard scaffolds (Brush & Saye, 2002) or adaptive and fixed scaffolds (Azevedo, et al., 2004) have been designed to provide students with support with different degree of flexibility. Soft/adaptive scaffolding

is dynamic and situation specific. It requires teacher or peers to continually diagnose students' understanding and provide timely assistance. Hard/fixed scaffolds are static and can be planned in advance based on students' understanding. They can be embedded in multimedia and hypermedia to support students' learning while they use the tool (Brush & Saye, 2002). Scaffolding has also been designed to serve different functions, such as procedural, conceptual, and metacognitive scaffolding (Molenaar, et al., 2010). Procedural scaffolding guides learners to use certain tools and resources, or accomplish certain tasks. Conceptual scaffolding provides support for learners' conceptual understanding and helps them reason through difficult concepts or problems. Metacognitive scaffolding provides support for monitoring learning. In this paper, we propose *epistemic scaffolding*, the support for epistemic understanding, as a separate category and different from other types of scaffolding (see Figure 1).

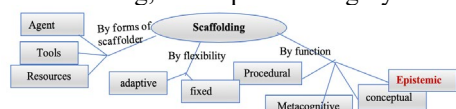


Figure 1. Types of scaffolding.



Figure 2. Synergistic epistemic scaffolding model.

To help illustrate this difference, consider a situation in which students engage in a scientific investigation of electrical conductivity. In this case, procedural scaffolding could support students with tasks such as setting up their experiments, and using tools etc. The support that helps students understand the mechanism of conductivity constitutes conceptual scaffolding; the support that helps students regulate the progress of their inquiry is metacognitive scaffolding. The support that helps them understand the role of theory and evidence in investigating the mechanism of conductivity is epistemic scaffold. Procedural scaffolding aims to assist learners' procedural activity of accomplishing a task; the conceptual scaffolding primarily aims to assist their understanding of the content knowledge of electricity; metacognitive scaffolding aims to assist the regulation of their cognitive activities and processes; whereas epistemic scaffolding aims to support their understanding of the nature of scientific inquiry--the role of theory and evidence in inquiry.

It should be noted that some of these scaffolds are usually intertwined. Take epistemic and conceptual scaffolding for example, conceptual scaffolding usually has implicit epistemic implications; while epistemic scaffolding is usually situated in a context where conceptual scaffolding is provided. As the above example shows, prompting students to understand why some materials conduct electricity is a conceptual scaffolding, while it also has the epistemic implication of the need for explanation. The guidance for helping students understand the role of theory and evidence in investigating conductivity is epistemic scaffolding, while it is also situated in the context of learning about electricity.

## Types of epistemic scaffolding

Based on extant literature and educational practice, we distinguish two types of epistemic scaffolding: implicit and explicit epistemic scaffolding.

### Implicit epistemic scaffolding

Implicit epistemic scaffolding refers to the support—including tools, activities, and resources—that has epistemic implications but is not made obvious to learners. For example, the activity of engaging students in inquiry that focuses on the relationship between explanation and evidence has the epistemic implication that evidentiary justification is an important part of scientific inquiry. Even though such underlying epistemology may not be made explicit to learners, it still has potential to influence students' epistemic thinking (Hofer, 2004; Perry, 1970).

Some of the technological tools could also provide implicit epistemic scaffolding. For example, CoMPASS, is an etextbook that is designed to facilitate students' science learning (Puntambekar & Stylianou, 2005). It visualizes connections among science concepts, helping students see how concepts and principles are related to each other. It uses both concept maps and text as representations to facilitate students' navigation and inquiry. The concept map mirrors the interrelated structure of the science concepts and phenomenon. The underlying epistemic idea guiding the design is that scientific knowledge is coherent and connected, rather than fragmented. It could serve as implicit epistemic scaffolding for promoting students' understanding of the structure of knowledge (Hofer & Pintrich, 1997). Knowledge Forum®, previously known as CSILE (Computer Supported Intentional Learning Environments), is a computer-supported collaborative learning platform designed to support students' knowledge building (Scardamalia, 2004). In Knowledge Forum, ideas could be connected and built upon each other for further improvement. Here the epistemic implication is that knowledge is socially constructed and is tentative (Lin & Chan, 2014).

### Explicit epistemic scaffolding

Explicit epistemic scaffolding refers to the support that intentionally makes epistemic ideas obvious to learners to promote their epistemic understanding and practice. there are different ways in which scaffolding could make



epistemic ideas explicit, including explicit in epistemic structure, explicit in epistemic criteria, and explicit in epistemic goal.

ExplanationConstructor (Sandoval, 2003) is an example of explicit epistemic scaffolding that makes the epistemic structure of inquiry explicit. ExplanationConstructor is an electronic journal that was designed for students to generate explanations. It linked question, explanation, and evidence in the interface, suggesting the importance of and connections among question, explanation, and evidence in scientific inquiry. Knowledge Forum is another example of making the structure of collective inquiry explicit to students through providing prompts for notes writing, such as “*your explanation cannot explain*”, “*a better theory*”, and so on.

Epistemic criteria are standards scientists use to evaluate the validity and accuracy of scientific products, such as arguments, models, and evidence (Pluta, et al., 2011). However, they could also be used as explicit epistemic scaffolds when presented to, or constructed by students as standards to evaluate scientific process and products. For example, Ryu and Sandoval (2011) examined students’ understanding of the epistemic criteria for argumentation, they found that explicitly using and talking about the epistemic criteria for argumentation were helpful for improving students’ epistemic practice. Similarly, Lin and Chan (2018) designed an instruction to let students reflect on the epistemic criteria of good collaborative discourse, and found it promoted students’ epistemic understanding about the social constructive nature of science.

Some studies also showed the importance of making epistemic goal explicit to students. For example, Schauble and colleagues (1995) found that students did better in inquiry after the instruction about the goal of experimentation.

It should be noted that in many educational practices, explicit epistemic scaffolds are most often not used on their own, but are usually combined with implicit epistemic scaffolds. In the next section, we will discuss how implicit and explicit epistemic scaffolds could be integrated to maximize the power of support for epistemic change in CSCL contexts.

## **Designing synergistic epistemic scaffolding in CSCL**

As we discussed earlier, the notion of distributed scaffolding suggests that multiple forms of supports could exist and interact with each other in a learning environment. Building on this idea, Tabak (2004) distinguished three patterns of distributed scaffolding: differentiated scaffolds, redundant scaffolds, and synergistic scaffolds. These patterns demonstrated how various scaffolds (e.g., resources, software, teachers, peers) could work together to support students’ learning. Differentiated scaffolds refer to the way multiple forms of supports are individually provided to support students’ different needs. Redundant scaffolds involve multiple supports for addressing the same need. Synergistic scaffolds refer to the multiple supports that co-occur to address the same need.

Building on Tabak’s framework on synergistic scaffolds, we propose that embedding explicit epistemic scaffolds in implicit epistemic scaffolds is a promising way to maximize the power of support for students’ epistemic development in CSCL (Figure 2). We emphasize their relationship as embedded because explicit epistemic scaffolds need to be situated in implicit epistemic scaffolds as well as mirror the objects of implicit epistemic scaffolding. For example, if the implicit epistemic scaffolds focus on the coordination between claim and evidence, the explicit epistemic scaffolds need to be provided within the implicit epistemic scaffolds, and they also need to mirror the evidence-based nature of science.

Some studies on science education and teachers’ epistemology have provided evidence for the importance of including both implicit and explicit scaffolds to support epistemic cognition, for example, Khishfe and Abd-El-Khalick (2002) compared explicit and implicit inquiry-oriented approach on students’ understandings of nature of science, and found that more participants from the explicit approach improved their nature of science views. Brownlee et al. (2001) employed both implicit and explicit approaches to foster preservice teachers’ epistemic cognition and also found positive results. They (Brownlee, et al., 2017) noted that to make the design effective, explicit reflection needs to be embedded in the contexts of actual teaching practice, which aligns with our proposal on the embedded structure of implicit and explicit epistemic scaffolding.

We propose that synergistic epistemic scaffolding is especially important for fostering epistemic growth in CSCL. Many of the CSCL tool and environment have been designed with epistemic underpinnings which may serve as implicit epistemic scaffolds to help students experience alternative ways of working on knowledge and ideas. For example, Knowledge Forum was designed to engage students in collaborative theory building (Scardamalia, 2004); Web-based Inquiry Science Environment (WISE) was designed to support students’ knowledge integration (Linn, 2006); and ExplanationConstructor was designed to help students build coherent explanations (Sandoval & Reiser, 2004). However, students may not understand these underlying epistemic ideas and therefore may not perform as expected. We argue that if we make the epistemic aim and epistemic criteria of the designed CSCL explicit to students, it may promote apt epistemic performance.

Some studies have provided evidences for the effectiveness of synergistic epistemic scaffolding for

promoting epistemic cognition in CSCL. For example, Lin and Chan (2014) embedded epistemic reflection in computer-supported knowledge-building environment to promote students' understanding of theory-building nature of science. They designed an epistemic model--Little Scientists Worksheet--to help students reflect on their own inquiry experience. The worksheet included epistemic ideas such as "improvable ideas" and also graphs to illustrate how scientists advance their community knowledge, which mirrored students' own inquiry process on Knowledge Forum. When students used these epistemic ideas as criteria to reflect on their inquiry, their epistemic practice were improved. In another study, Lin et al. (2018) embedded explicit epistemic reflection in students' collective inquiry using VidyaMap, which is a new generation of CoMPASS, and found that *reflecting on the epistemic role of the tool for inquiry* promoted students' inquiry and learning from VidyaMap.

## Discussion and future research

This paper proposes an epistemic scaffolding framework to understand the support for fostering epistemic cognition in CSCL. We identified two types of epistemic scaffolding: implicit and explicitly epistemic scaffolding, and proposed that embedding explicit in implicit epistemic scaffolds might help maximize the power of support for promoting epistemic growth. This epistemic scaffolding framework could enrich the literature on epistemic cognition and scaffolding, broadening the research agenda in both areas. On the one hand, it could enrich the epistemic cognition field by allowing researchers to explore a wider variety of questions informed by scaffolding literature. For example, fading, calibrated support, and ongoing diagnosis have been regarded as the key features of scaffolding. Future research could examine the fading of epistemic scaffolding, diagnosis of support for epistemic cognition, and the interaction of epistemic scaffolds with other types of scaffolding. On the other hand, it could enrich the scaffolding literature by adding a new type of support--epistemic scaffolding--to the existing cluster of scaffolding, in parallel to procedural, conceptual, and metacognitive scaffolding, etc., which could help us better understand the nature of support in complex learning environment.

This is an initial attempt to conceptualize epistemic scaffolding. The distinction between implicit and explicit epistemic scaffolding needs to be further clarified and developed in future research. More empirical studies are needed to examine the effectiveness of synergistic epistemic scaffolds in CSCL and to understand the nature of implicit and explicit epistemic scaffolding and their relations to other scaffolding, for example, given a certain CSCL context, what kinds of explicit epistemic scaffolding might provide better support; how do implicit and explicit epistemic scaffolding interact with other types of scaffolding (e.g., metacognitive scaffolding), and what kinds of interaction might be more effective to support students' epistemic cognition and learning? These are the questions we can further explore. We are hoping that the new questions brought up by this epistemic scaffolding framework could help open up new possibilities for exploring ways of fostering epistemic growth in CSCL.

## Selected references

- Brownlee, L. J., Ferguson, L. E., & Ryan, M. (2017). Changing Teachers' Epistemic Cognition: A New Conceptual Framework for Epistemic Reflexivity. *Educational Psychologist*, 1-11.
- Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Jrl of Research in Science Teaching*, 39, 551-578.
- Lin, F., & Chan, C. K. K. (2018). Promoting elementary students' epistemology of science through computer-supported knowledge-building discourse and epistemic reflection. *International Journal of Science Education*, 40(6), 668-687.
- Lin, F., Chan, C. K. K., & van Aalst, J. (2014). *Promoting 5th graders' views of science and scientific inquiry in an epistemic-enriched knowledge-building environment*. Paper presented at the 11th International Conference of the Learning Sciences, Boulder, Colorado, USA.
- Pluta, W. J., Chinn, C. A., & Duncan, R. G. (2011). Learners' epistemic criteria for good scientific models. *Journal of Research in Science Teaching*, 48(5), 486-511.
- Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching*, 42(2), 185-217.
- Puntambekar, S., & Stylianou, A. (2005). Designing navigation support in hypertext systems based on navigation patterns. *Instructional Science*, 33(5-6), 451-481.
- Sandoval, W. A., & Reiser, B. J. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry. *Science Education*, 88(3), 345-372. doi:DOI 10.1002/sci.10130
- Tabak, I. (2004). Synergy: A complement to emerging patterns of distributed scaffolding. *Journal of the Learning Sciences*, 13(3), 305-335.

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# Collaborative Remembering, Temporal Cement of Collaborative Learning: An Exploration

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**Abstract:** This theoretical paper explores the relations between two fields of research: collaborative remembering and collaborative learning. We argue that collaborative remembering processes scaffold collaborative learning and that both unfold over multiple and complementary timescales. These timescales help to maintain joint focus and continuity over successive learning sequences. In conclusion, we discuss implications of integrating collaborative remembering research into the design of CSCL situations.

## Introduction

Collaborative learning emerged as an independent field of research (e.g. Dillenbourg, Baker, Blaye & O'Malley, 1996; Dillenbourg, 1999) during the 1980's. On one hand, it can be understood as a reaction against the dominant psychology of learning and education focused on the individual, which gave rise to new theoretical perspectives, focused on the group (such as the theory of socio-cognitive conflict) or social practices (such as Cultural-Historical Activity Theory, Situated Learning). On the other hand, societal changes, such as globalisation, going hand in hand with the rise of Internet, emphasized the possibility and necessity of working in teams. But educational research was not the only field to be influenced by what might be termed the “collaborative turn”: it also influenced the study of social arenas such as the workplace (CSCW) and the study of psychological functions such as (group) creativity and memory.

Whilst it is necessary for their development for fields of research to be pursued in a largely autonomous manner, the present short paper is based on the conjecture that establishing links between them, within the “collaborative turn” may be fruitful. We thus explore here synergies between research in two fields, Collaborative Learning (“CL”) and Collaborative Remembering (“CR”) (e.g., Meade, Barnier, van Bergen, Harris, & Sutton, 2018). There are good *prima facie* reasons for this choice. The most basic reason is that, across diverse theoretical frameworks, in some sense, learning *is* remembering. Secondly, there are many parallels between the two fields, for example: (i) embodied communication (Hollingshead, 1998), rather than typewritten communication over the network, produces superior CR; (ii) just as creating a “sense of community” is important in online educational communities (Jones & Issroff, 2005), collective memories are means to create shared identities and community (Hirst & Echterhoff, 2012); (iii) CR sequences in interaction (e.g. Bietti & Baker, 2018b) are triggered by questions and have a structure analogous to collaborative problem sequences (Baker, 1995) and more generally, exchange structures of grounding (Clark & Schaefer, 1989).

. Collaboration involves taking the intentions, plans and goals of others into account (Knoblich, Butterfill, & Sebanz, 2011). Therefore, collaboration plays a central role in guiding acts of going back in time in our minds in social interactions. During shared remembering, collaboration influences the action and planning of interacting partners and shapes interactive outcomes, such as when partner A asks “Do you remember the name of the steakhouse we had lunch at last week?” B replies: “Yes, I do, its name was Cambalache”, and A acknowledges B: “Yes you're right, the place with the nice terrace near the river”. This short collaborative remembering sequence (Question => Answer => Acknowledgement) illustrates how interacting partners' intentions, plans and goals come into play during collaborative remembering.

We focus here on a single aspect that establishes a fundamental link between CL and CR: that of *temporality*. Remembering with other people involves re-evoking and re-creating a shared or partially shared past, distributed amongst interacting partners (Meade et al., 2018). Such re-evoking of past experiences involves the human capacity for mental ‘time travel’, the “faculty that allows humans to mentally project themselves backwards in time to re-live stages of their lives, or forward, to pre-live events” (Suddendorf & Corballis, 2007, p. 299). Within the Learning Sciences, from a sociocultural perspective (Lemke, 2001), learning is understood in terms of intersecting timescales of activity — the *hic et nunc*, hours of a lesson, years, historical time — and trajectories of participation (Ludvigsen et al., 2011). In practical terms, from a longitudinal perspective, learning sequences must build on previous ones and therefore on remembering them. Although such remembering is not necessarily a collaborative enterprise, we explore here what combining CR into CL could bring to the latter. Our main proposal is that *collaborative remembering is the ‘cement’ of collaborative learning* — that the former could help to maintain joint focus and continuity over successive learning sequences. We firstly centre discussion on timescales in CR, since this is less well represented in the CSCL research community. This leads to a concluding

discussion on temporality in CL and CR and proposals for integrating CR into (CS)CL.

## **Timescales in collaborative remembering**

CR in CL situations involves students engaged in recalling past experiences, which may themselves have been shared. Remembering with other people in collaborative learning situations often takes place in social interaction unfolding over multiple and complementary timescales (Bietti & Sutton, 2015), from a *micro* timescale involved in behavioural coordination processes (e.g., interactive behavioural matching) and a *meso* timescale responsible for the co-construction of shared memories to a *macro* timescale that drives the transmission of cultural information and skills between students over longer periods of time.

### **Micro timescale: Coordination**

When students jointly recall shared events in CL situations in the service of shared goals, there are complex bodily, linguistic and cognitive processes unfolding in synchrony over a micro timescale. Research on specific aspects of behavioural matching in dialogue (Pickering & Garrod, 2006) suggests that priming effects play a central role in successful communication. In this context, successful communication refers to “the development of similar representations in the interlocutors” (Pickering & Garrod, 2006, p. 203). Only recently has research on interactive behavioural matching focused on CR (Cienki, Bietti, & Kok, 2014). Bietti and Baker examined the CR of a previous interactive encounter in which groups had to collaboratively design its dream house under certain constraints relating to number of occupants, relationships, and funds (Bietti & Baker, 2018a). It was shown that participants collaboratively remembered better those moments of collaborative creativity when they were more jointly involved in elaborating the features of their design. That is, they remembered better what initially generated most joint activity during the previous co-design phase. Based on these results, it was concluded that participants did not necessarily collaboratively remember what was more important, but rather what initially generated most joint activity during collaborative design.

### **Meso timescale: Collaboration**

CR in CL goes beyond the coordination of verbal and non-verbal resources in synchronized fashion over time. At some point during the collaborative activity, interactants have to collaboratively create a shared account or expression of the past in order to actually remember together, as distinct from doing something else (e.g. imagining together). When paying particular attention to the outcomes of collaboration occurring at meso timescale, evidence suggests that communicative strategies and expertise determine recall performance in task-oriented communication in collaborative tasks (e.g., Peltokorpi & Hood, 2018). For example, an experimental study that compared collaborative recall performance in groups of nonexpert and expert pilots (Meade et al., 2009), collaborative facilitation was found in groups of expert pilots. This is to say that the performance of the groups of expert pilots was better than the sum of the performances of each of their members working separately. This positive effect was not found in the non-expert groups where collaborative inhibition was observed. Meade and colleagues analysed the verbal interactions in both types of groups and discovered that one key factor in successful collaboration for the expert group was the repetition of one’s partner’s contributions in order to make explicit common ground and support further elaboration (Meade et al., 2009). This communicative strategy was absent in the groups of non-experts that showed collaborative inhibition. The authors suggested that the effective communication found in the groups of expert pilots came from training and expertise in which the exchange of information is crucial. The collaborative inhibition effect observed in non-experts’ collaborative recall is a robust finding well documented in the literature (e.g., Barber, Rajaram & Aron, 2010). The ‘retrieval disruption hypothesis’ (Basden, Basden, & Henry, 2001) has been the typical way of explaining the collaborative inhibition effect: seeing or hearing other people’s responses disrupts the way each individual organizes his/her retrieval sequences and strategies, thus causing the collective failure to achieve potential (Barber et al., 2010).

### **Macro timescale: Cooperation**

CR in CL over a macro timescale (days, weeks and months) is grounded both in residual traces of social interactions occurring over micro and meso timescales. Such a macro timescale deals with the transmission of cultural information (Sperber & Hirschfeld, 2004) and social learning (Bandura, 1977) in groups and larger networks. Bartlett’s (1932) seminal research on how individual recollections change over repeated retelling provides a general framework for understanding the transmission of information and skills over time. A recent study examined the influence of coordination (micro timescale) and collaborative (meso timescale) processes in transmission chains (Tan & Fay, 2011) using the method of serial reproduction (Bartlett, 1932). In an interactive condition, chains of participants interacted freely with one another to transmit narrative information from one generation to the next. In a non-interactive condition, receivers of the information had to listen to audio-recordings of narrations produced by senders (previous generation) and then recorded their own accounts of what they had

listened to, which were passed on to a new generation of receivers for the same procedure. Transmission was more accurate in the interactive condition than in the non-interactive condition, due to the effect of receivers' behaviours, including backchannels or clarification questions.

Transmission chains have also been used to simulate social learning (i.e. learning by means of observation of, or interaction with, another animal or its products) and the continuous improvement of cultural artefacts (e.g. woven baskets, knots, paper airplanes, and stone tools) from one generation to the next (e.g., Caldwell, Atkinson, & Renner, 2016). Morgan et al. (2015) used an Oldowan tool-making task and six conditions (reverse engineering; imitation; emulation; basic teaching; gestural teaching and verbal teaching) to investigate the effectiveness of multiple teaching methods in social learning. The authors found that teaching helped to improve transmissions. When compared the two conditions that involved instructed teaching (gestural and verbal teaching), Morgan et al. reported that co-present verbal teaching promoted a much faster transmission of information than gestural teaching. The facilitative effect of social interaction on the accuracy of narrative information and skill information transmission shows that coordination and collaborative processes unfolding over micro and meso timescales affect longer-term cooperative processes.

## Concluding discussion: Temporality in collaborative remembering and learning

Time is crucial to the analysis of learning from a Cultural-Historical Activity Theory ("CHAT") perspective (Leont'ev, 1981), but is therein theorised somewhat differently from the account of time in CR presented above. The micro, meso and macro levels considered above are part of "chronological" time. The link with "mental time travel" in CR, mentioned above, is clear on this level, in that activity analysis seeks to understand how interactive events on the micro/meso levels relate to—possibly widely separated—past and future events (Ludvigsen et al., 2011). If complex activity systems can be considered as complex systems, this implies that learning 'effects' may (or may not) occur in a future that cannot be predicted beyond a short time-window. Lemke (2000) expresses such a non-linear perspective as time itself becoming "folded" (ibid. p. 276). Similarly, Engeström and Toivainen (2011) criticise most approaches to analysing interaction in learning situations as being concerned with narrowing down analysis to the here-and-now, to very short slices of interaction with "no history and no future" (ibid. p. 35). Furthermore, such (non-linear) chronological time in learning is distinguished from "cultural-historical" time, which is embedded in the (knowledge) artefacts that we use and is the site of conflicts, ruptures and resulting realignment of activity systems, corresponding to "learning by expanding" (Engeström, 1987). In sum, from a CHAT perspective, analysing different types of learning requires relating events on different timescales and conceptions of time. From the subjects' perspectives, too, "learning occurs when different timescales meet and intersect, and meaning potential becomes transformed to common objects (physical and discursive)" (Ludvigsen et al., 2011, p. 110). In collaborative situations, therefore, one way of creating such confluence of temporalities, i.e., learning, is by collaborative remembering, that we characterise as the "cement" of collaborative learning.

Returning to our above discussion, on the micro-level, just as CR has been shown to be an *embodied*, phenomenon, integrating gesture, gaze and behavioural resonance, the same conclusion follows for CR in CL. Furthermore, one implication would be that in *computer-supported* CL/CR across the Internet, facilitating *embodied* social interaction would be important. On the meso-level, group memories do not go beyond the sum of individual memories, in the case of non-experts, i.e. learners. This would imply that the possible value of CR in CL should *not* be seen as simply promoting 'better remembering', but rather in the elaboration of 'zones' of collective activity in which timescales coalesce. Finally, with respect to the macro-level of CR, research on social learning via 'transmission chains' and social networks would have implications for the organization of CL between groups and possibly age-levels in schools (e.g., horizontal transmission between children). To conclude, we have sought to establish and deepen possible links between research in CR and in CL. This has opened up possibilities for future research on studying the integration of specifically organized collaborative remembering sequences into CSCL, within a longitudinal approach. Since CR in the workplace enables team projects to stay 'on track', a similar function for CR in CL could occur within Project-Oriented Pedagogy.

## References

- Baker, M.J. (1995). Negotiation in collaborative problem-solving dialogues. In R. J. Beun, M.J. Baker, & M. Reiner (Eds.), *Dialogue and Instruction: Modeling Interaction in Intelligent Tutoring Systems* (pp. 39-55). Berlin: Springer-Verlag
- Barber, S. J., Rajaram, S., & Aron, A. (2010). When two is too many: Collaborative encoding impairs memory. *Memory & Cognition*, 38, 255-264
- Bartlett, F. (1932). *Remembering*. Cambridge: Cambridge University Press.
- Basden, B. H., Basden, D. R., & Henry, S. (2001). Costs and benefits of collaborative remembering. *Applied*

- Cognitive Psychology*, 1, 497-507.
- Bietti, L.M. & Baker, M.J. (2018a). Collaborating to remember collaborative design: An exploratory study. *Memory Studies*, 11 (2), 225-244.
- Bietti, L.M. & Baker, M.J. (2018b). Multimodal processes of joint remembering in complex collaborative activities. In M. Meade, A. Barnier, P. van Bergen, C. B. Harris & J. Sutton (Eds.), *Collaborative remembering: Theories, Research and Applications* (pp. 177-196). New York: Oxford University Press.
- Bietti L.M. & Sutton, J. (2015). Interacting to remember at multiple timescales: Coordination, collaboration, cooperation and culture in joint remembering. *Interaction Studies*, 16 (3), 419-450.
- Caldwell C.A., Atkinson, M. & Renner, E. (2016). Experimental approaches to studying cumulative cultural evolution, *Current Directions in Psychological Science*, 25 (3), pp. 191-195.
- Cienki, A., Bietti, L.M. & Kok, K. (2014). Multimodal alignment during collaborative remembering. *Memory Studies*, 7 (3), 354-369.
- Clark, H. H., & Schaefer, E. F. (1989). Contributing to discourse. *Cognitive Science*, 13, 259-294
- Dillenbourg P. (1999) What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and Computational Approaches* (pp.1-19). Oxford: Elsevier.
- Dillenbourg, P., Baker, M.J., Blaye, A., & O'Malley, C. (1996) The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in Humans and Machine: Towards an Interdisciplinary Learning Science* (pp. 189- 211). Oxford: Elsevier.
- Engeström, Y. (1987). *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research*. Helsinki: Orienta-Konsultit Oy.
- Engeström, Y. & Toivainen, H. (2011). Co-configurational design of learning instrumentalities. In S. Ludvigsen, A. Lund, I. Rasmussen & R. Säljö (Eds.) *Learning Across Sites: New tools, infrastructures and practices* (pp. 33-52). London: Routledge.
- Hirst, W. & Echterhoff, G. (2012). Remembering in conversations: The social sharing and reshaping of memories. *Annual Review of Psychology*, 63, 55-69.
- Hollingshead, A.B. (1998). Communication, learning and retrieval in transactive memory systems. *Journal of Experimental Social Psychology*, 34, 423-442.
- Jones, A. & Issroff, K. (2005). Learning technologies: Affective and social issues in computer-supported collaborative learning. *Computers & Education*, 44(4), 395-408.
- Knoblich, G., Butterfill, S., & Sebanz, N. (2011). Psychological research on joint action: theory and data. In B. Ross (Ed.), *The Psychology of Learning and Motivation*, 54 (pp. 59-101). Burlington: Academic Press.
- Lemke, J.L. (2000). Across the scales of time: Artifacts, activities and meanings in ecosocial systems. *Mind, Culture and Activity*, 7(4), 273-290.
- Lemke, J. L. (2001). The long and the short of it: Comments on multiple timescale studies of human activity. *Journal of the Learning Sciences* 10(1-2), 193-202.
- Leont'ev, A. N (1981). The problem of activity in psychology. In J. V. Werstch (Ed.) *The concept of activity in soviet psychology*, (pp. 37-71). Armonk, NY: Sharp.
- Ludvigsen, S., Rasmussen, I., Kränge, I., Moen, A. & Middleton, D. (2011). Intersecting trajectories of participation: temporality and learning. In S. Ludvigsen, A. Lund, I. Rasmussen & R. Säljö (Eds.), *Learning Across Sites: New tools, infrastructures and practices* (pp 105-121). London: Routledge.
- Meade, M., Barnier, A., van Bergen, P., Harris, C.B., & Sutton, J. (Eds.) (2018). *Collaborative Remembering: Theories, Research and Applications*. New York: Oxford University Press.
- Meade, M.L., Nokes, T.J. & Morrow, D.G. (2009). Expertise promotes facilitation on a collaborative memory task. *Memory* 17, 39 -48.
- Morgan, T. J. H., Uomini, N. T., Rendell, L. E., Chouinard-Thuly, L., Street, S. E., Lewis, H. M., Cross, C. P., Evans, C., Kearney, R., de la Torre, I., Whiten, A., & Laland, K. N. (2015). Experimental evidence for the co-evolution of hominin tool-making teaching and language. *Nature communications*, 6, [6029].
- Peltokorpi, V. & Hood, A. C. (2018). Communication in theory and research on transactive memory systems: A literature review. *Topics in Cognitive Science*. <https://doi.org/10.1111/tops.12359>
- Pickering, M.J. & Garrod, S. (2006). Alignment as the basis for successful communication. *Research on Language and Computation*, 4 (2-3), 203-228.
- Sperber D. & Hirschfeld, L. (2004) The cognitive foundations of cultural stability and diversity. *Trends in Cognitive Sciences*, 8, 40-46.
- Suddendorf, T. & Corballis, M.C. (2007). The evolution of foresight: What is mental time travel and is it unique to humans? *Behavioral and Brain Sciences*, 30, 299-313.
- Tan, R., & Fay, N. (2011). Cultural transmission in the laboratory: Agent interaction improves the intergenerational transfer of information. *Evolution & Human Behavior*, 32 (6), 399-406.

# Embedding Computational Thinking in the Elementary Classroom: An Extended Collaborative Teacher Learning Experience

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**Abstract:** We used design-based research to investigate an extended professional learning experience to prepare teachers to embed computational thinking in elementary science. Opportunities to interact synchronously in a community of practice - including through in-person engagement in embodied challenges, discussion, and resource sharing, appeared to productively support teacher preparedness to embed CT in their science teaching. However, asynchronous collaboration via an online platform was less effective. We describe planned adjustments for future iterations of the program.

**Keywords:** community of practice, computational thinking, science teacher education

## Introduction

The centrality of computing in modern science has elevated the importance of computational thinking (CT) as a critical skill for everyone (Wing, 2006). Elementary teachers have the potential to play an essential role in developing foundational CT competencies among all learners. However, there is a fundamental need for effective approaches to supporting teacher learning in this novel domain (Hestness, Ketelhut, McGinnis, & Plane, 2018). Because CT is heavily embedded with technological tools, we are particularly interested in the role of CSCL environments for facilitating teacher learning experiences. We are exploring the research question: “What computer supported design elements can help promote collaborative learning for enacting CT, a novel and potentially intimidating topic, in elementary science?” Because communities of practice (CoP; Lave & Wenger, 1991) have shown promise to support novices (i.e. teachers) enact new practices (i.e. CT-infused science pedagogies), we are seeking to cultivate a community of practice among veteran and preservice elementary teachers to support teacher learning related to CT integration in the classroom. To realize this goal, we created the CT Science Teaching Inquiry Group (STIG<sup>CT</sup>), a collaborative learning experience designed to create new knowledge of effective strategies to embed CT in the elementary science classroom.

## Methods

We adopted a design-based research (DBR) approach, entailing iterative cycles of design and analysis. For the first iteration of the STIG<sup>CT</sup>, we designed and facilitated seven 90-minute in-person professional development sessions that met monthly throughout the school year. The sessions began as primarily facilitator-directed, in which members of our team led collaborative learning activities and discussion. Midway through the year, we shifted the design of the sessions to be primarily participant-directed, in which participants worked together to create, share, and discuss learning activities to support CT integration. Between sessions, participants were invited to collaborate by sharing ideas and resources via an online platform ([piazza.com](https://piazza.com)). Participants (N=24) included practicing teachers (n=11) and preservice teachers (PSTs; n=13) interested in learning about integrating CT into their science teaching.

We used qualitative research methods (Miles, Huberman, & Saldana, 2014) to analyze the session plans and field notes for each STIG<sup>CT</sup> session, identifying key design elements included throughout the PD experience. Next, we analyzed data including field notes, written reflections collected at the end of each session, and focus group interviews collected at the end of the full experience. Where the focal design elements were referenced, we coded evidence of how (or whether) they appeared to promote collaborative learning toward CT integration in the elementary science classroom. We used the analysis to make inferences about effective strategies for PST learning CT integration, and to inform the redesign of the STIG<sup>CT</sup> for ongoing study.

## Findings

We describe how three focal design elements appeared to contribute to teacher collaborative learning related to CT integration in elementary science. A summary and examples are provided in Figure 1.

First, we found that collaborative engagement in hands-on activities, both computer-supported and not computer-supported, appeared to foster collaborative learning about CT conceptually and improve participants’ perceptions of their CT understandings. However, we did not encounter clear evidence that this design element

on its own supported teachers in transferring conceptual CT understandings into their own classroom practice.

Second, incorporating intentional discussion opportunities within the sessions helped participants generate ideas about how CT concepts could relate to the teaching of elementary science curriculum topics. In addition, preservice teachers expressed a sense of empowerment when able to learn from experienced teachers about how they were applying (or considering applying) CT in their classrooms. We encouraged participants to continue sharing their CT integration ideas with one another outside of the in-person sessions, but participants rarely made use of the online platform which was set up for this purpose.

Last, sharing resources to support CT integration helped participants design lesson plans to enact CT in their elementary science classrooms. During initial sessions, facilitators modeled various CT learning activities and resources. During later sessions, participants codesigned and presented original CT learning activities for integration. We found that both forms of resource sharing appeared to promote a sense of empowerment that participants understood and had the resources to enact strategies for applying CT in their classrooms. We noted, however, that the participant-designed lesson plans varied in the extent to which they accurately represented CT or integrated it into curricular content in science. As with the discussion design element, participants rarely made use of the online platform to share resources between sessions, which was one of its intended purposes.

Table 1: Element, activity example, and example participant response

Element	Activity examples	Example participant response
CT sensemaking through collaborative challenges and debriefing	-Teachers collaboratively manipulate an online ecosystem to learn about CT practice of models and simulations; -Teachers “program” a blindfolded teammate to walk a specified path, modeling problem decomposition	<i>“[Problem decomposition was... a really big and newer topic for a lot of us... I said something out loud to the class... I was approaching being right, but I was maybe 65% right, and you were like, “Um, let me refine that.” And then I was like, “Oh, okay. Now I get it a little bit more.”</i>
Discussing classroom applications of CT concepts	-Teachers examine science standards and discuss opportunities for CT integration -Teachers encouraged to update each other asynchronously on CT integration efforts via online platform	<i>“[At first, I wondered] how realistic is it to think that people are implementing these things in the classroom for real? ...Seeing teachers here [in the STIG] that have taught for many years kind of implementing it [CT] .... I think it just made it... seem like it was more attainable.”</i>
Sharing resources to support CT integration in elementary science	- Teachers are invited to borrow educational robotics tools for use in their classrooms and report back - Teachers co-author and present learning activities (lesson plans) that integrate CT into elementary science	<i>“I really liked the activity of having people create lessons and then teach it to us. Because... it gave people the opportunity to learn from different teachers, people they might not know. But also, I really liked learning how different people might take a lesson and interpret it in their own way. I thought it was really helpful.”</i>

## Conclusions and implications

The STIG<sup>CT</sup> design elements offered affordances and limitations relevant to promoting a CoP focused on collaborative learning of how to enact CT in elementary science. Specifically, we found that hands on experiences, discussions and resource sharing were helpful in facilitating collaborative learning around CT. However, we struggled to maintain our CoP virtually, with low participation in the asynchronous, online space. We plan to modify future iterations of the STIG<sup>CT</sup> by: 1) Retaining the collaborative design of CT-infused elementary science lessons to promote participant-created resource sharing, with greater facilitator support and more consistency; 2) Encouraging participants to test participant-created resources in their classroom and to share their experiences online between in-person sessions; 3) Considering an alternate, more familiar online platform to promote participant discussion between sessions, and incorporating the online discussion into in-person sessions; and 4) Inviting teachers from the first iteration of the STIG<sup>CT</sup> to continue their participation in the second year and serve as mentors for newcomers. Through our ongoing process of design and refinement, we plan to use our learning to



develop empirically-supported resources, tools, and measures to connect physical and virtual spaces in order to support teacher education around CT integration in elementary science.

## References

- Hestness, E., Ketelhut, D. J., McGinnis, J. R., & Plane, J. (2018). Professional knowledge building within an elementary teacher professional development experience on computational thinking in science education. *Journal of Technology and Teacher Education*, 26(3), 411-435.
- Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Miles, M. B., Huberman, A. M., & Saldana, J. (2013). *Qualitative data analysis*. Sage.
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35.

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# An Initial Look at the Developing Culture of Online Global Meet-ups in Establishing a Collaborative, STEM Media-Making Community

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**Abstract:** This project examines a network of informal digital makerspace clubs with over 100 adolescent participants across four continents. A key component to developing the community for collaboration was the use of online global meet-ups, or facilitated video conference sessions where participants from different sites share projects and feedback. Meet-ups were key to establishing social trust and motivating project collaboration across sites. This paper examines participant discourse at different stages of the community formation process. Data from three online meetings with U.S. and Kenyan students were analyzed using epistemic network analysis (ENA). Findings show significant changes in the patterns of discourse corresponding to the development of the community over time. The initial emphasis on self-awareness and superficial information sharing shifted toward peer teaching and knowledge acquisition after six months. These observations demonstrate how the depth of interactions within online global meet-up culture evolved into more substantive interactions towards collaborative learning.

## Introduction

Technology has impacted the education space in offering both innovative mediums (such as online courses and platforms) and tools (portable devices, tablets, web applications) for learning. As the world adjusts to further technology development, so will future learning environments evolve. This study examines how *computer supported collaborative learning* (CSCL) takes place through an international network of informal digital makerspace clubs focused on STEM topics. Participants hail from after school clubs in six countries on four continents, using technology to interact and collaborate both synchronously and asynchronously on the creation of STEM-oriented digital artifacts across borders. One key method of synchronous communication that has emerged from this CSCL community is the online global meet-up. These meet-ups have become critical in fostering a sense of community within the network, enhancing the collaboration experience.

Sense of community was defined by McMillan and Chavis (1986) as the feeling of belonging to a particular group, whereby participants share a feeling of mutual influence and emotional connectedness as well as the belief that their needs will be fulfilled through membership in the group. Applying this concept to the learning setting, both physical and virtual, Rovai (2002) conceptualizes the classroom community to consist of four components: spirit, trust, interaction, and the shared expectation of learning. Under this framework, spirit refers to elements such as membership, cohesion and friendship that enable students to support and challenge one another. Trust not only encompasses the confidence to rely on one another, but also the genuine interest and concern that members have for each other. Interactions may be driven by a focus on task completion or by socioemotional factors such as empathy or sharing of personal information. Here, social presence—the extent to which a person is considered to be “real” in the virtual communication contexts—plays an important role for allowing meaningful interaction and collaboration among participants (Gunawardena, 1995). Lastly, a sense of community requires the belief on the part of the members that their learning needs are being met through their active involvement (Rovai, 2002).

## Development of online global meet-ups

Online global meet-ups are video conference calls that provide an opportunity for participants to communicate synchronously to share, exchange and collaborate. These meet-ups are typically facilitated by a peer and become global when participants from at least 2 different countries join. Prior to the meet-up, participants indicate their participation by listing their name and project topics on an online agenda, then return to that agenda for the conference call link. The facilitator uses the agenda to anticipate who will be present and what topics will be discussed. At the end of the meet-up, participants write reflections on their experience at the bottom of the agenda.

The idea of global meet-ups for collaboration developed spontaneously. There was a desire from both the teachers and participants to “see” each other synchronously. Initially, these meet-ups were meant as one-time introductory meetings. However, the desire to meet synchronously continued and more took place successfully out of determination from the participants and teachers to coordinate. Participants were willing to meet at

inconvenient times amidst the time differences for the opportunity to connect. At initial meet-ups, examples of previously made artifacts, such as videos, were shared by participants who were part of a previous program at their school on media-making on STEM topics. This prompted students at other sites to work on their own media-making skills and have something to present at the next meet-up. For example, in one club site in Kenya, participants who started without any experience in media-making were later able to present at least one or two video projects consistently at meet-ups.

Many refinements to the organizational structure of meet-ups helped to shape the current global meet-up culture. As many participants and teachers initially encountered challenges with utilizing the video conference software, a technology protocol was developed as a resource for participants to review in advance to minimize technical difficulties undermining the meet-up experience. Early meet-ups had no limitation on the number of participants nor required advance notice of attendance. This resulted in large groups that limited active participation by individuals and created large periods of silence that required increased inclusive techniques by the facilitator. Following those experiences, Google Doc online agendas were developed as a place for participants to indicate their participation in advance and limit the size to four to five students to allow for richer interactions from each participant. Online agendas not only served as an organizing tool, but a common place for written reflections immediately following the end of the meeting. By visually observing the synchronous updating of written reflections by fellow participants, students and teachers alike were further motivated to write their reflections. Initial meet-ups were facilitated by the research team, but gradually transitioned to student facilitators after supportive training and mentoring. These adjustments allowed for predictable structural stability with meet-ups optimized for participants to focus on their interactions with one another.

Online global meet-ups have emerged as a key component to enhancing this CSCL community. The opportunity for visual, synchronous communication both motivated and built social trust among the participants which has increased the depth of interactions with time and experience. As more meet-ups took place, a shared understanding of the culture and behavior at meet-ups emerged. This included a shared understanding of the roles within the meet-ups, such as a facilitator that guides the conversation and presenter(s) who share their project. Increased social trust built from meet-up experiences appeared to increase the comfort in interacting with one another to be more collaborative and curious.

## Methods

Epistemic network analysis (ENA) is a quantitative ethnographic technique for modeling the structure of connections in data. ENA assumes: (1) that it is possible to systematically identify a set of meaningful features in the data; (2) that the data has local structure (conversations); and (3) that an important feature of the data is the way that codes are connected to one another within conversations (Shaffer, 2017; Shaffer, Collier, & Ruis, 2016; Shaffer & Ruis, 2017). ENA models the connections between coded constructs by quantifying the co-occurrence of codes within conversations, producing a weighted network of co-occurrences, along with associated visualizations for each unit of analysis in the data. ENA analyzes all of the networks simultaneously, resulting in a set of networks that can be compared both visually and statistically. The ENA algorithm uses a moving window to construct a network model for each line in the data, showing how codes in the current line of an utterance are connected to codes that occur within the recent temporal context (Siebert-Evenstone et al., 2017), defined in this model as 5 lines (each line plus the 4 previous lines) within a given conversation. The resulting networks were aggregated for all lines for each participant.

The data set used in this analysis came from three online global meet-ups: the first global meet-up that took place in March 2017, and later meet-ups in May and October 2017. The March 2017 meet-up included 22 total participants across two sites in the U.S. and two sites in Kenya. The May 2017 meet-up had 16 total participants from one site in Kenya and two sites in the U.S. The October 2018 meet-up included four participants from one site each in Kenya and the U.S. Meet-ups were transcribed and each line spoken by participants was considered an utterance. Binary coding was used to code for the presence of seven constructs: CURIOSITY, SELF-AWARENESS, FEEDBACK, CONTENT-FOCUS, PARTICIPATORY TEACHING, KNOWLEDGE ACQUISITION, and SOCIAL DISPOSITION. A total of 674 utterances were coded separately by two raters. This was followed by a process of social moderation, which allowed the two raters to reach agreement on the coding of each utterance in the data (Frederiksen et al., 1998; Herrenkohl & Cornelius, 2013). The coded data was then uploaded onto the ENA web-tool (<http://app.epistemicnetwork.org>) for visualization and analysis.

## Results

Figure 1 presents the individual ENA network models representing the discourse patterns of the three meet-ups held in March, May and October of 2017. The network model for the March meet-up (in red) depicts a prominent connection between CONTENT-FOCUS in the center and SELF-AWARENESS to the left. While thinner lines link

other constructs, including CURIOSITY, it can be seen that virtually no connections are made to KNOWLEDGE ACQUISITION and PARTICIPATORY TEACHING. This can be attributed to the introductory nature of the March meet-up, where students—meeting for the first time—mainly shared their interests around STEM topics. The May meet-up (in blue), however, shows strong associations between CONTENT-FOCUS, FEEDBACK and SOCIAL DISPOSITION. Slightly thinner connections can be observed linking these constructs to CURIOSITY and KNOWLEDGE ACQUISITION as well as to SELF-AWARENESS. The model is indicative of the increasing willingness of participants to interact socially and to offer suggestions about each other’s projects and presentations. In the network model for October (in purple), it is possible to see that the connections to SELF-AWARENESS have all but disappeared, whereas the most prominent associations have been made between CONTENT-FOCUS, CURIOSITY and FEEDBACK. A relatively thick connection is shown between CONTENT-FOCUS and SOCIAL DISPOSITION as well as PARTICIPATORY TEACHING. The model has shifted further to the right, representing a greater emphasis in the participants’ discourse on the learning and peer-teaching dimensions.

Figure 2 displays the means of the ENA network models (squares) with their confidence intervals (dotted lines) for the three meet-ups. The plotted points (dots) represent weighted centroid of the networks for each participant. The x-axis distinguishes between connections to SELF-AWARENESS on the left and connections between the codes KNOWLEDGE ACQUISITION, PARTICIPATORY TEACHING, and CURIOSITY on the right. The network mean for the March meet-up is located on the left, indicating stronger linkages to SELF-AWARENESS. The means of the May and October networks are situated further to the right of the ENA space, which signifies an increase in the prevalence of connections made to KNOWLEDGE ACQUISITION, PARTICIPATORY TEACHING, and CURIOSITY. Statistical comparison of the location of the means—conducted through a two sample t-test assuming unequal variances—showed significant differences along the x-axis between the March and May meet-ups,  $t(35.41) = 5.34, p < 0.001, d = 1.64$ , as well as between the May and October meet-ups,  $t(16.00) = 7.10, p < 0.001, d = 1.98$ .

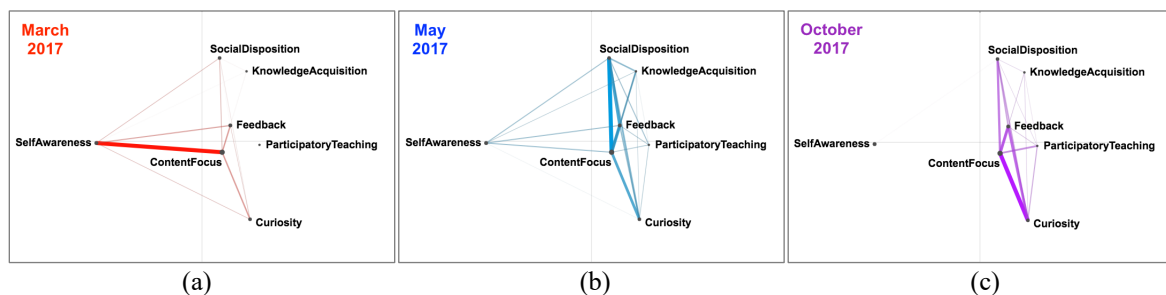


Figure 1. ENA network models for three online global meet-ups in (a) March, (b) May, and (c) October 2017.

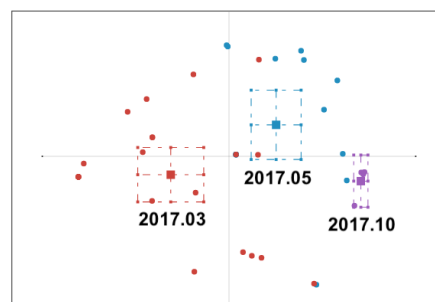


Figure 2. Plotted points, network means, and confidence intervals for the three online global meet-ups.

## Discussion

Findings from the epistemic network analysis show significant changes in the patterns of discourse corresponding to the increase in the sense of community over time. A progressive development of the elements comprising a sense of community according to Rovai (2002) can be identified across meet-ups from March to October 2017, as shown in Table 1. Sharing information about themselves and their interests during the initial session—as captured in the connection between SELF-AWARENESS and CONTENT-FOCUS—allowed the participants to build comradery and foster a spirit of membership in the group. The interactions were mainly task-driven, with discussions focusing on STEM topics. The May meet-up reflected a greater presence of pro-social interactions among the participants (SOCIAL DISPOSITION) as well as a growing sense of trust. This can be observed in their willingness to seek clarification and provide substantive comments about each other’s projects, as demonstrated

by the linkages between FEEDBACK, CURIOSITY and CONTENT-FOCUS. Participation in the meet-up has also created learning opportunities for students (KNOWLEDGE ACQUISITION). The October session presents a similar pattern, only with the learning dimension displaying a stronger emphasis on peer teaching (PARTICIPATORY TEACHING). These observations demonstrate how the depth of interactions within online global meet-up culture evolved into more substantive interactions towards collaborative learning.

Table 1: Development of elements comprising a sense of community from March to October 2017

Elements of Sense of Community (Adapted from Rovai, 2002)		March 2017 Meet-up	May 2017 Meet-up	October 2017 Meet-up
Spirit of membership		✓	✓	✓
Trust			✓	✓
Interaction	Task-driven	✓	✓	✓
	Socioemotionally-driven		✓	✓
Learning	Knowledge-based		✓	✓
	Collaborative			✓

These results contribute to a larger examination of learning beyond the traditional classroom experience. Future workforce environments are likely to embody the characteristics of integrated technology use and global interaction and collaboration embodied in this project, making the findings pioneering and relevant for future learning environments (Marope, 2017). Learning should go beyond the passing of knowledge acquisition from teacher to student, and be an engaged and involved process for the student (Freire, 1972). The peer-driven, CSCL settings from this project allows students to be actively engaged in their own learning, as observed by the sense of community developed by an online meet-up culture among participants which demonstrated increased curiosity and participatory teaching. Research on such learning environments set the stage for future, innovative approaches to education.

## References

- Frederiksen, J. R., Sipusic, M., Sherin, M., & Wolfe, E. W. (1998). Video portfolio assessment: Creating a framework for viewing the functions of teaching. *Educational Assessment, 5*, 4, 225-97.
- Freire, P. (1972). *Pedagogy of the oppressed*. New York: Herder and Herder.
- Gunawardena, C. N. (1995). Social presence theory and implications of interaction and collaborative learning in computer conferences. *International Journal of Educational Telecommunications, 1*(2-3), 147-166.
- Herrenkohl, L. R., & Cornelius, L. (2013). Investigating elementary students' scientific and historical argumentation. *Journal of the Learning Sciences, 22*, 3, 413-461.
- McMillan, D. W., & Chavis, D. M. (1986). Sense of community: A definition and theory. Special Issue: Psychological sense of community, I: Theory and concepts. *Journal of Community Psychology, 14*(1), 6-23.
- Marope, M. (2017). Future competences for future generations. *International Bureau of Education: In Focus, 2*, 80-87. Retrieved from <http://ibe-infocus.org/wp-content/uploads/2018/03/In-Focus-2017.pdf>
- Rovai, A. P. (2002). Building sense of community at a distance. *International Review of Research in Open & Distance Learning, 3*(1), 1-16.
- Shaffer, D. W. (2017). *Quantitative ethnography*. Madison, WI: Cathcart Press.
- Shaffer, D. W., Collier, W., & Ruis, A. R. (2016). A tutorial on epistemic network analysis: Analyzing the structure of connections in cognitive, social, and interaction data. *Journal of Learning Analytics, 3*(3), 9-45.
- Shaffer, D. W., & Ruis, A. R. (2017). Epistemic Network Analysis: A worked example of theory-based learning analytics. *Handbook of Learning Analytics, 175-187*.
- Siebert-Evenstone, A., Arastoopour Irgens, G., Collier, W., Swiecki, Z., Ruis, A. R., & Williamson Shaffer, D. (2017). In search of conversational grain size: Modelling semantic structure using moving stanza windows. *Journal of Learning Analytics, 4*(3), 123-139.

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# Application of the IBE-UNESCO Global Competences Framework in Assessing STEM-focused, Global Collaborative Learning within a Digital Makerspace Environment

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**Abstract:** This paper utilizes the UNESCO International Bureau of Education’s seven global competences framework for assessing a global, computer-supported collaborative STEM learning project. The discourse from a meet-up between students in Kenya and the U.S was coded with these global competences. Epistemic network analysis (ENA) is used to evaluate for meaningful connections between the codes. Upon analysis of the data, lifelong learning and trans-disciplinarity exhibit the strongest connection, which supports the fundamental goals of the project – fostering critical thinking among students globally through media-making and discussion of STEM subjects. Furthermore, the two groups of students – Kenyan and American – demonstrated different strengths; the Kenyan students focused on self-agency and using diverse tools, while American students were content-driven. These complementary behaviors collectively exemplify the seven global competences and are an example of building skillsets for future workforce environments.

## Introduction

In the context of a rapidly changing world, future workplace environments demand evolving needs and skillsets. In 2015, the United Nations adopted its 2030 Agenda for Sustainable Development, comprising 17 Sustainable Development Goals (SDGs) to address global social and economic issues. SDG #4 identifies quality education as a means to improve quality of life and empower talent to develop solutions to the world’s problems. In particular, Target 4.4 within this quality education goal seeks to “substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship” (United Nations, n.d.). Target 4.4 advocates a call for education to better prepare future generations with the skills and knowledge for anticipated workforce needs.

This paper focuses on a project that involves global, computer-supported collaboration within a network of informal, digital makerspace clubs focused on science, technology, engineering and mathematics (STEM) learning. The network is comprised of adolescent youth participants overseen by teachers that provide oversight for the club sites. Participants engage in developing multimedia artifacts around STEM topics and engage in online global meet-ups in their collaboration efforts. In fostering an intersection of learning, technology and cross-cultural collaboration among the future generation, this project offers a unique opportunity to address competency needs related to SDG4 in the context of a changing industry and workforce landscape. The global competences identified by the International Bureau of Education (IBE) at the United Nations Educational, Scientific and Cultural Organization (UNESCO) are used as a framework for this analysis.

The global competences framework was synthesized following extensive consultation with internationally recognized thought leaders in education, technology, industry, and the workforce. Published in 2017 under the title “Future competences for future generations,” the framework seeks to address the anticipated needs of the Industry 4.0 future, which involves navigating a more complex integration and optimization of technology in the work environment and social life (Marope, 2017). This evolving industry outlook calls for a shift in the learning paradigm to develop capacities to “interactively mobilize information, data, technology, knowledge, skills, values, and attitudes, and then use them ethically to engage effectively and act across diverse 21st century contexts for individual, collective, and global good” (Marope, 2017, p. 86). These capacities are reflected in the framework’s seven global competences to address the need for “multifaceted, transdisciplinary, technology savvy, and integrated competences” (Marope, 2017, p. 86). Within each global competence (also referred to as macro-competence) is a subset of micro-competences that are adapted based on context. The global and micro-competences are illustrated by utterances from the transcript utilized for this paper:

- **Lifelong learning:** The adaptive micro-competences include curiosity, creativity and critical thinking. This is exemplified in the project as a willingness to learn through curiosity, creativity, critical thought, seen in devising projects, while curiosity and critical thinking are expressed through interactions, such

as asking questions and expressing opinions during video conference calls. Sample utterance from the transcript data: *“Please I don’t know anything about Scratch and you claim (it) is the most basic coding language...will you please explain the Scratch a little bit?”* [Kenyan participant]

- **Self-agency:** The adaptive micro-competences include initiative/drive, motivation, responsibility, and endurance/grit/resilience. This is exemplified in the project as participants’ eagerness to act on their interest, as seen through the creation/execution of media artifacts, and expressed in dialogue in video conference calls. Sample utterance: *“Now I think okay you have the interests of making people to know coding and it’s starts with you now that you’ve informed me now that you’ve informed me can I then inform another person and then...”* [Kenyan participant]
- **Interactively using diverse tools and resources:** The adaptive micro-competences include impactful use of resources, efficient use of resources, and responsible consumption. This is exemplified in the project as finding different ways to learn and accomplish a task (e.g. looking at ways to learn coding; making use of tools around them; discovering new ways of using resources available). Sample utterance: *“...I think the best language to use for coding is Python because just gives you a hint on how coding is done so if you have a phone you can just download a version...the online version of Python and start creating codes.”* [Kenyan participant]
- **Interacting with others:** The adaptive micro-competences include teamwork, collaboration and negotiation. Interaction is the heart of what motivates the students to participate in the project. This is further seen in interest to work together on projects, listening to one another and giving feedback, negotiating roles to accomplish a task, asking for expertise and offering help and suggestions. Sample utterance: *“Now...you have the interests of making people to know coding and it starts with you... you’ve informed me...I then inform another person and then...”* [Kenyan participant]
- **Interacting in and with the world:** The adaptive micro-competences include being local and global, balancing rights with privileges, and balancing freedoms with respect. This is exemplified in the project as raising cross-cultural awareness and recognizing and learning from what makes us the same and different (e.g. finding commonalities in subject matter regardless of context, such as finding commonalities in their education systems). Sample utterance: *“You are in an already developed country and we are in a third world country such as Kenya...what do you think should be implemented so that kids who are very passionate...to learn coding at a very tender age as you started?”* [Kenyan participant]
- **Trans-disciplinarity:** The adaptive micro-competences include STEM, humanities, and social sciences. This is exemplified in the project as a focus on academic subject matter, making connections to the practical world around them (e.g. how coding helps create games to promote learning in other subjects; exploring the science behind music). Sample utterance: *“We start with Scratch then we move to xSpace and then we move into Java or Python.”* [U.S. participant]
- **Multi-literateness:** The adaptive micro-competences include reading & writing, numeracy and digital literacy. This is exemplified in the project as learning expressed in action through creation of tangible multimedia artifacts that synthesize their knowledge and skillsets (e.g. videos, games, presentations). Sample utterance: *“What 3D coding is we code something that turns into a virtual object and then we run it through a software that makes it out of plastic and it turns into a physical object.”* [U.S. participant]

## Methods

In order to meet the needs of an evolving future workforce, education will need to go beyond the acquisition of distinct pieces of knowledge, skills and experiences to foster environments where learners can “intelligently make connections across elements of competence, then integrate them and apply them interactively” (Marope, 2017, p. 86-87). Therefore, it will be increasingly important for educational research to examine the interrelationships that exist between cognitive, behavioral, affective and social competences.

In this context, this paper utilizes epistemic network analysis (ENA), a technique in quantitative ethnography that uses visualization and statistical methods to identify meaningful patterns in discourse. ENA is a methodology grounded in epistemic frames theory, which posits that “learning can be characterized by the structure of connections that students make among elements of authentic practice” (Shaffer & Ruis, 2017, p. 182). ENA operationalizes this theoretical approach by modeling the connections between salient constructs in the data, particularly by examining the co-occurrences of codes within conversations (Shaffer, 2017). ENA also allows for quantitative comparisons between epistemic network models through the calculated centroids, which are determined by the strength of connections between the codes. Furthermore, in its ability to capture complex

learning processes as they occur, ENA also provides an effective methodology for conducting learning assessments that are both summative and formative (Shaffer et al., 2009).

The data for this analysis was collected from an 80-minute video conference call (described in the project as a “meet-up”) held in May 2017 between 12 participants from project sites in Kenya (4 students, 1 adult) and the U.S. (4 students, 3 adults). In the meet-up, participants shared knowledge and experiences about computer programming tools and languages, including Scratch, Python and HTML. The discourse data was coded using UNESCO’s seven future global competences: lifelong learning; self-agency; interactively using diverse tools and resources; interacting with others; interacting in and with the world; trans-disciplinarity; and multi-literateness. A total of 235 utterances were coded by three raters for the presence of the seven global competences. This was followed by a process of social moderation undertaken for each utterance, which allowed the three raters to reach consensus on the coding of the data (Frederiksen et al., 1998; Herrenkohl & Cornelius, 2013). The ENA web-tool was used for visualizing and analyzing the coded data.

## Results

Figure 1 presents the ENA model of all participants in the meet-up, where nodes represent the global competences and the thickness of the edges indicate the strength of connection between them. The strongest connection can be observed between lifelong learning and trans-disciplinarity. During the meet-up, participants from both Kenya and the U.S. frequently exhibited a keen desire for learning—as reflected by their curiosity, creativity and critical thinking—along with interests in acquiring skills and knowledge in a variety of domains and topics. Other significant associations can be found among self-agency, multi-literateness, trans-disciplinarity, lifelong learning and the use of diverse tools and resources. However, the two interactional competences (interacting with others, interacting in and with the world) have relatively weaker connections to the other constructs.

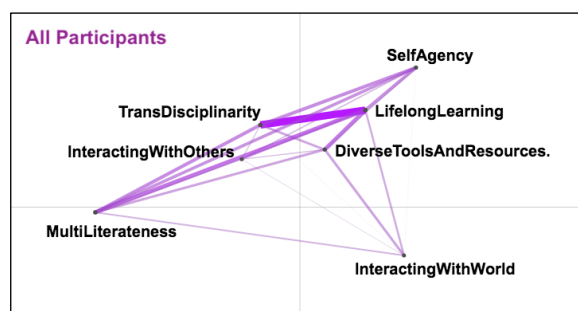
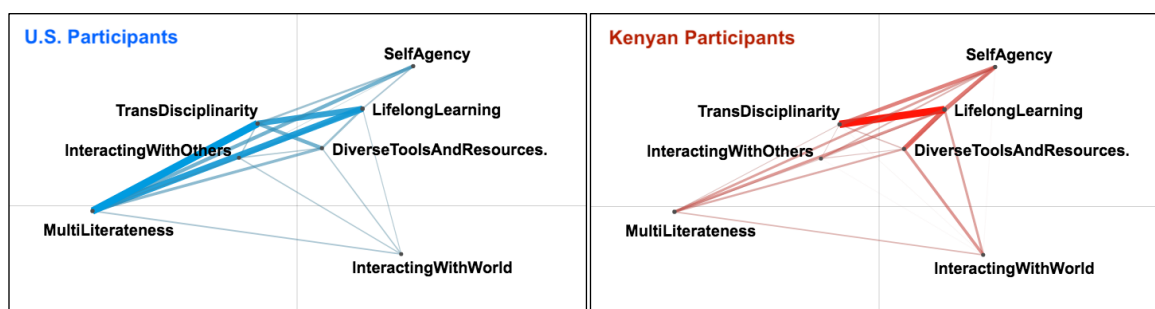


Figure 1. ENA network model of the meet-up discourse for all participants.

Figure 2 shows the ENA network models for the Kenyan and U.S. participants, respectively. While key differences can be observed between the two network models, the link between lifelong learning and trans-disciplinarity remains prominent for both groups. The x-axis is defined by connections to multi-literateness on the left and connections to self-agency and interacting in and with the world on the right. For the Kenyan participants, the discourse pattern shows a heavier presence on the right, with relatively stronger connections to self-agency, lifelong learning, trans-disciplinarity and use of diverse tools and resources. This is indicative of the initiative, motivation, and resourcefulness demonstrated by the Kenyan participants in the meeting. In contrast, the discourse pattern for the U.S. participants is situated more to the left side of the ENA space. Multi-literateness is heavily associated with both lifelong learning and trans-disciplinarity. This may be reflective of the students’ experiences with STEM-related activities at school, emphasizing problem-solving in an interdisciplinary setting.





(a) (b)  
**Figure 2.** ENA network models of the meet-up discourse for (a) U.S. and (b) Kenyan participants.

## Discussion

The discourse pattern of the computer-supported meet-up shown in Figure 1 demonstrates the strongest connection between the lifelong learning and trans-disciplinarity global competences. Without the use of ENA, the overall connection between these two competences would not have been clear through their frequencies alone. Furthermore, the connection between lifelong learning and trans-disciplinarity exemplifies the fundamental aims of the IC4 project. The baseline goals of this project are to foster conversational and critical thinking skills coupled with STEM subjects between students across the globe. Lifelong learning—curiosity, creativity, and critical thinking—best showcases the aforementioned conversational and critical thinking skills; trans-disciplinarity covers conversational topics related to STEM subjects, humanities, and the social sciences. The strong relationship between these two global competences as shown in the ENA models align these basic learning and topic-related aims of the project, meanwhile giving the project a path towards the development of more collaborative and interactive competences in the future. While this meet-up does include conversation between Kenyan and U.S. participants, the two groups of students demonstrate differences in their contributions to the conversation as reflected in their ENA network models: while the U.S. participants supply content-driven commentary (coded for as multi-literateness), the Kenyan participants show a stronger inclination towards self-agency and the use of diverse tools and resources. Ultimately, both groups of participants typify the global competences through relatively complementary behaviors, each bringing something different to the table.

In a broader context, this project examines global collaboration in the context of a STEM-focused digital makerspace community as way to develop and identify future learning environments in a changing workforce industry. As the global competences represent a framework to address the needs of future workforce environments, this paper is an initial attempt to evaluate how this project can address such competences. Participants demonstrated critical thinking and awareness that would not have necessarily been observed without involvement in this project. Particularly, the students' computer-supported collaborative discussion of coding demonstrates Target 4.4 of SDG #4 as the students educate each other on technically relevant skillsets. The results discussed in this paper provide a preliminary validation of the use of the global competences as a framework for assessment. In future analysis, ENA can be utilized to examine how the competences are addressed and how the relationships between concepts change as the project progresses, giving rise to youth gaining skills to solve problems globally and collaboratively together for the future.

## References

- Frederiksen, J. R., Sipusic, M., Sherin, M., & Wolfe, E. W. (1998). Video Portfolio Assessment: Creating a Framework for Viewing the Functions of Teaching. *Educational Assessment*, 5, 4, 225-97.
- Herrenkohl, L. R., & Cornelius, L. (2013). Investigating Elementary Students' Scientific and Historical Argumentation. *Journal of the Learning Sciences*, 22, 3, 413-461.
- Marope, M. (2017). Future Competences for Future Generations. International Bureau of Education: In Focus, 2. Retrieved from <http://ibe-infocus.org/wp-content/uploads/2018/03/In-Focus-2017.pdf>
- Shaffer, D. W., Hatfield, D., Svarovsky, G. N., Nash, P., Nulty, A., Bagley, E., ... Mislevy, R. (2009). Epistemic Network Analysis: A Prototype for 21st-Century Assessment of Learning. *International Journal of Learning and Media*, 1(2), 33–53.
- Shaffer, D. W. (2017). *Quantitative ethnography*. Madison, WI: Cathcart Press.
- Shaffer, D. W., & Ruis, A. R. (2017). Epistemic Network Analysis: A Worked Example of Theory-Based Learning Analytics. *Handbook of Learning Analytics*, 175–187.
- United Nations. (n.d.). United Nations Sustainable Development Goals: Quality Education. Retrieved from <https://www.un.org/sustainabledevelopment/education>

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# SciGirls Code: Computational Participation and Computer Science With Middle School Girls

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**Abstract:** SciGirls Code is a project comprised of 16 STEM outreach programs that provided 160+ middle school girls with computational thinking (CT) and coding skills between September 2017- June 2018. The research study investigates the ways in which these learning experiences impact girls' development of CT; interest and attitudes toward computer science; and their understandings of how participation in creation with technology impacts themselves and the world around them. Utilizing a qualitative multi-site case study design, the study found that a connected learning approach boosted the development of girls' CT skills, positively impacted attitudes towards computing pathways/careers, and increased understandings of computational participation. In addition, the educational experiences happening throughout the SciGirls Code program exemplifies the 4E learning model. Implications include how technology can be leveraged towards creating an inherently collaborative setting, acknowledging social, emotional, cultural, technological, and cognitive intersections in learning.

## Major issue addressed and potential significance

Women remain significantly underrepresented in the STEM workforce within the United States, particularly computer science. Women constitute only 25% of the computing workforce despite it being the STEM area with the most demand (Pew Research Center, 2018). Notably, the number of women in computing occupations has actually declined over the past 25 years (Pew Research Center, 2018). While NCWIT (2017) reports that 1.1 million computing job openings are expected by 2024, men constitute 81% of the computer/information sciences degrees conferred in the 2015-2016 academic year. Although more bachelor's degrees are conferred to women, computer/information sciences degrees make up only 1% of degrees conferred to women (NCES, 2017).

The issues that contribute to the computer science pipeline deficits are complex, and they begin early. For example, in 2018 girls represented only 28% of AP Computer Science (CS) test-takers ([www.code.org](http://www.code.org)). While this represents a slight increase from 2017 (26%), it demonstrates a continued, dramatic discrepancy between genders. *Girls in IT: The Facts* (Ashcraft, Eger, & Friend, 2012), a summary of research regarding factors that contribute to the gender gap in computer science education, suggests these ongoing issues: 1) curriculum that is irrelevant; 2) pedagogies that discourage collaboration; 3) lack of opportunities to take risks and make mistakes; and 4) heavy reliance on lecturing instead of hands-on, project-based learning. Starting early with interventions that introduce girls to computer science in elementary and middle school can help increase interest in CS; cultivating early interest is paramount because *interest* in STEM fields in high school, rather than *achievement* in these areas, is more closely associated with pursuit of careers in computer science (Corbett & Hill, 2015).

SciGirls Code is a project that aims to address the gender equity issue in the field of computer science by targeting middle school girls (Blikstein, 2018), which is the age when girls begin losing interest in STEM areas (Microsoft & KRC Research, 2018). SciGirls Code worked with 16 STEM outreach programs to provide 160+ middle school girls with computational thinking (CT) and coding skills within informal education spaces. The project theorized that a connected learning approach, which is based on sociocultural learning theory (Cole, 1998; Vygotsky, 1978), with the active support of trained educators and role models, would boost the development of middle school girls' CT skills, attitudes towards computing pathways/careers, and understandings of how participation in technology creation impacts themselves and the world around them.

## Theoretical approaches

### Connected learning and computational participation

The connected learning model advocates that "the most resilient, adaptive, and effective learning involves individual interest as well as social support to overcome adversity and provide recognition" (Ito et al., 2013, p.4). With an emphasis in meaningful practices and supportive connections with others, this model identifies three

contexts for learning: peer-supported, interest-powered, and academically-oriented. We applied connected learning in this project in order to understand how girls expanded their interest within production-focused CS activities and how they empowered their own learning within a gender-equitable, peer-supported environment.

Connected learning, in combination with computational participation, anchors our project and its research agenda. Computational participation (CP) is explained as “connecting through making, which leads to deeper, richer, and healthier connections among online youth” (Kafai & Burke, 2014, p. 132). With sharing and collaboration at its core, CP is described as “solving problems with others, designing intuitive systems with and for others, and learning about the cultural and social nature of human behavior through the concepts, practices, and perspectives of computer science” (Kafai & Burke, 2014, p. 128). CP, therefore, represents a shift from the previous “individualistic view of computing” to a view that focuses on “sociological and cultural dimensions” (Fields, Kafai, & Giang, 2017, p.2). Kafai and Burke (2014) suggest that computer programming “represents a crucial beginning step”, “a form of expressing oneself”, and “a community practice” to approach CP (p. 128).

## Computational thinking

Rooted in computer science, computational thinking (CT) is viewed as “a universally applicable attitude and skill” (Wing, 2006, p.33) that involves analytical thinking (Bers, 2018) and the process of problem-solving (ISTE, 2016). Bers (2018) argues, based on Papert’s (1980, 1999) earlier ideas of learning through making and “hard fun,” that CT is not only “involved problem solving, but also a notion of expression” (p.60). Operationally, this study’s research methods are grounded in a CT framework (Brennan & Resnick, 2012), which encompasses three dimensions: 1) concepts (e.g., sequence, loops), 2) practices (e.g., debugging, remixing, and 3) perspectives (e.g., expressing, connecting). We documented and assessed girls’ knowledge of computational concepts and abilities to employ them using computational practices.

## Fusion of ideas

We integrate a CP framework with connected learning in order to examine how middle school girls made sense of their participation with respect to their social and cultural contexts as they learn to code (Kafai & Burke, 2014; Ito et al., 2013). Burke and colleagues note that “whereas computational thinking uses an algorithmic lens toward problem-solving, computational participation extends this thinking beyond the individual to integrate social networks and digital tools in a networked society” (Burke, O’Byrne & Kafai, 2016, p.373). Similarly, we believe that a computational participation framework enables us to conceptualize how connected learning contributes to various aspects of CT development as well as interest in computer science.

## Methodological approaches

### Overview

The research study investigated the ways in which computational learning experiences impacted girls’ development of CT [*RQ1: Learning*]; interest and attitudes toward computer science [*RQ2: Interest*]; and their understanding/appreciation of how participation in creating with technology impacts themselves and the world around them [*RQ3: Participation*]. This study utilized a qualitative embedded, multi-case study design (Merriam, 2009). The 7 focal cases represent an array of settings (rural, suburban, urban) as well as a variety of programming contexts (museums, community centers, after school). The remaining 9 sites comprise the participating cases.

Data collection paralleled curriculum implementation at program sites occurring between late August 2017 – early August 2018. There were multiple data sources with different data collected at focal and participating sites. Focal programs were visited face-to-face, and participating site participants were engaged digitally. Notably, artifact-based interviews (in-person at focal sites) and shorts (video at participating cases) were collected from girls at three moments in the programming (beginning, middle, and end) in order to document any changes/growth in understandings and skills. Other data sources include girls’ pre- and post-program survey, curriculum artifacts including FlipGrid videos (<https://flipgrid.com>), and facilitator interviews. Approximately 88 girls across all sites participated in all research activities during the year-long programming.

### Analysis

There were two distinct stages of analysis; the first stage was the within-case analysis and the second stage was the cross-case analysis. For the within-case analysis, each case category (focus or participating) was first treated as its own case. Sub-unit analysis resulted in portraits of individual programs. Portraits were woven together to develop separate case narratives for focal and participating cases (within-case analysis). Next, these narratives were used to inform the cross-case analysis of all programs (in progress). All data were reviewed and coded first to align with related research questions and hypotheses. Next, using research questions as the anchors, open-ended

survey data as well as interview/short transcripts were analyzed using qualitative content analysis (Saldaña, 2013). Open coding processes were followed by grouping open codes into analytical/interpretive codes resulting in thematic findings (Harry, Sturgis, Klingner, 2005). Both open and analytical coding were done with common data sets by at least two researchers who engaged in clarifying conversations during these iterative stages.

## **Major findings and implications**

Due to this project's timing and CSCL's deadlines, this proposal briefly highlights initial findings related to our study's third research question [RQ3: Participation].

### **Girls' overall attitude about teamwork**

In the preliminary survey findings, girls' responses to the question, "*I can do different things when I work with others than I can when I work alone*" identified that the majority of girls hold positive attitudes toward teamwork (e.g., 68% indicated strongly agree or agree in the pre-survey compared to 75% in the post-survey). There is evidence that some girls who shared their concerns about teamwork in the pre-survey changed their attitudes in the post-survey.

### **Cross-case analysis of girls' reflections on teamwork**

#### Teamwork is essential in CS activities

Teamwork with others is valued by girls. By the final interview, many girls reported teamwork and the ability to work with others as the biggest takeaway from their experiences in SciGirls Code. In general, girls had an evolving sense of how teamwork was a significant part of doing CS activities.

#### Teamwork contributes to growth in problem solving

Overall, girls' view of the SciGirls Code group work was positive, with girls citing building strong friendships, growth in problem solving, and gaining teamwork skills. Despite feelings of frustration and stress, many girls mentioned how helpful it was to have other people to work with and to assist in troubleshooting when problems arise.

#### Teamwork nurtures creative freedom and ownership

Teamwork was instrumental in nurturing girls' sense of creative freedom and ownership through channeling their friendships towards choices and decisions related to how they engaged with tasks.

### **Themes situated with the 4E learning model**

The educational experiences happening throughout the program exemplify the 4E learning model: embodied, enactive, extended, and embedded cognition. While the individual program sites provide unique contexts for learning, we found central themes derived from the program design and curriculum that resulted in common outcomes for the girls. For purposes of this paper, we situating these themes within two aspects the 4E learning model: embodied and enactive cognition.

#### Embodied

Findings indicate that the participants at multiple sites wrestled with sense-making of both CT concepts and practices while engaged in physical interactions with technologies and other aspects of their learning environment. For example, at the end of each unit was a makeathon that challenged the girls to use the computational knowledge and skills scaffolded throughout the unit to create an end project in teams. These products were often the highlight of girls' experiences in the program. The teams had autonomy over their final artifact including its aesthetic, applicability, and functionality. The process of making decisions and having independence over their creations resulted in the girls' ownership and pride in their creations. Another source of pride was the success they experienced after facing constant challenges with the technology. Girls indicated they consistently used the CT practices of debugging and problem solving. The physical act of examining code, (de)constructing their code to understand the issue, and then celebrating when challenges were overcome made learning visible. "When we figured something out, I think that we felt like, you know that feeling when the light bulb goes off in your head?" (Hannah, Team Draco, Interview 1). The girls began to expect challenges when computing and their confidence grew as the program went on; "I think that they have the confidence that they can problem-solve when they come up against something they're not familiar with. I don't know that they had that before" (Adult facilitator, Canis Major).

## Enactive

Through our multiple interviews with the girls during the year, we were able to understand how the girls conceptualized new understandings about computing over time. The dynamic interaction between each girl and their peers, their adult facilitator, the curriculum, the physical setting, the volunteer mentors, and the technology, resulted in transformational perspectives of themselves and their role within computing. All of the activities in the SciGirls Code curriculum were designed with collaboration in mind and allowed girls to reconceptualize computer science as a participatory field rather than seeing it as an isolated relationship between a person and a computer. For instance, in the mobile app-making unit girls learned about pair programming, where one is given the role of driver and another is the navigator. Pair programming was a popular concept many girls throughout the sites identified as something they learned: “Pair programming--I didn’t know that two people could work on the same thing, and like help each other. I thought it was like maybe just one person and then another person just check[s] over it” (Katelyn, Team Mensa). Emma from Team Lynx found group work to be important to the coding process: “Yeah working in groups I feel with coding is a lot easier than working by yourself.”

## New models for learning 4E

Each of the SciGirls Code program sites serve as uniquely complex system but all sites had collaborative, computer-supported, and interdisciplinary factors. The 4E cognition aligns with the connected learning framework in that girls move from embodied and individual views of computing to the role of computing in society and embedded settings (Fields, Kafai, & Giang, 2017; Ito et al., 2013, Newen, De Bruin, & Gallagher, 2018). The result of these embedded factors included girls’ increased understandings of and skills related to computational thinking; increased interest and confidence in computer science; expanded understanding of the role of computing in society; and how they can engage in and shape technology. We offer collaborative learning as not just a learning phenomenon that needs to be further understood by researchers but as an essential factor for addressing gender equity within computing.

## **Selected references**

- Blikstein, P. (2018). Pre-college computer science education: A survey of the field. Mountain View, CA: Google LLC. Retrieved from <https://goo.gl/gmS1Vm>
- Brennan, K., & Resnick, M. (2012). *Using artifact-based interviews to study the development of computational thinking in interactive media design*. Paper presented at annual American Educational Research Association meeting, Vancouver, BC, Canada.
- Fields, D.A., Kafai, Y.B., Giang, M.T. (2017). Youth computational participation in the wild: Understanding experience and equity in participating and programing in the online scratch community. *ACM Transactions on Computing Education*, 17(3), 1-15.
- Ito, M., Gutierrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., Schor, J., Sefton-Green, J., Watkins, S.C. (2013). *Connected learning: An agenda for research and design*. Irvine, CA: Digital Media and Learning Research Hub.
- Microsoft in partnership with KRC Research. (2018). Closing the STEM gap: Why STEM classes and careers still lack girls and what we can do about it. Retrieved from <http://aka.ms/girls-in-stem-research>
- National Academies of Sciences, Engineering, and Medicine. (2018). *How people learn II: Learners, contexts, and cultures*. Washington DC: The National Academies Press. <https://doi.org/10.17226/24783>
- Newen, A., De Bruin, L., & Gallagher, S. (Eds.). (2018). *The Oxford handbook of 4E cognition*. Oxford, UK: Oxford University Press.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Book Publishers, Inc.
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35.

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# A Systematic Review of the Quantification of Qualitative Data in the Proceedings of International Conferences of CSCL from 2005 to 2017

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**Abstract:** In computer-supported collaborative learning (CSCL), verbal and non-verbal behaviors among group members are often examined to help investigate how people in groups interact and learn. Analytic methods used on language data that involve a certain degree of quantification are not rare. This study examines the quantification of qualitative data that involves some form of language use in articles included in the proceedings of international conferences on CSCL from 2005 to 2017. The goal of this systematic review is to identify gaps in methodological effort of quantifying human interactions and communication in terms of research contexts, levels of analysis, and time points of assessment. In synthesizing information on these three aspects, we hope to identify trends over the years and encourage more effort in less researched areas.

## Introduction

The interaction and communication between individuals who work in collaborative groups are key aspects in CSCL and is often times under investigation by researchers in the field. As CSCL grows and attracts effort from multidisciplinary fields, it presents the community with promising developments and tensions (Borge & Mercier, 2018). Previous effort has been made to review some key aspects of CSCL field to provide insights into the characters of CSCL and further into future paths. Those studies helped to reveal CSCL's membership (Hoadley, 2005), methodological approaches and theoretical frameworks (Jeong, Hmelo-Silver, & Yu, 2013), and similar issues in fields related to CSCL such as educational and instructional technology (Hrastinski & Keller, 2007). Research in CSCL produces large amount of qualitative data and has used methods of quantification to identify patterns and themes in interviews, student speech in naturalistic settings, online discourse, and other qualitative data forms, as well as to understand relationships in data and make predictions on learning behaviors and outcomes. Chi (1997) proposed a method of content analysis to quantify quantitative data; from then on, there have been other methods used for the same purpose, such as thematic analysis, open coding, social network analysis, as well as automatic analysis based on Natural Language Processing. However, we do not yet know how researchers in the community of CSCL, as identified by having work published in international conferences of CSCL proceedings, apply methods to quantify human interactions over the years, and how prevalent these different types of methods are in the CSCL conference community, what learning contexts we tend to prioritize, and to what extent we examine collaborative learning processes over time.

In this paper, we begin the process of examining our community's existing practices and trends by examining where the data being quantified was collected, which indicates where the researchers examined phenomena associated with learning; at what level(s) researchers analyzed language use; and how many time points assessments were administered. We believe an understanding of the contexts and participants is critical to a comprehensive view on the types of learning that has been under investigation and to revealing gaps in research. Thus, we ask the following research questions: (RQ1) In what contexts have data of group processes been quantified and how have they changed from 2005 to 2017; (RQ2) What are the levels of analysis that have been examined in when quantifying group process data and how they changed from 2005 to 2017? 3; (RQ3) How many times were assessments carried out and how has this aspect changed from 2005 to 2017?

## Methods

### Selection criteria

We examined CSCL conference proceedings from 2005 to 2017. Inclusion criteria were as follows: (1) articles had to be five or more pages long; (2) the data sources included some form of language use, i.e., text-based language, spoken language, or body language; (3) the analysis of the data should involve some type of quantification, from frequency counts to statistical comparisons or mathematically aided machine automation, e.g. natural language processing.

## Data collection and coding

The first author read through the methods section and findings of all conference papers that were over five pages to check for inclusion or exclusion. In total 30.51 % of all papers (180/599) met our criteria; 29/65 articles in 2017, 25/57 in 2015, 31/69 in 2013, 32/71 in 2011, 24/93 in 2009, 19/144 in 2007, and 20/100 in 2005. Information from methods sections was extracted on (1) research contexts, (2) level of analysis, and (3) number of assessment time-points.

Research contexts refer to the settings where the selected research was carried out; due to its variety, the first round of analysis focused on extracting keywords on these three dimensions with minimal interpretation; in the second round of analysis, categorization was based on the following codes. *Classroom*: studies in K-16 classrooms, including face-to-face courses or hybrid courses where only part of the learning activity was carried out online; these classrooms may or may not be technology-enhanced, depending on the research design. *Technology implemented in classroom*: studies with focus on technologies such as online systems incorporated in K-16 classrooms. *Lab*: studies were carried out in computer laboratories. *Technology implemented in informal learning (online)*: studies that extracted data from educational online technologies that were used outside of classrooms. *Informal learning (offline)*: studies in physical informal learning environments such as after school clubs, museums, and summer camps. *Informal learning (online)*: studies that extracted data from online communities that are not designed for educational purposes, such as forums where interest groups interact online. *Online classroom*: studies were carried out in completely online classes, including both those offered within degree programs and massive online open courses. *Classroom and lab*: studies were carried out in both classrooms and labs. *Company*: studies were carried out in company settings, such as corporate training sessions. *Email list*: studies that extracted data from emails in email lists. *N/A* refers to unspecified cases.

Level of analysis indicates whether the analysis was conducted at the level of the individual, dyad, group, or community. At *individual* level, data was extracted from individuals; research addressed the question(s) at the individual level; please note that even in cases where students worked in groups, but if the researchers used individual data to answer questions concerning individual learners, those studies analyzed data at the individual level and fell under this category. At *dyad* level, data was extracted from dyads; research addressed the question(s) at the group level. At *group* level, data was extracted from groups with three people or more; research addressed the question(s) at the group level; in some studies where students worked in groups, but if the researchers analyzed for individual learning, those studies were not included in this category. At *community* level, data was extracted from a community of learners both online and offline from cases where researchers considered the whole classroom as community to online communities; research addressed the question(s) at the community level. At *multiple* levels, data was extracted from two or more levels from above categories; research addressed the question(s) at multiple levels. *N/A* refers to unspecified cases.

Assessment and time point refers to how many times the researchers administered assessment and an approximate description of whether the interval is long or short to see whether they are looking at learning over time. Between the first and last time points, short intervals are less than half semester and long intervals are more than half semester. Cases where there was no information concerning assessment were coded as *N/A*. The possible codes for our database of papers included “1TP,” “2TP (long),” “2TP (short),” “5TP,” or “N/A.”

## Results

### Context

The five most common contexts were classrooms (47.31%), technology implemented in classrooms (12.90%), technology implemented in informal learning (online) (7.53%), informal learning (offline) (6.99%), and labs (11.29%). We examined the frequency of these contexts as settings for studies over time to look for trends. Figure 1 shows the frequencies of each category from 2005 to 2017. Classroom setting shows an upward trend, increasing from 6 cases in 2005 and 2006 to around 18 in 2013, 2015, and 2017. Technology implemented in informal learning (online) does not appear in 2015 and 2017, and the laboratory setting shows a slight upward trend.

### Level of analysis

As would be expected, the articles that studied groups and dyads account for the most, 81(45%) and 42(23%) respectively, followed by 20 papers (11%) studying individuals and 16 (9%) examining communities. Only 10 studies (6%) examined collaborative learning at multiple levels. Eleven studies did not report relevant information. We also examined trends of different categories over the years from 2005 to 2017 (Figure 2). While there are fluctuations in number of studies on groups, dyads, and communities, the general representations remain stable, with groups being the most represented, then dyads, and communities being the least represented of the

three. With the exception of 2017, the number of studies examining at the level of individual shows an increasing trend. Overall, the number of articles that examined multiple levels of analysis is the least represented of all the categories over time, with the exception of 2017.

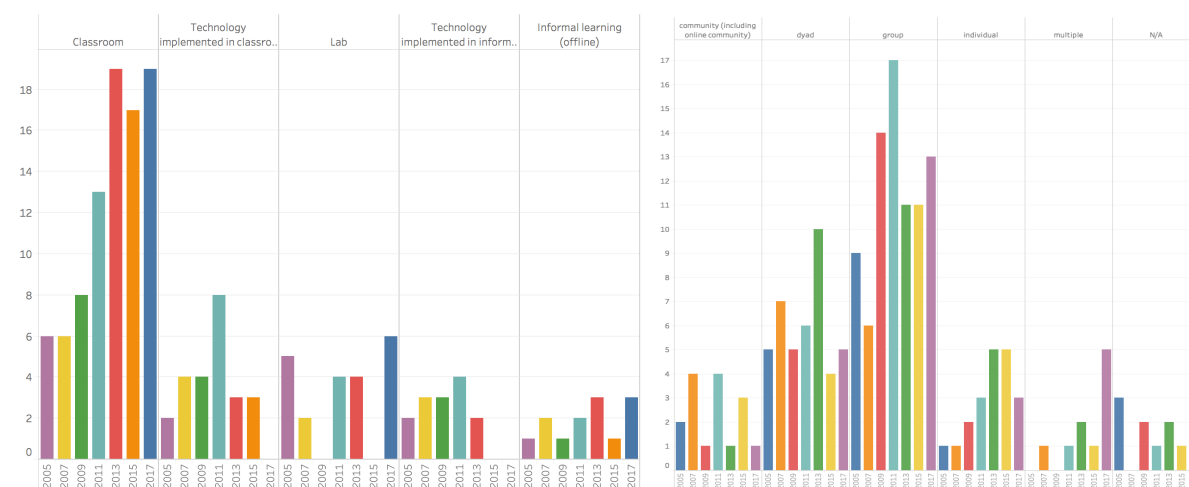


Figure 1. Changes of the most frequent five categories in contexts over the years from 2005 to 2017 (left).

Figure 2. Changes in the number of papers for different levels of analysis from 2005 to 2017 (right).

### Assessment time point

The majority of papers in our sample (116/64.09%) did not provide an analysis of collaborative processes at different time points. Of those that provided an analysis of collaborative processes at different time points, 44 papers (24.31%) included only two time points; these were primarily pre- and post- tests administered at the beginning and end of the study over a short period. Articles with two time points of assessments show an increasing trend from 2013 to 2017. Followed afterwards are those with one time point of assessment (15/8.29%), which usually had pretests. Notably, the number of assessments administered to measure change over half semester is extremely low. Five studies had pre- and post- tests to measure change over half semester from 2009 to 2017, and only one study administered more than two assessments; they measured collaborative processes at five time points that spanned over 11 weeks.

### Discussion

This study examines the studies that quantified language that occurs during collaboration in the conference proceedings of CSCL from 2005 to 2017, as seen representative of the overall effort made in CSCL community. Being a first step to illustrate the effort, this study focuses on the research contexts, level of analysis, and assessment time points in the selection of articles.

In terms of research contexts, findings showed a dominance of research conducted in classroom settings over other types of learning environments. Researchers in learning have emphasized the importance of conducting research in naturalistic settings (Barab & Squire, 2004), which offers a possible explanation for the majority of studies that quantifies human interaction and communication in real classrooms. Nonetheless, our findings show that there is a context gap since there are other types of naturalistic learning environments that show potential in offering various learning opportunities which learners might not be able to get from formal classrooms. According to Enyedy and Stevens (2014, p. 207), the collaborative learning in informal learning sites could be as much different as they differ from formal schooling; to them, the difference is “striking”. Though there are collaborative learning activities in those formal learning environments and most of the studies were conducted there, those activities would have less impact on the collaborative learning than other informal, collaborative learning contexts where learners work as groups. Thus, to have a fuller and more in-depth understanding of collaborative learning, more research is needed in underrepresented contexts (i.e., informal and professional work spaces) as well as between contexts (i.e., between classroom and informal contexts, between classroom and work contexts, etc.). Increasing representation of different learning contexts will help learning scientists gain a richer, deeper understanding of how people enact collaborative learning and learn to collaborate.

Findings on levels of analysis shows that the majority of selected articles are focused on dyad or group level, which causes little surprise. However, researchers in the CSCL community have called for effort to address collaborative learning at multiple levels (Borge & Mercier, 2018; Stahl, 2013; Strijbos, 2011; Zhao & Frank,



2003). The findings indicate more effort needs to be exerted to address this multi-level analytic needs to further investigate collaborative learning as it happens across individuals, dyads, small groups, and communities. The need for studies on individuals and small groups is inherent in learning from sociocultural perspective (see more on “internalization” from Vygotsky, 1978, p. 56), and the research on learning communities not only offers opportunities to examine learning phenomena and knowledge dissemination, retention, and transfer at the larger scale. The multi-level research could also benefit other effort in education research, such as design-based implementation research (Fishman, Penuel, Allen, & Cheng, 2013).

Equally important is the need to include more studies conducted at the community level. The low representation of such studies is problematic, given that people organize their learning around the social communities to which they belong and the process of learning and membership in a community of practice are inseparable (Lave & Wenger, 1991). Thus, more research in CSCL is needed that operationalizes interactions within a community or at multiple levels that include the community. Such research would have the potential to generate innovative insights and contribute to the field.

Lastly, findings on the assessment of collaborative processes highlights how little research has measured learning of content or changes in processes over time. While our community values the close examination of language that occurs during collaboration, the measurement of learning and process changes over time gives critical information on learning progressions and provides more in-depth analysis of the effectiveness of some interventions. However, our findings show that in most cases, no assessment was administered, and even for those pre- and post-tests, most of them were measuring learning in a short time and thus did not consider knowledge retention or the actual development of competence. The lack of assessments might be a result of practical complexities, restrictions in conducting research, or a lack of measurements that are of high reliability and validity, but this current status nevertheless creates an urgent need to develop measurements in the field of CSCL. The quantification on human interactions unlocks potential for learning analytics to exploit process data, which could be used for measurement in connecting the interpretation of process and outcome data and thus help fill this gap.

## References

- Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1-14.
- Borge, M., & Mercier, E. (2018). Towards a cognitive ecological framework in CSCL. In *Proceedings of International Conference of the Learning Sciences, ICLS* (Vol. 1, pp. 336-343). International Society of the Learning Sciences.
- Chi, M. T. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences, 6*(3), 271-315.
- Enyedy, N., & Stevens, R. (2014). Analyzing collaboration. In *The Cambridge Handbook of the Learning Sciences, Second Edition*. Cambridge University Press.
- Fishman, B. J., Penuel, W. R., Allen, A.-R., & Cheng, B. H. (Eds.). (2013). *Design-based implementation research: Theories, methods, and exemplars. National Society for the Study of Education Yearbook*. New York, NY: Teachers College Press.
- Hoadley, C. M. (2005). The shape of the elephant: Scope and membership of the CSCL community. In *Proceedings of the 2005 conference on Computer Support for Collaborative Learning: learning 2005: the next 10 years!* (pp. 205-210). International Society of the Learning Sciences.
- Hrastinski, S., & Keller, C. (2007). An examination of research approaches that underlie research on educational technology: A review from 2000 to 2004. *Journal of Educational Computing Research, 36*(2), 175-190.
- Jeong, H., Hmelo-Silver, C. E., & Yu, Y. (2014). An examination of CSCL methodological practices and the influence of theoretical frameworks 2005–2009. *International Journal of Computer-Supported Collaborative Learning, 9*(3), 305-334.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.
- Stahl, G. (2013). Learning across levels. *International Journal of Computer-Supported Collaborative Learning, 8*(1), 1-12.
- Strijbos, J. W. (2011). Assessment of (computer-supported) collaborative learning. *IEEE transactions on learning technologies, 4*(1), 59-73.
- Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.
- Zhao, Y., & Frank, K. A. (2003). Factors affecting technology uses in schools: An ecological perspective. *American educational research journal, 40*(4), 807-840.

# Reflective Assessment for Idea Improvement Through Collective Concept Mapping

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**Abstract:** The current research investigated Grade 5 students' reflective discourse during their co-design of an ecological concept map as a way to assess collaborative knowledge building. The result showed that students sustainably built on each other's ideas and inquiries about various ecological concepts to advance their scientific knowledge as a community. They also incorporated more academic and ecological terms as they participated in the co-designing activity. This study illustrated the potential use of the collective concept mapping to collaboratively advance knowledge in science disciplines as the student-driven reflective assessment.

## Introduction

The 21<sup>st</sup>-century education needs to facilitate students' high-level agency to direct their learning and inquiry. Research on knowledge building communities (Chen, Scardamalia, & Bereiter, 2015; Zhang, Scardamalia, Reeve, & Messina, 2009) offers a model of education that engages student-directed collaborative efforts for sustained inquiry and idea improvement (Chen & Hong, 2016; Scardamalia & Bereiter, 2006; Scardamalia & Bereiter, 2010). A critical challenge is to design new classroom assessments in alignment with student-directed collaborative knowledge building. Such assessments need to engage student-directed, ongoing efforts to reflect on their collaborative knowledge progress and make informed decisions to refine their inquiry (van Aalst & Chan, 2007).

The current research explores using a co-designed concept map to support students' reflective assessments of knowledge building. In the related literature, concept maps have been used to track students' scientific knowledge (Novak & Musonda, 1991) and facilitate students' meaningful learning. In particular, concept mapping enhances students' creative thinking by presenting focal questions about key concepts, clarifying the concepts, exploring cross-links between the different concepts (Novak & Cañas, 2008). In this study, students worked collaboratively to create the concept map to co-organize their collective knowledge, reflect on idea progress and connection, and facilitate further collaboration. We investigated students' online and face-to-face discourse that occurred during the concept mapping activity. The research questions included: a) How did the students collectively design a concept map to assess their community's shared understandings, through what types of reflective conversation?; and b) How did the knowledge building discourse change from before to after the reflective assessment through collaborative concept mapping?

## Data collection and analysis

The present study investigated 21 Grade 5 students' discourse during their co-design of a concept map in the ecology unit. The data sources were students' discourse in an online discussion forum called Knowledge Forum (KF) and videotaped face-to-face metacognitive meeting (MM). The ecology unit was covered twice a week for 14 weeks. Students discussed food chain, bees, animal behavior, underground, and plants by theorizing, building on ideas and raising inquiries. In the 8<sup>th</sup> week, students brought picture cards of concepts (creatures) that they researched and put them on a big paper. While building on ideas, they drew arrows between the creators to indicate the energy flows. They updated the concept map throughout five MMs until the end of the ecology unit. A teacher facilitated students' knowledge building by encouraging them to build on each other's ideas.

Discourse in students' notes on KF was analyzed by using text analysis tools called *AntConc* (Anthony, 2018) and *Vocabprofile* (Cobb, 2018) to classify words into academic words (Coxhead, 1998; Coxhead, 2000) and off-list words (special words beyond general and academic words). Words indexed in the life science section of Next Generation Science Standards (NSSS) were extracted (Marzano, Rogers, & Simms, 2010). The categorized words were compared between the two time spans (before and after the initial co-design of the concept map). Students' focal topic change was traced during the discussion in MM using *AntConc* (Anthony, 2018) and on KF through *KBDeX* (Oshima, Oshima, & Matsuzawa, 2012) to figure out the concepts with high betweenness centrality (how a certain word is mentioned with other words as it plays a central concept in the discourse network), respectively. In order for more in-depth analysis of students' idea improvement, Content

Analysis was conducted in terms of questioning, theorizing/explaining, collecting evidence, referencing sources, connecting and integrating (Tao & Zhang, 2018).

## Findings

### How did the students co-design a concept map to assess their community's shared understandings?

The teacher started the initial concept mapping by stating the purpose of the activity. She emphasized that students had discussed many different ecological concepts and needed to make connections between the concepts. She also pointed out making the connection between various concepts would provide students with driving ideas for further research. Students continued the collective concept mapping through four more consecutive MMs.

As students proceeded with the co-design of the concept map, they found the energy flows between the creatures and connected the creatures with arrows (see Figure 1), continuing research on the concepts on KF (see Figure 2). For instance, the left illustration in Figure 2 shows a segment of students' discourse with a stream of discussing 12 concepts over time. In this illustration, each vertical line demonstrates the moment when each focal concept was mentioned. Students started the discussion about *energy* and mentioned it intermittently throughout the discussion. S4 asked peers about where to put the *sun* on the concept map. Then, he constructed his theory, "I think it starts from everything, so I think it should be connected to everything," and put the *sun* at the top of the concept map. As the MM progressed, S8 mentioned that "Every different *ecosystems* have different *food chains*." After then, students expanded the focal topic to various habitats where different species of creatures live (e.g., *desert, ocean, pine bush, woodland, forest*). Around the point when students had this conversation, students' discourse on KF contained a dramatic increase in the betweenness centrality of the focal concepts that students discussed during the concept mapping (see Figure 2).



Figure 1. The concept map that students co-designed.

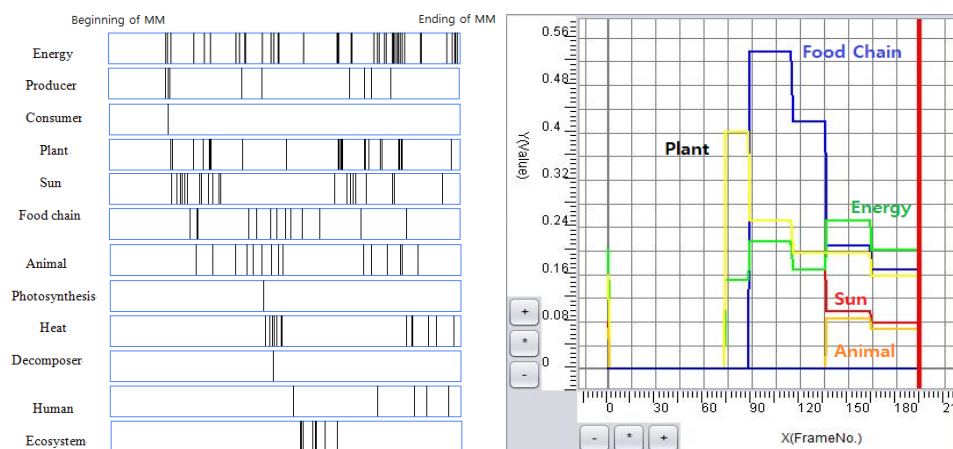
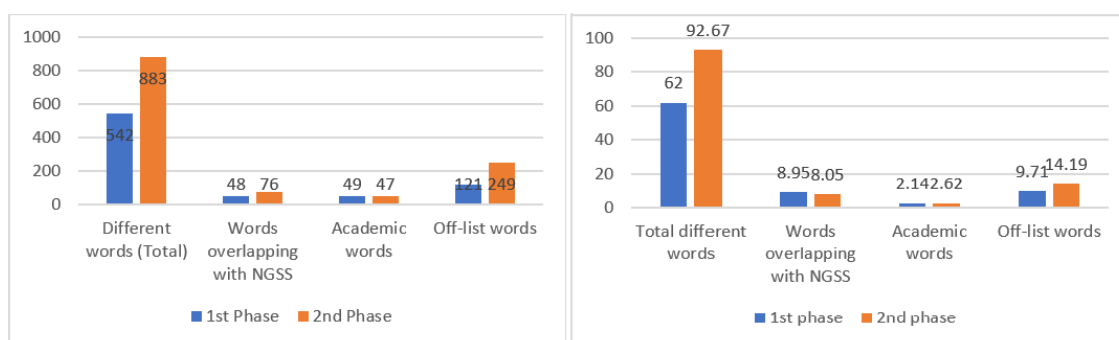


Figure 2. Timeline flow of focal concepts during collective concept mapping in MM (left) and dramatic increase in betweenness centrality of the focal concepts on KF (right).

### How did the knowledge building discourse change?

Students used more diverse words on KF after the initial co-designing activity (see Figure 3). They used more off-list words and words indexed in life science of NGSS in the 2<sup>nd</sup> phase while using slightly fewer academic words. The higher mean of individual students' word use was also found in academic words and off-list words.



**Figure 3.** Sum of word types (left) and mean of individual students' word types (right) before and after initial concept mapping.

Students' discourse in their KF postings was coded based on knowledge contribution types (Tao & Zhang, 2018) (see Table 1). Students showed the advanced discourse moves after the initial activity of collaborative concept mapping. They elaborated more refined and sophisticated explanations by stating opposite opinions and describing complicated concepts. Moreover, they wrote higher-quality writings with personal stories of conducting scientific experiments, knowledge obtained from online and reading resources, and synthesis of diverse ideas. They asked questions to explore more in-depth inquiries and seek explanatory ideas in the 2<sup>nd</sup> phase.

**Table 1: Knowledge building discourse on KF before and after initial concept mapping**

	1 <sup>st</sup> Phase	2 <sup>nd</sup> Phase
Questioning	29	<b>32</b>
Factual question	7	5
Explanatory question	4	<b>6</b>
Idea-initiating wonderment	6	<b>7</b>
Idea deepening/elaborating question	12	<b>14</b>
Theorizing/Explaining	<b>36</b>	31
Intuitive explanation	<b>28</b>	14
Alternative explanation	4	<b>6</b>
Refined explanation	4	<b>11</b>
Referencing sources	28	<b>38</b>
Collecting evidence	0	<b>7</b>
Connecting and integrating	1	<b>7</b>
Total	94	<b>115</b>

## Conclusion

The current research investigated Grade 5 students' reflective assessment of collective knowledge building by co-designing the concept map. The results showed that students cumulatively visualized the energy flows between ecological concepts through the on-going reflection of the community's idea improvement. They expanded the focal concepts, built and synthesized in-depth theories and inquiries, used reliable resources, produced more academic and scientific words, and continued to discuss the concepts in the online learning community.

The findings infer that students monitored their progressive idea improvement regarding the scientific concepts which they should pay attention to during and after the collaborative concept mapping. Students' collective designing of the concept map facilitated their conceptualization of the key ecological concepts and their understanding of the invisible mechanism behind how the creatures survive together in the ecosystem by

consuming other creatures (Novak & Cañas, 2008). What's more significant about this activity is that students were the core contributors to the reflective assessment and knowledge building in the community, while the teacher facilitated students' activity. The future research should assess students' on-going idea improvement more systematically through iterative and concurrent analytics of the learning data to deepen collective knowledge.

## References

- Anthony, L. (2018). AntConc (Version 3.5.7) [Computer Software]. Tokyo, Japan: Waseda University. Retrieved Oct 25<sup>th</sup>, 2018 from <http://www.laurenceanthony.net/>
- Chen, B., & Hong, H. (2016). Schools as knowledge-building organizations: Thirty years of design research. *Educational Psychologist, 51*(2), 266-288.
- Chen, B., Scardamalia, M., & Bereiter, C. (2015). Advancing knowledge-building discourse through judgments of promising ideas. *International Journal of Computer-Supported Collaborative Learning, 10*(4), 345-366.
- Cobb, T. (2018). Vocabprofile [Computer Program]. Retrieved Oct 25<sup>th</sup>, 2018 from <https://www.lexutor.ca/vp/>
- Coxhead, A. (1998). *An academic word list* (English Language Institute Occasional Publication No. 18). Wellington, New Zealand: Victoria University of Wellington.
- Coxhead, A. (2000). A new academic word list. *TESOL Quarterly, 34*(2), 213-238.
- Marzano, R., Rogers, K., & Simms, J. (2015). *Vocabulary for the New Science Standards*. Bloomington, IN: Marzano Research.
- Novak, J. D. & Cañas, A. J. (2008). The theory underlying concept maps and how to construct and use them. *Technical Report IHMC CmapTools*, 1-36.
- Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal, 28*(1), 117-153.
- Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge building discourse explorer: a social network analysis application for knowledge building discourse. *Educational Technology Research & Development, 60*, 903-921.
- Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97-118). New York: Cambridge University Press.
- Scardamalia, M., & Bereiter, C. (2010). A brief history of knowledge building. *Canadian Journal of Learning and Technology, 36*(1), 1-16.
- Tao, D., & Zhang, J. (2018). Forming shared inquiry structures to support knowledge building in a grade 5 community. *Instructional Science, 46*(4), 563-592.
- van Aalst, J., & Chan, C. K. K. (2007). Student-directed assessment of knowledge building using electronic portfolios in Knowledge Forum. *Journal of the Learning Sciences, 16*, 175-220.
- Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge building communities. *The Journal of the Learning Sciences, 18*(1), 7-44.

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# Mapping Individual to Group Level Collaboration Indicators Using Speech Data

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**Abstract:** Automatic detection of collaboration quality from the students' speech could support teachers in monitoring group dynamics, diagnosing issues, and developing pedagogical intervention plans. To address the challenge of mapping characteristics of individuals' speech to information about the group, we coded behavioral and learning-related indicators of collaboration at the individual level. In this work, we investigate the feasibility of predicting the quality of collaboration among a group of students working together to solve a math problem from human-labelled collaboration indicators. We use a corpus of 6th, 7th, and 8th grade students working in groups of three to solve math problems collaboratively. Researchers labelled both the group-level collaboration quality during each problem and the student-level collaboration indicators. Results using random forests reveal that the individual indicators of collaboration aid in the prediction of group collaboration quality.

## Introduction and theoretical background

Management and assessment of collaborative learning tasks is difficult in typical classrooms when teachers attempt to monitor 10-15 groups with 2-3 students in each group. Teachers need tools to help them identify groups of collaborating students that are doing well and those that need help (and what kind of targeted help they need). Ideally, teachers would listen to peer interactions in each group for long enough to understand how discourse is proceeding. However, teachers cannot listen to more than one group at a time and therefore this in-depth listening, evaluation, and feedback they provide cannot be done at scale, even within a single classroom with more than a few groups (Kaendler et al., 2014). Students talking to one another in face-to-face environments is the natural setting for classroom collaboration, and so speech-based solutions are needed to address this problem. We see speech-based analytics functioning to not replace the teacher's role, but rather to inform the teacher's exploration of group dynamics, diagnosis of issues, and development of intervention plans.

In this work, we investigate the feasibility of using students' speech during collaborative activity to determine group collaboration quality. While speech activity alone is indicative of some basic features of good/productive (or bad/unproductive) collaboration (e.g., one person is doing all of the speaking in a group or one person never talks), some key information is left out that is relevant to assessing collaboration quality. What students are talking about, and the function of that speech, plays a large role in determining collaboration quality. One student could have been talking about their plans for the weekend or just automatically agreeing with everything the other two people said without adding anything new. Productive collaboration requires the participants to directly engage in one another's thinking, which includes listening and responding to the others in the group (Kuhn, 2015). Automatically detecting this type of complex thinking and behavior will likely require more than just speech activity information. Incorporating individual indicators of collaborative actions, based on what individuals are doing to contribute to the group's problem solving, should help assess the overall group collaboration quality. One major challenge is how to effectively map individual contributions along a quickly moving timescale to the overall collaboration of the group at specific time points.

## Methods

### Data collection

Data collection took place in the spring of 2015. 134 middle school students (67 in sixth grade, 35 in seventh grade, and 32 in eighth grade; 68 female, 66 male) from six different schools participated. Students worked on the collaborative activities after school. 80 collaborative sessions were recorded (about 15-20 minutes each). Most students participated in two sessions with different group configurations. Each student had an individual head-mounted microphone and the whole group was video recorded.

Participating students worked together in groups of three on a set of collaborative math activities on iPad stations. The collaborative math activities included 12 items, where each item required the three students to work together and talk to each other to coordinate their three answers to the problem. The tasks are similar to those described by Roschelle and colleagues (2010). These tasks incorporate two important principles for effective collaborative learning tasks: positive interdependence (students must each contribute to the overall task for it to succeed) and individual accountability (students cannot succeed by freeloading) (Roschelle et al., 2010).

## Collaboration coding schemes

All audio recordings made during active work on the mathematics problems were manually annotated by education researchers for (1) indicators of collaboration performed by individual students and (2) the overall collaboration quality of the group for each item. Annotators assigned collaboration indicator codes (or “I-codes”), each with a start and end time, to the individual audio channels. The I-codes are: Monitoring the progress of the group, Verbalizing their thoughts, Reading the problem aloud, Communicating that they are thinking, Making plans to solve a problem, Turn sharing, Ignored speech, Acknowledging another student, Explaining the problem to the group, Expressing lack of understanding, Giving away an answer, Inviting others to contribute, Asking a question, Agreeing with another student, and Disagreeing with another student.

A separate group of researchers annotated the data set for group-level collaboration quality codes (or “Q-codes”). These codes represented the degree to which the three students collectively were engaging in good collaboration. Importantly, they depend not on how much student talked but on whether and how much each student was engaged intellectually in the group problem solving. Annotators assigned collaboration quality codes at the item level which varied in length depending on how long it took to solve the problem.

The Q codes are: *good collaboration* (all three students are working together and intellectually contributing to problem solving), *out in the cold* (two students are working together, but the third is either not contributing or is being ignored), *follow the leader* (one student is taking the intellectual lead on solving the problem and is not bringing others), *not collaborating* (no students are actively contributing to solving the problem (either off-task or independently working)). More information about the coding procedures, the coding schemes, and the descriptive statistics of the Q-codes and I-codes can be found in Richey and colleagues (2016).

## Features

Making predictions about the collaboration quality of a group of students by using individual student speech requires some form of mapping from the information contained in the individual speech signals to information about the group. In previous papers (Basiou et al., 2016; Smith et al., 2016), we explored the mapping of features derived from speech activity detection and acoustic, prosodic, and temporal information extracted from the speech signal. We found that features extracted from speech activity detection (SAD) produced the best classification results. In this paper, we explore a different approach: first coding the speech with behavioral and learning-related indicators of collaboration (I-codes) at the individual level and mapping these I-codes to the group-level Q-codes in different ways.

### Features derived from collaboration indicator codes

We extracted several features to aggregate the I-codes assigned to the individual students’ speech to the group level for each item that the group solved. The first set of features we computed capture information about the frequency of the codes, the co-occurrence of the codes, and the number of students per group with each code.

We hypothesized that the frequency of certain codes would correlate with collaboration quality. Due to sparsity among many of the I-codes, using frequency codes for each student was unfeasible. Thus, looked at group-level frequency along with a count of the number of students with that code. We also hypothesized that the co-occurrence of the I-codes within an item might provide important information. For example, if both *verbalize* and *agree* occur within a item, then we know that at least one student expressed their thought process to the group and at least one student expressed agreement. However, due to I-code sparsity, we found that the combination of the co-occurrence features, the frequency of each I-code, and the count of students who received each code was not enough information for our model to predict collaboration quality above chance.

Upon further inspection of the I-codes, we realized that we needed to account for variation in both the length of the items and the length of the I-codes. Some items were very short (less than a minute) and others were quite long (six or more minutes). Thus, we created a length-normalized version (i.e., codes per minute within the item) of the counts of each I-code.

We also hypothesized that I-code duration may be important for prediction. For example, a student who *verbalizes their thinking* for one second might say: “I think the speed should be five“, while a longer *verbalize* utterance could be: “Since speed is distance divided by time, shouldn’t we be dividing 15 by 3? That would

make 5.” The latter utterance should be weighted differently from the former. We computed the relative duration of each I-code by summing the total duration of each I-code per channel and dividing by the length of the item. We also ordered these item-length-normalized-durations by the students’ talkativeness. This resulted in codes like “the proportion of the item that the least talkative student spent verbalizing.”

### Speech activity features

The data collection setup allowed students to speak freely, resulting in audio recordings with overlapping speech from the three students. To address this issue, we used a speech activity detection (SAD) system based on speech variability (Ghosh, Tsiartas, & Narayanan, 2013) and ran the system independently on each of the three student channels. Using the segmental and durational information resulting from the speech activity segmentation, we extracted SAD-based features that characterized either the individual student speech or the speech patterns of the group. The features capture information about the number, duration and location of the speech regions, similar to those used in studies of dominance in multi-party meetings (e.g., Hung et al., 2011).

Specifically, we extracted features that capture information about the overall speech duration and the “spurts” of speech. Spurts were defined as regions of speech that are at least 50ms long and were uninterrupted by pauses longer than 200ms. As students deal with the cognitive load of simultaneously solving math problems and negotiating with their peers, they frequently interrupt each other or speak in short incomplete phrases.

We extracted these SAD-based features across the channels individually and in combination, taking into consideration speech activity from regions in which: each individual student was the only speaker, each individual student spoke, ignoring speaker overlap, each pair of students spoke simultaneously, all students were silent, or all students spoke simultaneously.

Duration-based features for individual and pairs of students were mapped to the group level using ratios and entropy of the statistics as described in Smith and colleagues (2016). These features capture information about the distribution of speech duration across the members of the group. The spurt-based features capture information about the turn-taking and other features of the speaking style of the group.

## Machine learning experimental setup

### Feature sets

Classification experiments were run on multiple different feature sets. The first was “I-Codes-1”: the initial set of I-code-derived features comprised of the counts of each I-code, co-occurrences of each pair of I-codes, and the number of students with each I-code. Next, we ran experiments on “I-Codes-2”: the set of I-codes that took the length of the item and I-code duration into account. Specifically, the item-length-normalized counts of each I-code, the relative durations of each I-code (ordered by talkativeness), and the ratios of the relative durations. We also tried a feature-level-fusion of the two I-code sets, which we call “I-Codes-1+2”. For comparison, we ran classification using the SAD feature set, comprised of all the duration and spurt based features derived from speech activity detection. We also fused the SAD and I-Codes-1+2 sets at the feature level.

### Classifier

We used random forest models (RF) (Breiman, 2001) to classify the quality of collaboration from our features. The individual decision trees are created by selecting a random sample with replacement of the training set, along with a random sample of the variables and fitting a tree to that subset. This process makes for a collection of weak classifiers that are less susceptible to over-fitting than a single decision tree. In this study, we tuned the number of variables (“n\_var”) used to build each tree using the training split of each fold.

Classification was performed using leave-one-day-out cross validation to ensure that no student(s) were in both the training and the testing sets. This cross validation set up was chosen because, for each day of the data collection, most students were in two different groups. Thus, the only way to ensure that there was no speaker overlap between the training and testing set was to leave out an entire day. This resulted in 21 folds.

We built multiple RF models for each of the training sets in the 21 folds, varying the n\_var parameter and then repeating 10-fold cross-validation three times for each value of n\_var. The accuracy from each model within a fold was used to select the best model for that training set. Then, the corresponding test set was used to calculate classification weighted and unweighted accuracy and F1-scores.

## Findings

Collaboration quality prediction was investigated using I-Codes-1, I-Codes-2, I-Codes-1+2 and SAD features. A baseline system, calculated by always predicting the most frequent class, was the comparison. We also used the SAD features as a baseline, because they were the best performing features in (Smith et al., 2016).



All feature sets derived from collaboration indicators outperform chance and the I-Codes-2 set also outperforms the SAD derived features in UWA. UWA takes into account the accuracy of prediction across classes and is a better measure of performance for this application because teachers will be concerned with accurately predicting all types of collaboration, not just the dominant class, "good collaboration".

In terms of UWA, the I-Codes-1 and I-Codes-2 set achieve a 36.0% and 72.8% relative improvement over Baseline, respectively. The I-Codes-2 set also outperforms the SAD derived features, with a 11.9% relative improvement. The main difference between the two sets is that the former does not take I-code duration or item duration into account. I-code duration information may be especially important in this problem due to variability in the style of the human annotators; the start and end times of the coded utterances were hand selected by the annotators and the pauses in speech may have been treated inconsistently. The I-Codes-2 set also featured item-length-normalization which is crucial due to the variable length of time it took students to complete the items.

Fusing I-Codes-1 and I-Codes-2 ("I-Codes-1+2") did not produce an increase in accuracy. This is potentially due to increasing the dimensionality of the feature set. Moreover, using both I-Codes-1 and I-Codes-2 feature sets may not offer additional information. We also calculated the results of collaboration quality prediction using feature level fusion of the best predictors. The results indicate that fusing the I-codes with the SAD features give a ~5% relative improvement in terms of weighted accuracy, but no improvement in UWA.

## Conclusions and implications

Classification results align with the education literature and indicate that the I-codes are an important speech-based indicator of collaboration. Thus far, we have explored modeling of the I-codes that takes item length and duration into account, but ignores additional dialogue-level information, such as turns, speaker sequence, and I-code sequence. Future work will explore new ways of modeling I-codes to further improve the classification performance.

We plan to evaluate additional transformations and methods to convert the I-codes to meaningful information for collaboration prediction. We also plan to evaluate the effect of reducing the dimensionality of the codes by clustering the I-codes. In addition, we plan to extract new information from the dialogue between the students, such as turn-taking and sequence modeling of the I-codes. Moreover, we plan to explore additional speech features that can describe additional verbal and non-verbal speech behaviors.

## References

- Bassiou, N., Tsiartas, A., Smith, J., Bratt, H., Richey, C., Shriberg, E., D'Angelo, C., & Alozie, N. (2016). Privacy-preserving speech analytics for automatic assessment of student collaboration. *Proceedings of the Speech Prosody Conference 2016*. Boston, MA.
- Breiman, L. (2001). Random forests. *Machine learning*, 45(1), 5–32.
- Ghosh, P. K., Tsiartas, A., & Narayanan, S. (2011). Robust voice activity detection using long-term signal variability. *IEEE Transactions on Audio, Speech, and Language Processing*, 19(3), 600–613.
- Hung, H., Huang, Y., Friedland, G., & Gatica-Perez, D. (2011). Estimating dominance in multi-party meetings using speaker diarization. *IEEE Transactions on Audio, Speech, and Language Processing*, 19(4), 847–860.
- Kaendler, C., Wiedmann, M., Rummel, N., & Spada, H. (2014). Teacher Competencies for the Implementation of Collaborative Learning in the Classroom: a Framework and Research Review. *Educational Psychology Review*, 27, 505–536.
- Kuhn, D. (2015). Thinking together and alone. *Educational Researcher*, 44(1), 46–53.
- Richey, C., D'Angelo, C., Alozie, N., Bratt, H., & Shriberg E. (2016). The SRI Speech-Based Collaborative Learning Corpus. *Proceedings of the Speech Prosody Conference 2016*. Boston, MA.
- Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, B., Nussbaum, M., & Claro, S. (2010). Scaffolding group explanation and feedback with handheld technology: Impact on students' mathematics learning. *Education Tech Research Dev*, 58, 399–419.
- Smith, J., Bratt, H., Richey, C., Bassiou, N., Shriberg, E., Tsiartas, A., D'Angelo, C., & Alozie, N. (2016). Spoken interaction modeling for automatic assessment of collaborative learning. *Proceedings of the Speech Prosody Conference 2016*, pp 277–281. Boston, MA.

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# Advancing Elementary Students' Reading Comprehension Scores Through Knowledge Building

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**Abstract:** This study employs Knowledge Building pedagogy and Knowledge Forum technology to advance reading literacies in a third-grade elementary reading class in Taiwan. We hypothesized that sustained engagement in idea-centered discussions surrounding reading materials would lead to higher levels of reading comprehension (i.e., interpretation, and integration). Using a quasi-experiment design, we collected: (a) students' online Knowledge Building behaviors, (b) group reading discussions, and (c) students' reading comprehension assessment. Our findings reveal that the experimental group (Knowledge Building) outperformed the control group (direct instruction) on the comprehension assessment. Additionally, we found that the Knowledge Building intervention supported the development of students' higher-level reading comprehension.

**Keywords:** Knowledge Building, Knowledge Forum, reading comprehension.

## Introduction

Digital technologies have vastly redefined what it means to be literate in an open information world, offering new opportunities and challenges for students to engage with multimedia representations of information (Coiro et al., 2014; Goldman & Scardamalia, 2013). It is common nowadays for students to navigate search engines, sift through multiple webpages, and participate in online communities in order to exchange ideas and information online (Leu et al., 2004). From an education perspective, the challenge for literacy education is engaging students in sustained collaborative work with their ideas toward enriching learning and understanding (Resta & Laferrière, 2007; Scardamalia & Bereiter, 1991). Since online reading is becoming increasingly more important, this study aims to explore how educators can help elementary students read, comprehend, and interpret reading materials effectively – furthermore, construct meaning, make inferences, integrate and evaluate information in a Knowledge-Building environment.

## Literature Review

Knowledge Building is a principle-based pedagogy (Scardamalia, 2002; Scardamalia & Bereiter, 2010) that aims to enculturate students in idea-centered discussions and sustained idea improvement through the process of co-constructing community knowledge (Hong & Sullivan, 2009; Zhang et al., 2011). Knowledge Forum (KF), was developed to integrate technology and pedagogy to improve students' reading skills in a Knowledge Building community (Bereiter, & Scardamalia, 1991). KF represents a community space for students to engage in high levels of epistemic agency and collective responsibility for developing questions they care about, exchanging conceptual resources with peers, and building on one another's ideas. Knowledge Building unfolds as sustained knowledge advancement in KF (Bereiter, 2002). Previous studies have indicated that elementary school students' reading, writing, and related activities on KF were positively related with vocabulary growth (Chen et al., 2015), reading skills (Zhang, & Sun, 2011), and essay writing performance (Lin et al., 2018).

Building on these studies, the current study aims to address a better understanding of students' reading comprehension within KF. More specifically, we conducted a quasi-experimental study to explore whether students improve their reading skills via Knowledge Building activities in a third-grade reading class. Our three research questions are: (1) How were students involved in online reading activities in KF? (2) How did the discussions on KF unfold? (3) Did the KB group or the comparison group do better on reading comprehension?

## Method

### Research context and participants

The current study took place in an elementary school in Taipei, Taiwan. The sample included 51 third-graders from two classes: 24 students were in the experimental group with a teacher using Knowledge Building pedagogy, and 27 students were in the control group with a teacher using the traditional teaching method. The typical Chinese

literature class in Taiwan is taught in a lecture-based and teacher-centric styled, with students' reading comprehension assessed based on mastery of textbook contents. On the other hand, in the Knowledge Building class, the teacher encouraged students to engage in collaborative reading and writing to sustain idea improvement. To understand students' reading comprehension in both conditions, we compared their comprehensive skills at the end of the intervention.

## Pedagogical design

The current study took place over one semester (14 weeks). Although the two teachers used different teaching methods, they used the same regular reading articles (11 articles/lessons in total in the textbook). Each reading lesson was taught over 6 periods (40 minutes per period).

### The experimental group

The teacher in the experimental group has five years of teaching experiences (including two years of Knowledge Building teaching experiences). The class activities were divided into two parts: face-to-face (i.e., lectures, textbook reading, and class discussion etc.) and online activities (i.e., students' online collaborative reading). The online activities were designed and guided by Knowledge Building principles to collaboratively question and discuss ideas as a reading community. The students participated in the following Knowledge Building activities in KF: (1) summarized their main ideas after reading based on the lesson from textbook; (2) asked questions to one another; (3) further elaborated/clarified their initial ideas and/or integrated various ideas by addressing the questions being asked by others. The teacher encouraged the students to summarize and ask questions based on the texts, as well as integrate their classmates' comments with their initial ideas in order to advance the community knowledge.

### The control group

The teacher in the control group has more than ten years of teaching experiences. In the control class, the reading activities were teacher-led, well-structured procedures. The teacher acted as the sole authoritative knowledge source – she gave lectures for every article and then asked students to individually respond to factual questions based on the texts. Each lesson followed the same script over the 14 weeks.

## Data sources

Data was collected from KF and the pre-post reading comprehension test scores. For research question 1, we collected students' online collaboration, which included the number of notes contributed, read, and built on in KF. For research question 2, we analyzed the content of the discussion according to four different levels (low to high) of comprehension skills: (1) *retrieving explicitly stated information* (2) *making straight forward inferences* (3) *interpreting and integrating ideas and information* and (4) *examining and evaluating contents and textual elements*. For research question 3, we surveyed pre-post reading comprehension tests, which were obtained from PIRLS literacy passages (i.e., 28 multiple choice questions and several open-ended essays). We analyzed these according to the PIRLS scoring guideline to evaluate students' reading comprehension on four levels (same as RQ2). 30% of the open-ended essay questions were randomly selected to calculate the inter-rater reliability (using Spearman's,  $r = .839, p < .01$ ).

## Results

### Students' online reading activities in Knowledge Forum

The result showed that the amount of activities that students were involved in on KF was increased over the 14 weeks. We divided online reading activities into two phases (7 weeks per phase). Our statistical analyses show that the number of notes contributed (first phase:  $M = 12.42, SD = 3.63$ , second phase:  $M = 16.42, SD = 3.91$ ;  $t = -5.35, p < .001$ ), number of notes read (first phase:  $M = 92.63, SD = 46.22$ , second phase:  $M = 161.17, SD = 106.76$ ;  $t = -4.15, p < .001$ ), number of keywords used (first phase:  $M = 9.17, SD = 4.03$ , second phase:  $M = 11.67, SD = 3.74$ ;  $t = -3.49, p < .001$ ) and number of scaffolds used (first phase:  $M = 11.25, SD = 4.33$ , second phase:  $M = 15.75, SD = 4.10$ ;  $t = -5.21, p < .001$ ) significantly increased from the first phase to the second phase. These results indicate that students were more engaged in posting their thoughts online and interacting with others in the later phase of the semester. However, the number of notes built-on, which means the number of replies to peers, was not shown to be significantly different (first phase:  $M = 8.29, SD = 3.46$ , second phase:  $M = 8.50, SD = 2.62$ ;  $t = -0.34, p > .05$ ) between the two phases of the semester.

### Students' reading comprehension in Knowledge Forum

Figure 1 shows a KF view that students extended what they read in the Chinese literacy class — *Hynobius formosanus* (an endangered species in Taiwan). In the beginning, their discussions were focused on understanding characteristics of *hynobius formosanus*; content of these notes were basically retrieved from the textbook and the Internet. Their discussion then shifted toward bigger issues, such as the decline of *hynobius formosanus* in Taiwan and what people can do to conserve them, which indicates that students were integrating and interpreting previous information (i.e., characteristics and living habits etc.) into authentic problems for them. Students were discussing ideas to propose possible solutions to conserve the species in Taiwan. Moreover, Figure 1 shows that students marked their notes with problems and keywords to identify their ideas and information, and in turn, used scaffolds to organize their notes – features specifically designed for enhancing idea-centered discussions in KF.

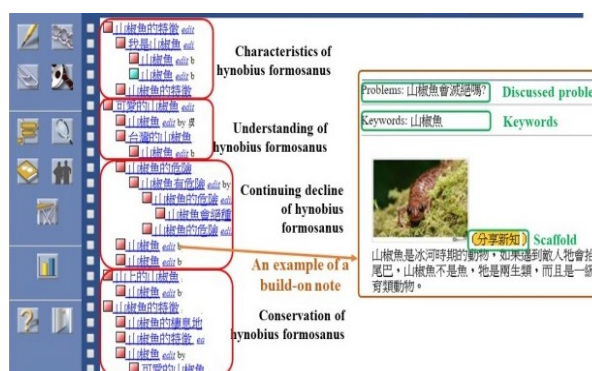


Figure 1. A KF view shows students' discussion the reading topic.

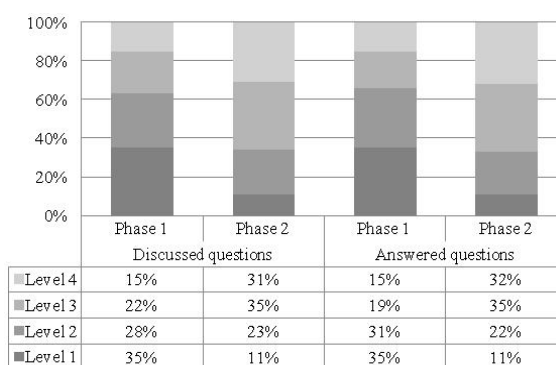


Figure 2. Students' notes related to questions and answered questions in four comprehensive levels on KF.

For our analyses, we divided all Knowledge Forum notes into questions they discussed and answered. We further coded notes' content according to four reading comprehension levels: (1) *retrieving explicitly stated information* (e.g., S15: The *hynobius formosanus* has white spots on the skin.) (2) *making straight forward inferences* (e.g., S1: The *hynobius formosanus* is a threatened species, its kin mucus is toxic that could protect it from danger.) (3) *interpreting and integrating ideas and information* (e.g., S24: The *hynobius formosanus* is a rare species and it lives in the high-altitude habitats. Their habitat is lost and degraded when global warming is increasing so that they cannot live there.) and (4) *examining and evaluating contents and textual elements* (e.g., S18: The *hynobius formosanus* lived since Ice Age, it can only live in high mountains. We should protect their habitats, the most important thing is to prevent global warming from becoming worse. As a result, they will not become endangered.). As shown in Figure 2, we also ran t-tests and showed that questions of level 1 ( $t = 2.07, p < .05$ ) and level 2 ( $t = 2.08, p < .05$ ) decreased significantly in the second phase (i.e., less retrieving explicitly stated information and making straightforward inferences). On the contrary, the questions of level 3 ( $t = -3.28, p < .01$ ) and level 4 ( $t = -2.15, p < .05$ ) positively increased in the second phase (i.e., more interpreting and integrating ideas and information and examining & evaluating content and textual elements). Our statistics revealed that that students' discussion progressed from basic comprehension levels (level 1 and 2) in the first phase to deep comprehension processes (level 3 and 4) in the second phase.

### Comparison of students' reading comprehension

We examined whether our Knowledge Building intervention enhanced students' reading comprehension. Firstly, the pretest showed no differences between the experimental and control groups with respect to students' reading comprehension ( $F = 2.697, p = 0.107$ ). Next, MANOVA indicated that the posttest scores were statistically significant at the .05 level. The experimental group outperformed the control group (experimental versus control:  $M = 26.29, SD = 0.65; M = 23.11, SD = 0.61; F = 11.924, p < .001$ ) on the PIRLS, confirming our hypothesis.

### Discussion and future directions

In this study, we examined Knowledge Building activities and reading comprehension development of third-graders in a Chinese literacy class. First, we examined the experimental group's online collaborative Knowledge Building activities in KF. Notes written, notes read, keywords used, and scaffolds used significantly increased during the semester. Second, we analyzed the experimental group's KF discussion and coded it along 4 levels of comprehension skills. We found that in the earlier phase, students were mainly focused on basic comprehension level (retrieving explicitly stated information and making straight forward inferences), whereas in the later phase,

their discussion turned to deeper comprehension (interpreting and integrating ideas and information and examining and evaluating contents, languages and textual elements). Third, we compared the reading comprehension of students in the experimental and control groups and found that Knowledge Building pedagogy and technology significantly advanced students' reading comprehension scores.

Previous studies on literacy education place an emphasis on explicit teaching strategies to provide effective instruction for students' reading comprehension (e.g., Guthrie et al., 2004). Based on this perspective, the teacher's role is to implement and manage instructional practices while monitoring student understanding. Our study, on the other hand, provides support for teachers adopting a principle-based approach to literacy instruction (i.e., identifying authentic problems, making use of authoritative texts to improve students' ideas, connecting ideas and building community knowledge through collective responsibility). Our findings suggest that when students engage in reading activities with appropriate Knowledge Building pedagogical and technological supports, students benefit in a way that advanced high-level reading comprehension. This is an important implication for embodying students' reading ideas during the Knowledge-Building process in a computer-supported collaborative learning environment. More specifically, our study shows that KF supports are especially helpful for engaging young students in deep and productive discussions surrounding complex ideas. Future work should aim to explore over extended periods of time the evolution of group knowledge processes that facilitate the development of students' higher-level literacy skills during Knowledge Building.

## References

- Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, N.J.: L. Erlbaum Associates.
- Chen, B., Ma, L., Matsuzawa, Y., & Scardamalia, M. (2015). The development of productive vocabulary in knowledge building: A longitudinal study. In *Proceedings of the Computer Supported Collaborative Learning (CSCL) Conference 2015*, Volume 1 (pp. 443-450). Gothenburg, Sweden: The International Society of the Learning Sciences.
- Coiro, J., Knobel, M., Lankshear, C., & Leu, D. J. (Eds.). (2014). *Handbook of research on new literacies*. Routledge.
- Goldman, S. R., & Scardamalia, M. (2013). Managing, understanding, applying, and creating knowledge in the information age: Next-generation challenges and opportunities. *Cognition and Instruction*, 31(2), 255-269.
- Guthrie, J. T., Wigfield, A., Barbosa, P., Perencevich, K. C., Taboada, A., Davis, M. H., ... & Tonks, S. (2004). Increasing reading comprehension and engagement through concept-oriented reading instruction. *Journal of educational psychology*, 96(3), 403-423.
- Hong, H. Y., & Sullivan, F. R. (2009). Towards an idea-centered, principle-based design approach to support learning as knowledge creation. *Educational Technology Research and Development*, 57(5), 613-627.
- Lin, P.-Y., Ma, L., Chang, Y.-H., Hong, H.-Y., & Lin, C. P. (2018). Improving Elementary Students' Literacy through Knowledge Building. In Kay, J. and Luckin, R. (Eds.). *Rethinking Learning in the Digital Age: Making the Learning Sciences Count, 13th International Conference of the Learning Sciences (ICLS) 2018*, Volume 3 (pp. 1527-1528). London, UK: International Society of the Learning Sciences.
- Leu, D. J., Kinzer, C. K., Coiro, J. L., & Cammack, D. W. (2004). Toward a theory of new literacies emerging from the Internet and other information and communication technologies. *Theoretical models and processes of reading*, 5(1), 1570-1613.
- Resta, P., & Laferrière, T. (2007). Technology in support of collaborative learning. *Educational Psychology Review*, 19(1), 65-83.
- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal Education in a Knowledge Society* (pp.67-98). Chicago: Open Court.
- Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *The Journal of the learning sciences*, 1(1), 37-68.
- Scardamalia, M., & Bereiter, C. (2010). A brief history of knowledge building. *Canadian Journal of Learning and Technology/La revue canadienne de l'apprentissage et de la technologie*, 36(1).
- Zhang, J., Hong, H.-Y., Scardamalia, M., Teo, C. L., & Morley, E. A. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *The Journal of the Learning Sciences*, 20(2), 262-307.
- Zhang, J., & Sun, Y. (2011). Reading for idea advancement in a Grade 4 knowledge building community. *Instructional Science*, 39(4), 429-452.

# Using Digital Interrupted Case Studies for Whole Class Inquiry in Life Sciences

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**Abstract:** This short paper describes BioScann, a high school *STEM* inquiry curriculum that uses a CSCL environment to support an interrupted case studies (ICS) method. This technology-enhanced curriculum supports autonomous, sustained student engagement, scientific argumentation, conceptual understanding, and the development of student self-efficacy and career awareness. The BioScann technology platform scaffolds student activities, collects student artifacts, and helps the teacher advance the curriculum through various stages. We discuss how our designs were improved across multiple pilot studies, including two major versions of the curriculum and technology. Each new pilot allowed us to improve the materials and technology environment, as well as student engagement, career awareness, and collaborative data-based decision-making.

## Major issues addressed

Scholars, visionaries, and policymakers have called for education that prepares students to face the complex challenges of an increasingly technology-driven “knowledge society” (OECD, 2016; Pellegrino, & Hilton, 2013). In response to such calls for change, STEM education has generally shifted away from the memorization of facts toward engaging students in authentic science inquiry and scientific argumentation.

Researchers have advanced problem-based learning (PBL) as a pedagogical framework to develop 21<sup>st</sup> century competencies and to increase student understanding of science (Slotta, 2010; Bell, 2010). Our work is concerned with one such approach, called case-based learning (e.g. Riesbeck, & Shank, 1989; Foran, 2001) first developed for students in medical education. In case-based learning, students are engaged within peer groups to deliberate on carefully constructed “cases” (e.g., cases of medical scenarios) that provide opportunities for analytical thinking and application of concepts to real-world scenarios. Case-based learning can also integrate the evaluation of evidence and data-based arguments – skills that are critical for 21st-century health literacy. Our team (Jacque et al., 2015) has advanced a more structured model of case-based learning called interrupted case studies (ICS). By structuring cases into a clear progression, ICS provides “interruption points” that (1) allow teams of students to stay in sync and (2) give teachers an opportunity for planned or spontaneous whole-class discussions.

ICS can be challenging for teachers who must keep track of student progress, monitor their ideas, and ensure that the case itself remains at the center of attention. To support teachers and students, we combined ICS and CSCL methods to build on the advantages of technology-enhanced learning environments (Slotta, 2010) to help track student ideas, scaffold their learning activities, and prompt them for reflection. The ICS method also advances CSCL methods by opening the door for the design of CSCL “scripts” (Dillenbourg & Jermain, 2010) that provide teachers with strategic opportunities to pose questions, review student responses, and to use those responses to address student misconceptions and model answering questions appropriately (Herreid, 2005). In this way, the combination of ICS and CSCL methods has a synergistic effect, allowing for more control over the technology environment and more support for both students and teachers. To support the use of ICS in high school settings, we have developed a technology environment called BioScann that engages students in collaborative STEM inquiry explorations. Students document their thinking and work in BioScann’s collective knowledge base/shared workspace and teachers use the digital records to lead discussions and help students debate issues.

With CSCL environments – even those enhanced by ICS like BioScann – there is a substantial risk that the teacher will spend inordinate time ensuring the technology is functioning smoothly and keeping students “on task”. We are finding that teachers are challenged to coordinate such complex forms of interaction and that the technology environment, while critical (e.g., in providing materials and collecting student responses), is an additional source of complexity and strain on the teacher’s capacity to guide meaningful student inquiry. This paper reports on our efforts to improve the BioScann environment based on early classroom pilots and teacher interviews. At the time of paper submissions, we have completed multiple rounds of pilots and revisions, with a major iteration of the technology to be completed by the time of the conference in June 2019. Sections below

describe the theoretical perspective and specific approach and materials supported by BioScann, as well as our iterative designs of the technology environment, together with findings about teacher orchestration and student experience.

### **Potential significance of the work**

We recognize the fit of our work to this year's conference theme: *A wide lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings*. Preparing students with vital 21<sup>st</sup> century competencies (Scardmalia et al., 2015) will necessitate a wide range of interactions for learning, including collaborative forms of inquiry. To accomplish this, CSCL environments and materials must be able to support complex forms of inquiry that transform the nature of learning and teaching.

To achieve this goal, we produced a suite of innovative technology-enhanced curricula and tools that can be integrated into existing science courses offered in high schools. The robust and flexible web-based platform and ICS authoring toolkit, BioScann.org, enables classrooms to scaffold scientific inquiry in the form of ICS pedagogy. Our objective was to develop a learning environment and curricula capable of engaging underserved high school students' in scientific inquiry, addressing the challenges of a learning community approach, as well as increasing STEM career interest and awareness and retention in science. Such an environment will work best when it supports the teacher in orchestrating the curriculum.

Finally, we have developed and tested innovative professional development approaches for high school teachers to support implementation. At present, we are engaged in a substantive trial with 25 classrooms with over 600 students, with whom we hope to develop knowledge of and interest in bioscience careers.

### **Theoretical and methodological approaches pursued**

From a theoretical perspective, BioScann employs a multi-role ICS approach set within a web-based, interactive environment to integrate conceptual learning with competency building and the development of awareness about STEM careers. The BioScann curriculum was guided by design principles from problem-based learning (PBL) and CSCL. PBL offers a pedagogical perspective that is well suited to students' development of critical 21<sup>st</sup> century competencies, long-term retention of content and improved critical thinking skills (Bell, 2010; Kolodner et al., 2003; Strobel & Van Barneveld, 2009). CSCL complements this view, allowing the design of environments and activities that foster critical scientific inquiry and work-life skills, such as collaborative problem-solving with shared decision-making (Scardmalia & Bereiter, 1994; Means et al., 2015). By combining these perspectives with the ICS approach, BioScann cases reveal new information (data) that is critical for solving the problem facing the class at defined interruption points. In this way, BioScann models the processes of scientific discovery while simulating participation in STEM careers, as students become a workforce team collaborating to solve authentic inquiry-based problems.

BioScann was created using a design-based research (DBR) approach, in which the designed innovation is itself one of the outcomes to be analyzed as a source of findings relating to the research questions (The Design-Based Research Collective, 2003). A co-design model was applied, involving education researchers, biomedical scientist and teachers (e.g., Roschelle & Penuel, 2006). This ensured that teachers have been deeply involved in the design process, that their values of pedagogy and practice are incorporated within the design, and that they emerge from the process with a full sense of ownership and familiarity with all aspects of the innovation. This method has been shown to improve the viability of designs in diverse school settings and ultimately leads to increased adoptability and adaptability (Voogt et al. 2016; Jacque et al., 2013, 2015).

The Bioscann curriculum and technology were designed and developed in parallel by a team that included six high school biology teachers, researchers, content experts, and technologists over a period of two years (Roschelle & Penuel, 2006). They went through multiple cycles of 'design, enactment, analysis, and redesign' (Collins et al., 2004) to assess the quality as well as the effectiveness of both the design and its theoretical underpinnings. This included: (1) initial testing by co-designers in laboratory and classroom settings; (2) refinement of any features, functions or interfaces; (3) testing in settings with a second cohort of classrooms by teachers who are not members of the co-design team; (4) further refinements. In this way, we tried to rigorously address any emerging problems with implementation. From a research perspective, the design-based process also uncovered new areas of research.

### **Materials, findings, and discussion**

The original goal of BioScann was to create a technology platform that could be used independently by students to work through interrupted case studies allowing the teacher to lead extemporaneous interactions. Version One (v1.0) of BioScann.org contained all the content needed to participate, guiding each student team through the activity. BioScann v1.0 was a four-day curriculum that placed students into teams of 3-4 students and each team



in the class worked independently to design a new drug to combat HIV – a scenario that provides real-life context and is highly engaging at the high school level. On Day One, students learned about the HIV life cycle and worked as a team to consider the pros and cons of four drug candidates with the goal of selecting the best one to test. On Day Two each team learned about cell culture and animal models to test their drug for efficacy and toxicity. On Days Three and Four students learned about Phase I-III Clinical Trials for testing efficacy and safety of drugs in humans. Each day of the curriculum required that students understand experimental designs and utilize results in the form of graphs to make decisions that would set the stage for the next step of the ICS. Based on the group decisions, teachers would manually release the next step of the ICS on bioscann.org. Students received career information through infographics.

In our initial pilot testing of BioScann v1.0 with 19 public school students, we documented the need for improving the usability of the technology to a) allow for more student interaction within groups and as a class and b) to simplify teacher facilitation. Students felt the overall BioScann experience was positive, commenting: “It was fun to have a first hand on how being a scientist works.” “If all tech problems are fixed, this program can be used without a problem and people can learn something new.” “Program was great and a lovely experience.” Analyzing observation and interview data, we identified five key challenges to consider in the re-design: One, running the case required more teacher facilitation than expected. Two, using the technology to regulate individual group workflow required more support than expected. Three, students requested additional time for small group and class discussions. They wanted to review and debate each other’s work as a class in addition to within their individual teams. Four, students wanted to do more work off-line using paper rather than the computer. Five, although a pre-post survey indicated that student’s knowledge and awareness of bioscience careers increased (paired t test,  $p = <.001$ ), student feedback indicated that they needed more context to understand and assess the careers.

Version Two (v2.0) allowed more flexibility to a) increase student interaction within groups and as a class and b) to simplify teacher facilitation. Specifically, we developed a new script whereby students are placed into five “expert” groups, each of which is given a distinct role as a member of a drug discovery team with career relevant information and role-specific data to contribute to a team decision. Mirroring how interdisciplinary teams solve complex scientific challenges, students then work in “jigsaw” teams, integrating information (data) from the five career-focused perspectives. To support data-based discourse and class-based decision-making, we added a “results page” to the BioScann platform. Expert group data and discussion posts are shared via the results page and students use their posts to contribute their expert perspective in the jigsaw groups, informing the ICS progression. Throughout this iterative workflow (Figure 1), students practice data interpretation, data-based decision-making, and group communication - critical STEM mastery skills. As well, we created a student workbook to support student accountability. Finally, we developed a teacher power point to help them guide students through the lesson and enable adaptability to support different student populations. This re-design reduced teacher facilitation of asynchronous group work, creating a single point of regulation to release the next step in the ICS in bioscann.org, rather than multiple steps for each group during class. It also brought the whole class together for critical decisions and it further integrates career roles and encourages collaboration between groups. Together, these changes have resulted in a *multi-role ICS authoring tool* (Figure 1).

BioScann responds to the challenges of enacting ICS by: (1) allowing for multidirectional decision making – in which students can choose their own path of inquiry; (2) providing distinct content to each group to encourage classroom discourse; (3) utilizing interactive technologies for group decision-making and reporting to

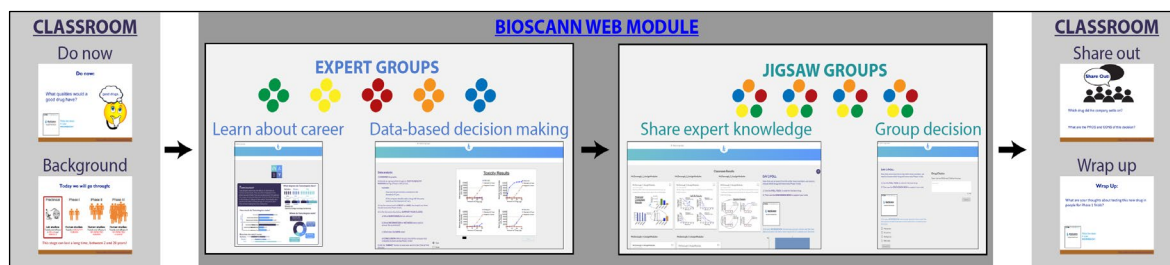


Figure 1. BioScann v2.0 - multi-role ICS approach.

the class; (4) creating a common data and results workspace that supports teacher-led discourse. The platform affords scaffolding that emulates scientific discovery and practices, while providing instructors with opportunities to manage discussions by posing questions, reviewing student responses, and using those responses to address student misconceptions. Preliminary analysis of classroom observations and interviews revealed that BioScann v2.0 is usable and adaptable across a range of classroom settings – from advanced classes in exam schools to



special education classes. However, the use of the results page varies across implementations and the depth of data-driven decision making differs greatly across teachers and students. Preliminary data from pre-post testing indicates that student's data interpretation skills (paired t test,  $p < 0.017$ ) and awareness of bioscience careers increases (paired t test,  $p < 0.0001$ ). That said, we are not yet able to relate aspects of the curriculum, technology or implementation to student-level outcomes.

## Conclusions and implications

The iterative design process has enabled us to refine BioScann into a flexible technology-enhanced curriculum that fosters career awareness and engagement in authentic scientific inquiry as students make collaborative, data-driven decisions using multidisciplinary perspectives. When looking at the impact of the BioScann intervention, we identified several important design implications. The addition of a "results page" was critical to scaffolding discussions and data-based decision-making as it made student artifacts the centerpiece of discourse. The design of a new workflow that moves students from an expert group to a multi-role jigsaw group deepened the quality of the data-informed decision-making. Finally, integrated career-based role playing significantly improved career awareness and interest.

## Relevant scholarly references

- Bell, Stephanie. (2010). Project-Based Learning for the 21st Century: Skills for the Future. The Clearing House. 83. 39-43. 10.1080/00098650903505415.
- Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, 13(1), 15-42.
- Dillenbourg, P., & Jermann, P. (2007). Designing integrative scripts. In *Scripting Computer-Supported Collaborative Learning* (pp. 275-301): Springer US.
- Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5-8.
- Foran, J. (2001). The case method and the interactive classroom. *Thought and Action*, 19(1), 41-50.
- Herreid, C. F. (2005). The interrupted case method. *Journal of College Science Teaching*, 35(2), 4-5.
- Jacque, B., Malanson, K., Bateman, K., Akesson, B., Cail, A., Doss, C., . . . Galego, M. (2013). The Great Diseases Project: a partnership between Tufts Medical School and the Boston public schools. *Academic medicine: Journal of the Association of American Medical Colleges*, 88(5), 620.
- Jacque, B., Koch-Weser, S., Faux, R., & Meiri, K. (2015). Addressing Health Literacy Challenges With a Cutting-Edge Infectious Disease Curriculum for the High School Biology Classroom. *Health Education & Behavior*, 43(1), 43-53.
- Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., . . . & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice. *The Journal of the Learning Sciences*, 12(4), 495-547.
- Means, B., Shear, L., & Roschelle, J. (2015). Using technology and evidence to promote cultures of educational innovation: The example of science and mathematics education. *Menlo Park, CA: SRI International*.
- OECD, D. S. E., Unemployed, N. E. E. T., & Inactive, N. E. E. T. (2016). Society at a Glance 2016.
- Pellegrino, J.W. & Hilton, M.L. (Eds.). (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: The National Academies Press.
- Roschelle, J., & Penuel, W. R. (2006, June). Co-design of innovations with teachers: Definition and dynamics. In *Proceedings of the 7th international conference on Learning sciences* (pp. 606-612). International Society of the Learning Sciences.
- Riesbeck, C. K. & Shank, R.C. (1989). *Inside case-based reasoning*. Psychology Press.
- Scardamalia, M & Bereiter, C. (1994) Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, 3(3), 265-2984.
- Scardamalia, M., & Bereiter, C. (2015). Education in an open informational world. In R. Scott, and S. Kosslyn (Eds.). *Emerging trends in the social and behavioral sciences*. Wiley Online Library.
- Slotta, J. D. (2010). Evolving the classrooms of the future: The interplay of pedagogy, technology and community. In K. Mäkitalo-Siegl, F. Kaplan, J. Zottmann & F. Fischer (Eds.). *Classroom of the Future*. Orchestrating collaborative spaces. (215-242). Rotterdam: Sense.
- Strobel, J. & van Barneveld, A. (2009) When is PBL more Effective? A meta-synthesis of meta-analyses comparing PBL to conventional Classrooms. *Interdisciplinary Journal of Problem-based Learning*, 3(1), 4.

# Longitudinal Analysis and Visualization of Participation in Online Courses Powered by Cohesion Network Analysis

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**Abstract:** Online learning environments are increasingly used by students and instructors. Cohesion Network Analysis (CNA) can be employed by instructors to analyze discourse structure in terms of cohesive links in order to model student participation and interactions in collaborative learning environments. This paper presents an extended longitudinal analysis together with corresponding visualizations of participation generated for an online math course, powered by CNA. Multiple interactive views centered on the evolution of participation and of interactions between students clustered into three layers are generated using the CNA indices provided by the *ReaderBench* framework. Two types of sociograms are used to show the interactions between learners in the two course weeks that exhibited extreme conditions, namely: a) week 6, when a dramatic decrease of participation was identified, and b) week 16, when the highest number of participants and contributions were logged. In addition to the views centered on participants, we introduce a heatmap depicting the evolution of keyword relevance over time, as well as a Chord diagram for visualizing concept maps based on semantic relatedness. Our analytics dashboard can be used by tutors to monitor students throughout the term and to better ascertain the correlation of course material, schedule, and deadlines with the participation of students, as well as their interactions among themselves and with the tutor.

## Introduction

Online courses have become a useful learning platform due to their accessibility in terms of distance and time management. These platforms help students learn through collaboration and interactions with peers. However, tutors are faced with the difficult task of tracking a large audience; thus, automated analyses of students' participation are required. This paper relies on Cohesion Network Analysis (CNA) (Dascalu, McNamara, Trausan-Matu, & Allen, 2018) to automatically assess students' participation. Going beyond Social Network Analysis (SNA) (Scott, 2017) that considers the number of exchanged messages, CNA indices are used to evaluate interactions between participants based on the cohesion graph (e.g., out-degree indices reflect a higher participation, in-degree indices indicate a higher collaboration). CNA considers the content of the discourse and participants' interactions by examining semantic cohesion of the links between student forum posts.

This article is a continuation of the studies conducted by Sirbu et al. (2018). The paper introduces a longitudinal analysis and detailed visualizations of participation useful for gaining a better understanding of how students interact during an online math course. The *ReaderBench* framework (Dascalu, Trausan-Matu, McNamara, & Dessus, 2015) was used to generate multiple CNA indices and to extract keywords, which were afterwards used to generate different views to model trends in student participation using the *d3.js* library, as well as concept maps relying on the semantic relatedness between keywords found in the discussion forums.

## Method

Our corpus was collected from a discrete math course for undergraduate students in a Computer Science Department (Crossley, Barnes, Lynch, & McNamara, 2017). The course combined standard lectures with the support of online tools, which include a standard online question-answer forum. The total number of students on the forum was 250, out of which 169 had at least one contribution. Altogether the students produced more than 2000 posts. The class lasted for 18 weeks (Aug 23, 2013 - Dec 24, 2013).

The *ReaderBench* framework was used to analyze the interactions between participants and to evaluate their contribution by generating multiple CNA indices. Using the method proposed by Nistor, Panaite, Dascalu, and Trausan-Matu (2017), we clustered the members based on CNA indegree and outdegree into three clusters in descending order of the average of their indegree scores defined as central, active, and peripheral scores. A hierarchical clustering algorithm was applied using the Ward Criterion for minimizing variance after the merging

of clusters. Based on the indices provided by the *ReaderBench* framework and the clustering method, we created multiples types of views and graphics to illustrate interactions among participants, trends in their participation over time, as well as the most relevant topics discussed.

A longitudinal analysis based on CNA was performed to visualize different interactions patterns throughout the course. The visualizations from Figure 1 presents the evolution of participation using Line Chart and Trend Chart. Figure 1.a presents the number of participants (orange line) and contributions (green line) throughout the course, where the X axis represents the period, and Y axis the corresponding number of participants or contributions. A large number of participants/contributions can be observed at the beginning of the course (first 2 weeks), followed by a drastic decrease in the 6th week, and an accelerated increase in the final weeks, with a maximum number of participants and contributions in the 16th week. Figure 1.b presents the density of the community network calculated as  $m/(n*(n - 1))$ , where  $m$  is the number of edges between participants, and  $n$  is the number of participants. We also generated a line chart to observe changes in participation over time for specific individuals. Figure 1.c shows the evolution of participation for 10 randomly chosen students. Patterns similar to Figure 1.a are observed, including a decrease at the beginning of the course followed by an increased involvement towards the end (see participant with ID 564600000 marked with yellow). Figure 1.d presents the median weekly participation values for all participants, together with 5th and 95th percentiles in order to depict the course trends.

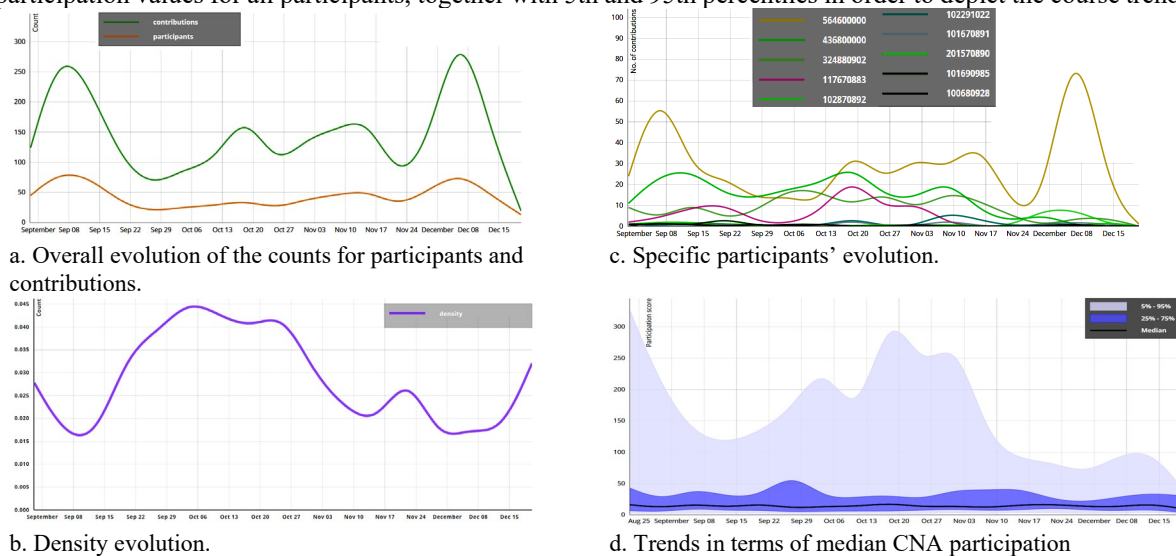


Figure 1. Longitudinal Analysis of participation.

In addition to the previous participant-centered views, we examined which topics were most frequent by using the keywords extraction mechanism from *ReaderBench*. We used a Heatmap visualization presented in Figure 2 to represent the 10 most relevant keywords from each week identified in participants' discussions. Words such as "grade", "exam", and "assign" are used intensively in the last 4 weeks of the course, "homework" is present during the weeks in which homework was due, while "number", "post" and "proof" were used throughout the entire course.

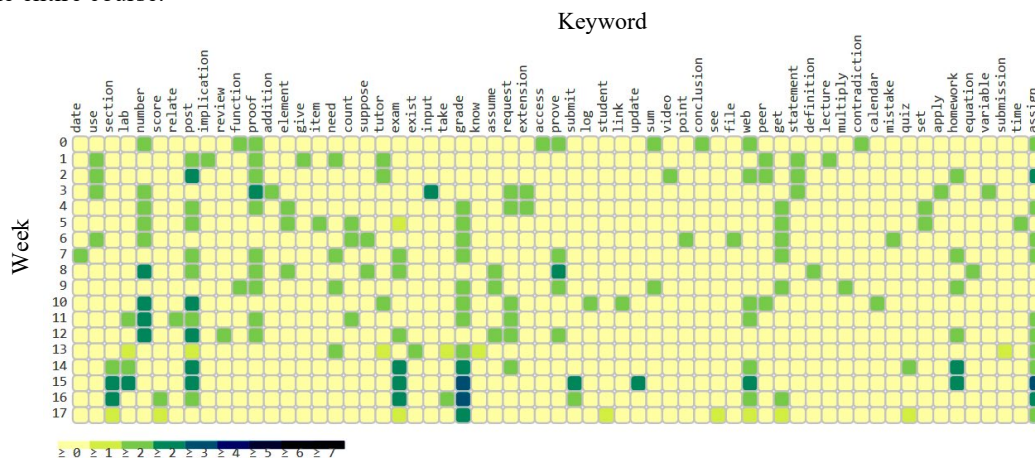


Figure 2. Keywords used by participants.

The semantic similarity between the most relevant 20 keywords is represented using a Chord diagram (see Figure 3) in which the external circle is populated with concepts and edges reflect the similarity between two concepts above an imposed threshold (i.e., edge width is proportional to semantic relatedness between concepts). Three concepts were not included in the diagram (i.e., “lab”, “section”, and “post”) because these concepts were isolated in relation to the other extracted keywords. Figure 3.a presents the similarity between the remaining 17 concepts. Mouseover on the concept *grade* results in Figure 3.b, which isolates the visualization to concepts that are semantically related with *grade* within the discussion board comments.

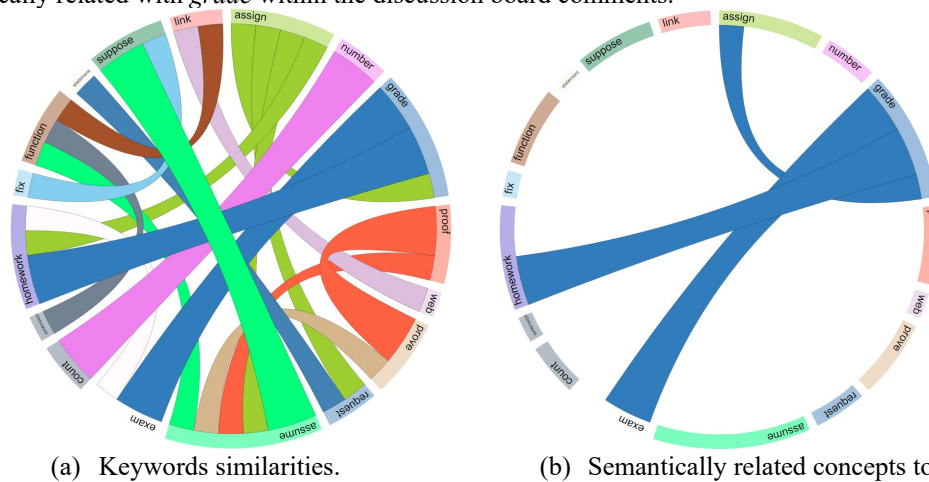


Figure 3. Concept maps relying on the semantic similarity between concepts.

In addition, different sociograms are used to observe the interactions between participants, the participants’ distribution over the three clusters, and the evolution of participation over time. Weekly snapshots are generated to examine how participation in the community evolves from one week to the next. Two types of interactive sociograms are generated to display interaction patterns between participants. First, the Clustered Force Layout presented in Figure 4 shows the position of each participant in the hierarchical structure using circles proportional to their CNA participation scores. The sociograms from Figure 4 reflect the participation of course members in week 6 (when a drastic decrease occurred) and in week 16 (when the highest number of participants and contributions was observed). Dark red nodes represent the central participants, active participants are colored in dark grey, whereas light grey denotes peripheral members.

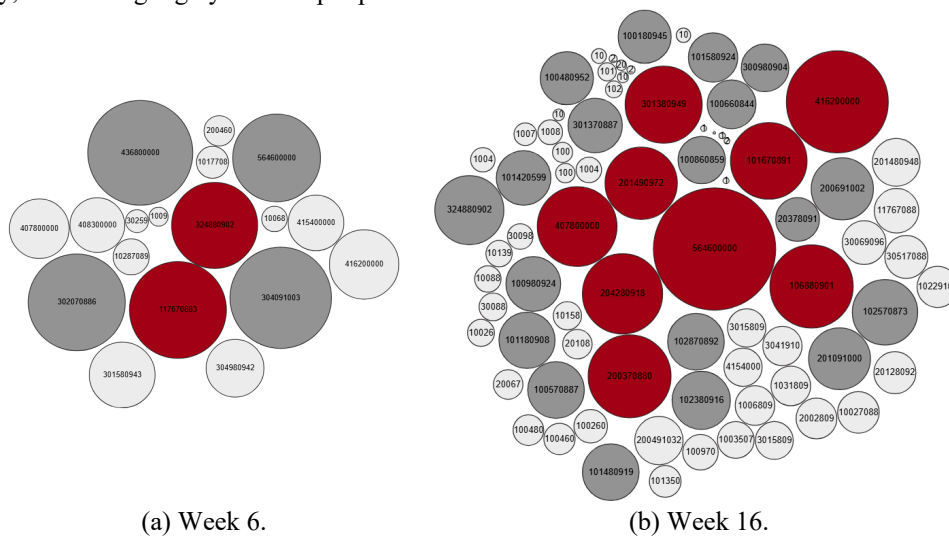
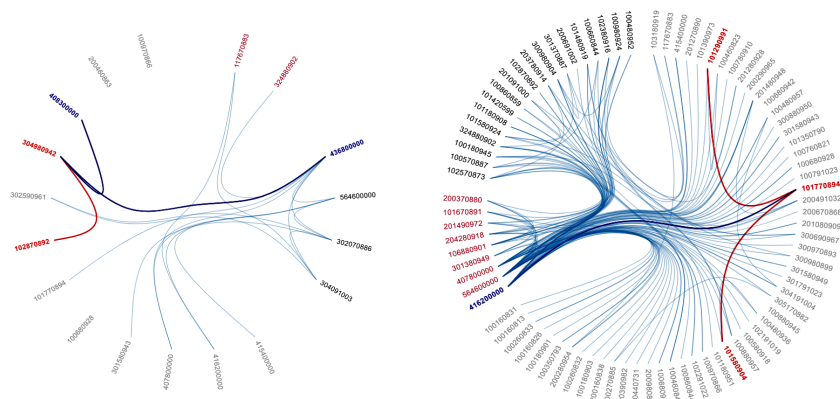


Figure 4. Clustered Force Layout.

Second, the interactions between participants are modeled using Hierarchical Edge Bundling sociograms. Figure 5 presents the dependencies between participants in Weeks 6 (left) and 16 (right) in a radial manner. Similar to the previous type of sociograms, the participants are grouped into their corresponding cluster, whereas the dependencies are grouped into spline bundles. The incoming and outgoing links are displayed on mouseover as follows: incoming links are colored in dark blue, whereas outgoing links are marked in red.



(a) Week 6. (b) Week 16.

Figure 5. Hierarchical Edge Building.

## Discussions

This paper introduces a longitudinal analysis and new visualizations based on CNA for an online math course generated with the *ReaderBench* framework. The evolution of participation is depicted using Clustered Force Layouts and Hierarchical Edge Building models, while the most frequently used keywords and their semantic similarity are visualized using heatmaps and Chord diagrams.

The provided visualizations facilitate the understanding of course dynamics over time and can be used to derive specific characteristics, namely that: a) peripheral members tend to dominate the interactions – most students had singular inquiries and responses, without being engaged in multiple discussion threads; b) the degree of participation grows from peripheral members to active and central ones; and c) the course is not dominated by a single participant. Our tools are designed to ensure an in-depth longitudinal analysis of course participation based on discourse and text cohesion, while focusing on interaction patterns, clustering of students based on their participation, and monitoring course trends.

As follow-up directions, we plan to integrate the learning analytics tools within the README platform (Botarleanu et al., 2018) in order to facilitate interactions, monitor students, and to automatically identify changes in the community structure (e.g., participants who exceed the peripheral layer and gain a more central role).

## References

- Botarleanu, R.-M., Dascalu, M., Sirbu, M.-D., Crossley, S. A., & Trausan-Matu, S. (2018). README – Generating Personalized Feedback for Essay Writing using the ReaderBench Framework. In *3rd Int. Conf. on Smart Learning Ecosystems and Regional Development* (pp. 133–145). Aalborg, Denmark: Springer.
- Crossley, Scott, Barnes, Tiffany, Lynch, Collin, & McNamara, Danielle S. (2017). Linking Language to Math Success in an On-Line Course.
- Dascalu, M., McNamara, D. S., Trausan-Matu, S., & Allen, L.K. (2018). Cohesion Network Analysis of CSCL Participation. *Behavior Research Methods*, 50(2), 604–619. doi: 10.3758/s13428-017-0888-4
- Dascalu, M., Trausan-Matu, S., McNamara, D.S., & Dessus, P. (2015). ReaderBench – Automated Evaluation of Collaboration based on Cohesion and Dialogism. *International Journal of Computer-Supported Collaborative Learning*, 10(4), 395–423.
- Nistor, N., Panaite, M., Dascalu, M., & Trausan-Matu, S. (2017). Identifying Socio-cognitive Structures in Online Knowledge Communities (OKCs) using Cohesion Network Analysis. In *9th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing*. Timisoara, Romania: IEEE.
- Scott, John. (2017). *Social network analysis*. London, UK: Sage.
- Sirbu, M.-D., Dascalu, M., Crossley, S. A., McNamara, D. S., Barnes, T., Lynch, C. F., & Trausan-Matu, S. (2018). Exploring Online Course Sociograms using Cohesion Network Analysis. In *19th Int. Conf. on Artificial Intelligence in Education (AIED 2018), Part II* (pp. 337–342). London, UK: Springer.

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# The Effects of Online Peer Feedback Supported by Argumentation Instruction With Worked Example and Argumentative Scripts on Students' Learning Outcomes

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**Abstract:** This study investigates the effects of online peer feedback supported by argumentation instruction with worked example and Argumentative scripts on students' argumentative essay writing, argumentative feedback quality and domain-specific knowledge acquisition in the field of educational sciences. Participants were 52 students who were randomly divided over 26 dyads and randomly assigned to three conditions (unscripted peer feedback, Instruction with worked example, scripted peer feedback). To do so, an online peer feedback system was designed and developed. They were then asked to write an argumentative essay (individually), to engage in argumentative peer feedback with their learning partner (collaboratively), and finally to revise their essays based on feedback which received (individually). The findings indicate that the online peer feedback supported by argumentative scripts outperformed other two conditions in terms of argumentative essay writing, argumentative feedback quality and students' learning. Implications, limitations and suggestions for future research are discussed.

## Introduction

Online peer feedback is one of the promising educational strategies to improve student's learning outcomes. For example, researchers have shown that peer feedback can improve students' writing quality (Huisman et al., 2018; Gielen & De Wever, 2012, 2015; Noroozi & Hatami, 2018; Noroozi et al., 2016; Valero Haro et al., 2018), students' feedback quality (Gielen & De Wever, 2015; Noroozi et al., 2016), domain-specific knowledge gain (Noroozi & Mulder, 2017; Valero Haro et al., 2018), and students' attitudes toward the subject at hand (Noroozi & Mulder, 2017). Although, these studies have confirmed the effectiveness of online peer feedback, there are some main criticisms on the way in which the peer feedback is implemented. For example, there are concerns about the quality of peer feedback because of students' limited knowledge, experience and language ability (Saito & Fujita, 2004). Also, there are emotional and psychological issues with giving and receiving critical feedback (Andriessen, 2006), such as perceiving critiques and counterarguments as personal attacks (Rourke & Kanuka, 2007). Therefore, peer feedback should be supported in the online environments to fully guarantee its effectiveness (Noroozi et al., 2016). Different instructional approaches have been proposed to support online peer feedback. These approaches include sentence starters, open text-boxes, assigning and rotating roles, peer interactions, input text fields and question prompts including procedural, elaboration and reflection prompts (Noroozi et al., 2012). All of these approaches fall under the name "scripting". Although, studies have shown the effectiveness of scripting approaches on improving students' academic writing, some researchers point out that this approach can be challenging. For example, overly detailed scripts or "over-scripting" can impose cognitive load (Dillenbourg, 2002) and impede learning (see Noroozi et al., 2013). To cope with this challenge, researchers have proposed to use instructional strategies to reduce cognitive load such as instruction with worked example (see Clark & Mayer, 2016). Valero Haro et al. (2018) showed the effectiveness of worked example on improving students' argumentative essay writing quality. This study therefore compares the impacts of online peer feedback supported by argumentation instruction with worked examples and argumentative scripts on students' learning outcomes such as students' argumentative essay writing, argumentative feedback quality and domain-specific knowledge acquisition in the field of educational sciences. This overall research focus was divided into three research questions:

1. What are the effects of an online peer feedback supported by argumentation instruction with worked example and argumentative scripts on students' argumentative essays quality?
2. What are the effects of an online peer feedback supported by argumentation instruction with worked example and argumentative scripts on students' argumentative feedback quality?
3. What are the effects of an online peer feedback supported by argumentation instruction with worked example and argumentative scripts on students' domain-specific knowledge acquisition?



## Methods

The study took place at Kharazmi University, Tehran, Iran. The participants were 52 BSc students who enrolled for the course “Applying Computer in Educational Sciences”, and were randomly divided over 26 dyads and were assigned to unscripted (9 dyads), instruction with worked example (9 dyads) and scripted (8 dyads) conditions. Students in the unscripted condition were regarded as a control group without any support during the online peer feedback. Students in the instruction with worked condition received instruction on “how to provide an argumentative peer feedback”. Then, they were provided with a worked example. Students in the scripted condition were supported by argumentative scripts in the form of a question prompts during their online peer feedback. The mean age of the students were 20.21 (SD = 1.51) years. All participants were female. The topic for discussion was Mobile Learning. Students were asked to write an argumentative essay on the following statement: “The use of mobile phones and tablets in the classroom should be banned”. They were provided with the description of the case, summary of the theoretical text regarding the topic and sets of links to article and webpages. They were provided with some additional links to websites to further study the concept of the “M-Learning”. The students were asked to take into account the various perspectives on the use – or lack thereof – of using “Mobile Learning (such as, Tablets and Smartphones) in classroom”. Then, the students engaged in argumentative peer feedback, and finally they revised their essays based on feedback which received. A self-made online learning environment (EduTech) was designed and used in this study. This online learning environment had a series of steps (see Figure 1).

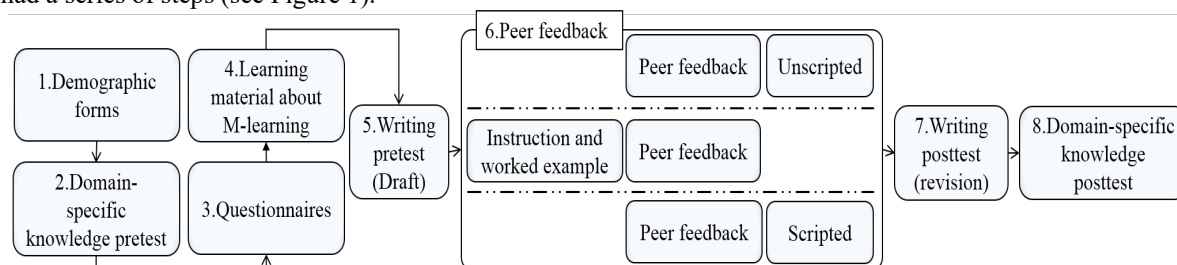


Figure 1. The steps that students should take in EduTech

All these steps had to be completed individually except for the peer feedback step (all steps were completed by student in double anonymous format). EduTech not only helped with regard to managing and monitoring students’ learning activities, but also it provided us with data gathering. EduTech provided students with various forms of information presentation, such as texts, exercises, graphs, diagrams, and pictures with the feedback features to stimulate interactions between members of a group in an active learning environment by getting them thinking together about topics, media or material that is relevant to them. The feedback features in EduTech (for scripted condition) was designed in such a way as to guide the interaction style for both synchronous and asynchronous interactions – promoting reasoning, critical discussion, and justified arguments. The structure of the guided peer feedback (i.e., argumentative peer feedback scripts) was designed on the basis of argumentation literature (Toulmin, 1958; Andrews, 2010; Noroozi et al., 2016; Wingate, 2012; Schmeer, 2014) and a high-quality argumentative essay in the field of Educational Sciences; because, various disciplines have different features of structure, discipline’s value, epistemology, and argumentation (Andrews, 2010; Wingate, 2012). Therefore, specific requirements of the essay and presentation of the arguments in the essays should be taught to students in a given discipline by disciplinary experts (Wingate, 2012). To do so, a series of meetings were held with the experts of the field (three professors in the field of Educational Sciences and first author of this article) to define the elements of a high-quality argumentative essay for students in the field of Educational Sciences. These meetings resulted in a list of items that should be included in argumentative essays of students. The panel of experts concluded that a high-quality argumentative essay in the field of Educational Sciences should include: the expression of a clear position on the topic at hand, expressing the context of topic (introduction), the arguments and evidences (examples, facts, Expert opinion etc.) for and against the topic, integration of various pros and cons, and the final conclusion on the first position. We then designed our argumentative peer feedback script as well as Instruction with worked example on the basis of these items and embedded them in EduTech.

Overall, implementation of the study took about 5:30 hours and consisted of five main phases (each phase in one session in five consecutive weeks). 1) During the introduction and pretest phase, students received introductory textual and verbal explanations in the online learning environment and completed several questionnaires on demographic variables, and their domain-specific knowledge (about 30 minutes). 2) In the study and draft phase, students were asked to read theoretical text and articles on the topic at hand (M-learning), to search the Internet based on keywords that were bolded in the theoretical text (40 minutes), and to write an

argumentative essay on the following statement: "The use of mobile phones and tablets (Mobile Devices) in the classroom should be banned" (80 minutes). 3) In the peer feedback phase, each student were asked to read the draft argumentative essay of her learning partner and provide feedback on them (50 minutes). 4) During the revision phase, students were asked to read the comments of their learning partners and then revise their draft argumentative essay (60 minutes). 5) Finally, in the posttest phase, students were asked to fill out several questionnaires to assess their domain-specific knowledge on the topic at hand (15 minutes).

## Measurements

The quality of student's written argumentative essays (in the draft and the revision phases), was measured using the coding scheme developed by the authors. The scheme considers the features of a high-quality argumentative essay in the field of Educational Sciences and was developed in conformity with the literature (Toulmin, 1958; Andrews, 2010; Noroozi et al., 2016; Wingate, 2012; Schneer, 2014). The scheme included eight components. A single score was assigned for each of these component. Each student was given no point for each level 1 assessment (e.g. not mentioned), one point for each level 2 assessment (e.g. non-elaborated), and two points for each level 3 assessment (e.g. elaborated). Thus, for each component, students could get a score of between zero and two. Subsequently, all points assigned to each student were added together and served as the final score for students' written argumentative essay quality. Two trained coders coded 10% of the data to evaluate reliability index of inter-rater agreement. This resulted in identical scores in 80% of draft and 82% of the revision phases. The same coding scheme was adjusted to assess the quality of students' feedback quality. Two trained coders coded 10% of the data resulted in identical scores in 83% of the data. The pre- and post-test questionnaire, which was completed by students before draft phase and after revision phase consisted out of 10 multiple-choice questions to measure students' domain-specific knowledge. For these questionnaire, students needed to choose one answer out of four options. Each correct answer was given one point and as a result each student could receive 10 points at maximum for both pre- and post-test.

## Findings and discussions

Repeated measures ANOVA test showed that the written argumentative essays quality of students in all conditions improved significantly from the draft phase to the revision phase,  $F(1, 49) = 70.28, p < .001, \eta^2 = .58$ . Also, there was a significant difference between the conditions in terms of argumentative essay quality,  $F(1, 49) = 40.82, p < .001, \eta^2 = .62$ . The post hoc Tukey HSD test showed that the mean score for the scripted condition was significantly higher than unscripted condition,  $p < .001$ . In addition, this test showed that the mean score for the instruction with worked example condition was significantly higher than unscripted condition,  $p < .001$ . Also, students in the scripted condition scored higher than students in the instruction with worked example condition in terms of argumentative essays quality,  $p < .001$ . This is in line with previous studies that emphasize the positive effects of scripts on quality of students' written argumentative essays (Huisman et al., 2018; Gielen & De Wever, 2012, 2015; Noroozi et al., 2016). Giving and receiving a high-quality feedback allow students to consider these features during the revision phase. Students in the scripted condition outperformed students in the Instruction with worked example condition in terms of argumentative essay quality. The reason may be that, although students in Instruction with worked example learned how to write argumentative essay, they were not prompted in the feedback phase to provide a high-quality feedback. This matter should be considered in future research on the use of scripts; i.e. when scripts and Instruction with worked example are used in combination.

One-way ANOVA showed a significant difference between various conditions in terms of argumentative feedback quality,  $F = 31.77, p < .001$ . The post hoc Tukey HSD test revealed that the mean score for the scripted condition was significantly higher than unscripted condition,  $p < .001$ . In addition, the mean score for the instruction with worked example condition was significantly higher than unscripted condition,  $p < .001$ . Also, students in the scripted condition scored higher than students in the instruction with worked example condition in terms of argumentative feedback quality,  $p < .001$ . This is in line with previous studies that emphasize the positive effects of scripts on quality of students' argumentative feedback (Gielen & De Wever, 2015; Noroozi et al., 2016). Peer feedback scripts provided students with criteria that help them to assess partners' essays clearly. Therefore, using these scripts, students assess their peers' essays based on predesigned criteria, not on their personal perspective. Also, EduTech was designed in such a way that the assessee and assessor were double anonymous. Bostock (2000) proposed two ways for increasing the validity and reliability of peer feedback: the use of clear criteria for assessment, and double anonymity of assessors and assessees.

Repeated measures ANOVA test showed that the domain-specific knowledge of students in all conditions improved significantly from the pretest to the posttest,  $F(1, 49) = 87.70, p < .001, \eta^2 = .64$ . Also, there was a significant difference between the conditions in terms of the domain-specific knowledge,  $F(1, 49) = 4.43, p < .001, \eta^2 = .15$ . The post hoc Tukey HSD test revealed that the mean score for the scripted condition was



significantly higher than unscripted condition,  $p < .001$ . In addition, the mean score for the instruction with worked example condition was significantly higher than unscripted condition. However, there was no significant difference between the scripted and the instruction with worked example condition,  $p < .62$ . This is in line with previous studies that emphasize the positive effects of scripts on quality of students' domain-specific knowledge (Noroozi & Mulder, 2017; Valero Haro et al., 2018). The peer feedback scripts in this study allow students to engage in higher cognitive processing (such as, argumentation, evaluation, criticism, justification, clarification, elaboration and analysing); as a result, students process learning material in deep manner.

## Conclusions and implications

This study investigated the effects of online peer feedback supported by argumentation instruction with worked examples and argumentative scripts on students' learning outcomes such as students' argumentative essay writing, argumentative feedback quality and domain-specific knowledge acquisition in the field of educational sciences. The online learning environment designed for this study led students to improve their domain specific knowledge about the subject at hand. Also, peer feedback script allowed students to elaborate learning material included in EduTech and process them in a higher level. The peer feedback script provided students with high-quality feedback on partners' essays by clarifying criteria of assessment and features of a high-quality feedback. Students in the instruction with worked example condition outperformed students in the unscripted condition in terms of quality of feedback and argumentative essay writing. However, they were not as successful as the scripted condition. Therefore, this matter should be considered in future research on the use of scripts; i.e. when scripts and instruction with worked example are used together in combination.

## References

- Andrews, R. (2010). *Argumentation in higher education. Improving practice through theory and research*. New York, London: Routledge.
- Andriessen, J. (2006). Arguing to learn. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 443–460). New York: Cambridge University Press.
- Bostock, S. (2000). Student peer assessment. *Learning Technology*, 5.
- Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*. John Wiley & Sons.
- Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design.
- Gielen, M., & De Wever, B. (2012). Peer assessment in a wiki: Product improvement, students' learning and perception regarding peer feedback. *Procedia-Social and Behavioral Sciences*, 69, 585-594.
- Gielen, M., & De Wever, B. (2015). Scripting the role of assessor and assessee in peer assessment in a wiki environment: Impact on peer feedback quality and product improvement. *Computers & Education*, 88, 370-386.
- Huisman, B., Saab, N., van Driel, J., & van den Broek, P. (2018). Peer feedback on academic writing: undergraduate students' peer feedback role, peer feedback perceptions and essay performance. *Assessment & Evaluation in Higher Education*, 1-14.
- Noroozi, O., & Hatami, J. (2018). The effects of online peer feedback and epistemic beliefs on students' argumentation-based learning. *Innovations in Education and Teaching International*, 1-10.
- Noroozi, O., & Mulder, M. (2017). Design and evaluation of a digital module with guided peer feedback for student learning biotechnology and molecular life sciences, attitudinal change, and satisfaction. *Biochemistry and Molecular Biology Education*, 45(1), 31-39.
- Noroozi, O., Biemans, H., & Mulder, M. (2016). Relations between scripted online peer feedback processes and quality of written argumentative essay. *The Internet and Higher Education*, 31, 20-31.
- Rourke, L., & Kanuka, H. (2007). Barriers to online critical discourse. *International Journal of Computer-Supported Collaborative Learning*, 2(1), 105–126.
- Saito, H., & Fujita, T. (2004). Characteristics and user acceptance of peer rating in EFL writing classrooms. *Language Teaching Research*, 8(1), 31–54.
- Schneer, D. (2014). Rethinking the argumentative essay. *TESOL Journal*, 5(4), 619-653.
- Toulmin, S. (1958). *The uses of argument*. Cambridge: Cambridge University Press.
- Valero Haro, A., Noroozi, O., Biemans, H. J., & Mulder, M. (2018). The effects of an online learning environment with worked examples and peer feedback on students' argumentative essay writing and domain-specific knowledge acquisition in the field of biotechnology. *Journal of Biological Education*, 1-9.
- Wingate, U. (2012). 'Argument!' helping students understand what essay writing is about. *Journal of English for Academic Purposes*, 11(2), 145-154.

# Embedding Microblogging Technology to Support Classroom Dialogue

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**Abstract:** It's crucial for teachers to support the development of students' dialogic skills. Such skills refer to the students' use of language as a tool to enable understanding of each other's knowledge, which creates the possibility of constructing new knowledge together. Digital technology in classroom activities can support this form of dialogue, but it must be embedded into a classroom's complex ecosystem to be beneficial. This paper explores how a group of seventh grade students were taught dialogic skills through the integration of microblogging in the classroom. The data analysed consists of video from the classroom, and the study is grounded in sociocultural theory. Findings suggest that integrating microblogging in classroom activities increased participation and made students' contributions more visible, thus creating the opportunity for students to build on each other's knowledge. However, this is dependent on the teachers' facilitation of the activities.

## Introduction

This paper reports on a study of embedding new technology into classrooms to support and develop students' dialogic skills during group discussions and whole-class discussions. Dialogic skills refer to the specific use of language as a tool to enable understanding of one another's knowledge and perspectives. It is a way of reasoning that creates understanding based on one's perceptions while allowing other ideas and opinions to adapt or integrate into one's own thinking. Participants in this type of dialogue learn to think together and construct new knowledge and ideas as a collective (Mercer, 2002). Students' dialogic skills can be an important predictor of academic achievement (Applebee, Langer, Nystrand, & Gamoran, 2003; Howe & Abedin, 2013). Thus, we argue that it is valuable that teachers can support the development of students' dialogic skills. The use of digital technology in classroom activities may enhance new forms of dialogue (Rasmussen & Ludvigsen, 2010). Within the Computer Supported Collaborative Learning (CSCL) community, research has shown that it is not technology itself that increases quality in classroom discussions; technologies need to be integrated into the teacher's practices and task design (Dillenbourg, Järvelä, & Fisher, 2009). Research has also shown the importance of establishing norms and ground rules that are defined and regulated in the context of the classroom to productively handle the presence of technologies (Rasmussen, Lund, & Smørdal, 2012). To date there is little in-depth research on the use of hybrid technologies to support classroom dialogue. Hybrid technologies here refer to technologies that are designed to support synchronous, collocated interaction, such as microblogging tools. Despite the fact that few studies have examined this type of technology in a classroom context, some findings indicate that the format of microblogs may enhance engagement and increase participation (Gao, Luo, & Zhang, 2012; Luo & Gao, 2012) and that using tools like Twitter in classroom discussions can support collaborative learning, encourage reflective thinking and help initiate conversations, (Gao et al., 2012). In addition, it can be used to explore and bring new information into conversations (Thoms, 2012).

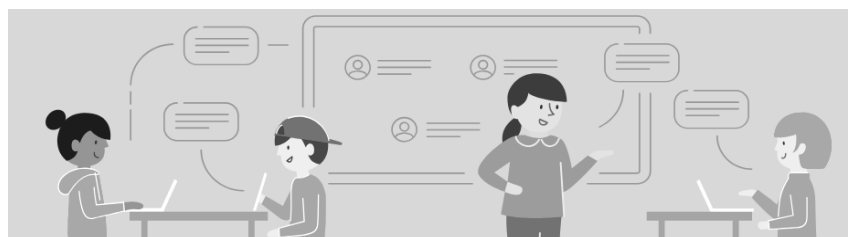
In this paper, we investigate how students in a Norwegian seventh-grade classroom were taught dialogic skills during a Norwegian language and literature class with the use of a microblogging tool called Talkwall. The data consists of videotaped student-teacher and student-student interactions from a primary school class that took part in a design-based research (DBR) project called Digital Dialogues Across the Curriculum (DiDiAC) where 21 teachers and their students from Norway and the UK took part. The study is grounded in a sociocultural approach to learning, and here dialogue is understood as a specific use of language to help people *Interthink* in order to understand each other's knowledge and perspectives (Mercer, 2002). To guide the analysis, we asked; *In what ways can the microblogging tool Talkwall facilitate the teaching of dialogic skills?*

## Research context

In the DiDiAC project, the participating teachers were encouraged to use the material from the *Thinking Together approach* (Mercer, 2002) and to experiment with Talkwall as a means to support the development of dialogic skills. Talkwall (see Figure 1) is a microblogging tool specifically designed to promote and support student participation in classroom dialogues. Talkwall draws on the microblogging approach of using only short messages to communicate, using this to encourage students to engage in learning and share their developing

ideas, in turn, promoting productive classroom dialogues. Short texts/messages can be produced either collectively or individually and are shared on digital devices. These texts can be sorted using hashtags (#) to make it easier for students to follow specific topics or selected concepts.

The participants presented in this paper were one teacher and a class of 25 primary school students (N = 25), aged 11–12 years. In the beginning of the project, this class and their teacher created and agreed to a set of ground rules for talk as part of the project intervention. The ground rules are examples of suggested strategies used as scaffolds to promote dialogic skills (Rojas-Drummond et al., 2003). The class focussed on two or three rules at a time. In the example presented here, they focussed specifically on *being a good listener* and *building on each other's ideas*. The ground rules were applied to the different subjects. The presented data in this paper is from one lesson in the subject Norwegian language and literature lesson.



**Figure 1.** The use of Talkwall in classroom interaction. Students can write on individual or shared devices. Their contributions appear on the whiteboard.

## Methods and data analysis

The data analysed is part of the material from the DiDiAC project. In this paper we have chosen to focus on one specific episode of whole class discussion to illustrate some of the main findings from the qualitative analysis of the whole material. All the data collected in the research project was coded on a minute by minute level for an overview of the whole corpus. This allowed us to see the data set selected for this paper in relation to the larger corpus. The data set selected consists of three research lessons recorded over a six months period in a primary school in Oslo (seven hours of video: three and a half hours each from a camera focussing on group discussions and a camera focussing on the teacher and teacher-student interactions). In order to explore key features concerning the interactional work performed to teach and develop students' dialogic skills, excerpts of teacher-student interactions were selected for detailed analysis using techniques from a microanalytical approach (Derry et al., 2010). The interaction analysis applied involved a sequential analysis of the interactions between the participants. Each utterance in the selected excerpt was analysed in relation to the previous utterance, and the focus was not on a single utterance but on how meaning was created within the discourse (Jordan & Henderson, 1995).

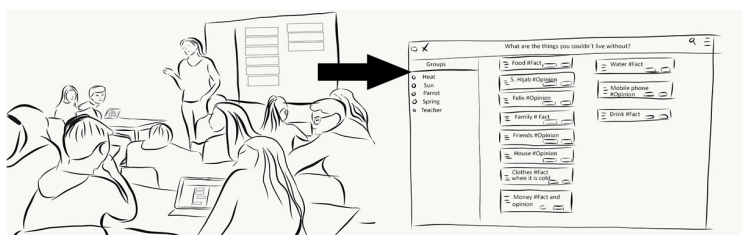
## Findings

As mentioned, the episode presented was selected because it illustrates some of the main findings. These findings indicate that embedding Talkwall in the classroom with the support of the *Thinking Together* material can: 1) provide insight into the knowledge of peers, 2) act as a starting point for the teacher to initiate whole-class discussions based on the students' contributions, and 3) engage the students in whole-class discussions by extending the voices of the individuals from a small group conversation.

The excerpt chosen (see Figure 3) shows some characteristics of how Talkwall can be embedded in both group and whole-class discussions. In the lesson analysed, the students were engaged in a larger learning activity about different literature genres. The genre in focus was self-biography, and the task was to discuss the theme 'what you cannot live without' as preparation for writing their own self-biographies. To prepare for this discussion, students individually wrote five things that they cannot live without on a Talkwall created by the teacher. In the classroom, the teacher divided the class into groups of three to discuss their opinions about this theme and then to hashtag the different contributions of their peers with *#opinion* or *#fact* using an iPad. Each group had to engage in discussion before assigning the hashtags. The discussion was strictly directed by the teacher and by the ground rules the class previously agreed on. The teacher reminded the students several times that they were *expected* to contribute to the discussion and that they were not allowed to decide the hashtags before everyone in the group had the opportunity to state their opinions. They were also expected to give reasons for their opinions. These expectations were among the ground rules the class had developed. In addition to following the expected ground rules, the teacher focussed specifically on helping the students follow the ground rules; *being a good listener* and *building on each other's ideas* in this lesson.

During the group discussions, the teacher walked around the in classroom listening to all the groups'

discussions. In addition, the teacher used her own computer to read the appearing contributions from the groups on Talkwall, both via the feed and also via the *participants walls* (see Figure 2). When all the groups had hashtagged the Talkwall contributions, the teacher started a class-wide discussion concerning one group's Talkwall (see Figure 3).



**Figure 2.** Talkwall on both the groups' iPads and on the whiteboard. Group contributions on Talkwall with #fact or #opinion.

The teacher displayed the group's Talkwall contributions on the whiteboard (see Figure 2) and encouraged the students in the selected group to share their discussion with the class. The teacher asked the group to elaborate on why they chose the hashtags and what they discussed the most. One group member, Lina, said that clothes were the biggest subject of discussion in their group. She then offered the group's reasoning, saying that clothes could be an opinion because people can survive without them, but they could also be a fact because humans need to protect their bodies. Lina concluded that it depends on where one is in the world (see Figure 3, lines 2–7). On their Talkwall, Lina and her group wrote that clothes are a #fact when it is cold (see Figure 2).

- 1 Teacher: Clothes. Yes, Yes. Tell us about this.  
 2 Lina: Because, if no one in the world had clothes then it  
 3 would not be like it would be strange.  
 4 But you would survive without clothes. But we could say that it  
 5 is a fact because clothes are something that we use to  
 6 protect the body. So, it depends a bit on where you live  
 7 in the world.  
 8 Teacher: Yes. Good. Cindy, did you have a comment to this?  
 9 ((points to Cindy))  
 10 (1.0)  
 11 Cindy: Uh I think clothes is a fact because you need clothes. But  
 12 you can cover yourself in a plastic bag. But you cannot  
 13 run around naked. You need clothes to cover the body. To  
 14 protect it from snakes and so on.

**Figure 3.** Excerpt from whole-class discussion.

The group's Talkwall contributions were displayed to the whole class on the whiteboard (see Figure 2), and other students signalled to the teacher that they wanted to comment on this group's contributions. The teacher called on Cindy, who elaborated on what Lina had said and what Lina and her group wrote on Talkwall. Cindy elaborated on why you need clothes: not only because it can be cold, but also 'to protect the body from snakes and so on' (see Figure 3, lines 11–14). Here, Cindy built on Lina and her group's contributions in Talkwall by elaborating, providing a reason, and providing an example.

The teacher used the Talkwall contributions as a starting point for directing the whole-class discussion by displaying and leading attention to one group's Talkwall. Using Talkwall in this way enabled the teacher to get insight into what the groups were discussing. This insight was possible because of the ability to read the groups' contributions in real time as they were appearing on Talkwall. In addition, this activity created the opportunity for other students to build on the ideas their peers expressed in the Talkwall contributions and to elaborate further, thereby developing their dialogic skills. Furthermore, the visualisation of the Talkwall contributions and the display of the outcomes of the group discussions extended the voices of all the group members to the whole class. This was made possible because they all had to contribute to the group discussion due to the ground rules that obligated everyone to participate.

## Conclusion and implications

Research has demonstrated that embedding technology in classroom activities may support the development of students' dialogic skills (Rasmussen & Ludvigsen, 2010). For example, the microblogging technology has potential to support students building on each other's thinking and also to increase participation in classroom discussions (Gao et al., 2012; Luo & Gao, 2012). However, research on CSCL settings has shown that digital

technologies in the classroom are not beneficial in and of themselves; they need to be embedded in the design of the activities (Dillenbourg et al., 2009).

By using detailed microanalysis of classroom interaction, this study contributes to existing research by illustrating how digital artefacts—when embedded in the activity design—can provide new opportunities for students to develop dialogic skills. Based on our analysis, we argue for the importance of the design of the learning activity. Moreover, we argue that the teacher’s role in orchestrating the complex ecosystem of the classroom is crucial for the realisation of the potential of a digital artefact, such as Talkwall. The case of Talkwall demonstrates how this digital artefact provide new possibilities by making visible written contributions from students, thus providing the teacher with access to developing knowledge and ideas that can be used as a starting point for continuing whole-class discussion. Furthermore, how technology can facilitate the engagement of more students by extending group conversation through blog-contributions that make visible segment of each individual voice that contribute to the building of a collective knowledge base for the whole class.

This study has certain limitations, it is work mentioning that the teacher in this case is experienced both in teaching and with the use of digital technologies in the classroom which has implications on how she designed the learning activity. Also, Talkwall opens up the possibility to gain insight into the knowledge of peers, further studies are necessary to obtain more empirical documentation of how this information is being used to for e.g. build on each other’s knowledge. Third, to provide a deeper understanding and also to get a broader perspective on how this technology can support the development of students’ dialogic skills will require more investigation of different teachers design of learning activities and how they adapt the tool in their classrooms.

The teacher in this case creatively adapted both the technology and the material from the *Thinking Together approach* to further develop her teaching repertoire and facilitate students’ dialogic skills, i.e. the process through which they learn to reason, discuss, argue, and explain their developing knowledge and ideas (Mercer, 2002). As such, this study contributes to the existing body of CSCL research with knowledge about what it takes to successfully embed technologies in classroom activities to enhance learning opportunities.

## References

- Applebee, A., Langer, J., Nystrand, M., & Gamoran, A. (2003). Discussion-based approaches to developing understanding: Classroom instruction and student performance in middle and high school English. *American Educational Research Journal*, 40(3), 685–730.
- Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Ricki, G., . . . Sherin, B. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences*, 19, 3–53.
- Dillenbourg, P., Järvelä, S., & Fisher, F. (2009) The evolution of research on computer-supported collaborative learning: From design to orchestration. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes (Eds.), *Technology-Enhanced learning: Principles and products* (pp. 3-19). Springer.
- Gao, F., Luo, T., & Zhang, K. (2012). Tweeting for learning: A critical analysis of research on microblogging in education published in 2008–2011. *British Journal of Educational Technology*, 43(5), 783–801.
- Howe, C., and M. Abedin. 2013. “Classroom dialogue: A systematic review across four decades of research.” *Cambridge Journal of Education* 43 (3): 325-356.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39–103.
- Luo, T., & Gao, F. (2012). Enhancing classroom learning experience by providing structures to microblogging-based activities. *Journal of Information Technology Education: Innovations in Practice*, 11.
- Mercer, N. (2002). *Words and minds: How we use language to think together*. Routledge.
- Rasmussen, I., & Ludvigsen, S. R. (2010). Learning with computer tools and environments: A sociocultural perspective. In K. Littleton, C. Wood, & J. K. Staarman (Eds.), *International Handbook of Psychology in Education* (pp. 399–433). London: Emerald Group Publishing Limited.
- Rasmussen, I., Lund, A., & Smørdal, O. (2012). Visualisation of trajectories of participation in a Wiki: A basis for feedback and assessment? *Nordic Journal of Digital Literacy*, 1(2012), 21–35.
- Rojas-Drummond, S., Pérez, V., Vélez, M., Gómez, L., & Mendoza, A. (2003). Talking for reasoning among Mexican primary school children. *Learning and Instruction*, (13), 653–670.
- Thoms, B. (2012). Student perceptions of microblogging: Integrating Twitter with blogging to support learning and interaction. *J Inf Technol Educ*, 11, 179–197.

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# BacToMars: A Collaborative Video Game for BioDesign

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**Abstract:** We present BacToMars, a collaborative multiplayer educational video game that engages elementary school children in creative bio-design. We describe the design of the game, its learning goals, and findings from its preliminary evaluation when deployed in informal settings accompanied by a curricular intervention. Our findings shed light on how children play a collaborative multiplayer game while co-located, and on the potential of collaborative video games as a tool for teaching biological engineering to young children and for making a positive impact on their attitudes towards science.

## Introduction

Bioengineering is an emerging area at the forefront of science and technology, with far-reaching consequences for addressing important real-world problems related to space travel, food production, energy, and medicine. To date, concepts related to bioengineering are not yet introduced in school curricula until late middle school or high school (National Research Council, 2013). However, introducing children earlier to this burgeoning field at the intersection of science and engineering could foster interdisciplinary thinking and positive attitude towards STEM (science, technology, engineering, and math) (Strawhacker et al., 2018). To expose children in primary school to the excitement, challenges, and core ideas of biology engineering, we developed a collaborative video game, BacToMars, to engage elementary school children in biodesign activities, giving them a playful way to learn concepts that were traditionally considered too complex. We describe its design and implementation in detail and share findings from its evaluation.

## Background

Bioengineering is a multidisciplinary field at the intersection of engineering and biology, which produces biology-based solutions to real-world problems. Despite the importance and promise of bioengineering, its foundational concepts are not introduced to students until at least middle school (National Research Council, 2013). Young children are able to learn core concepts surrounding bioengineering (Bers, 2017; Clements & Sarama, 2003) and can engage meaningfully in foundational concepts of engineering design (Auerbach & Silverstein, 2003; Bers, 2012). Researchers have created engineering toys that are screen-free, tangible, interactive platforms that leverage children's ability to learn-by-doing (Ainsworth, 2006; Bers, 2012; Strawhacker & Bers, 2015; Verish et al., 2018). Bioengineering is a promising field for engaging young students' imaginations because it combines the openness of engineering with the constraints of a modular building system.

## Related work

### Bioengineering concepts

Elementary-aged children (2nd-5th graders) are at a prime age to understand key foundational concepts of bioengineering. Bioengineering combines STEM concepts that are already required in most learning standards for this age range (National Research Council, 2013; Common Core State Standards Initiative, 2013). In spite of the evidence about developmental readiness, bioengineering is likely not taught at this age due to a lack of teaching tools available to educators. The few existing educational tools and initiatives that teach bioengineering are designed for students in high school and beyond (Barone et al., 2015; Kafai et al., 2017).

### Collaborative game-based learning

Children can master complex content when learning tools are designed to leverage their intuitive understanding and logic about the world (Druin, 2010), to maximize learner engagement and understanding by offering open-ended problems requiring creative solutions (de Freitas, 2006; Hoffmann, 2009), and to avoid issues of traditional

academic structure and inflexibility (Sandford et al., 2018). Game-based learning can be supported by collaborative interactions (de Freitas, 2006; Steinkuehler, 2006, Okerlund et al., 2016). Multi-player science games can offer opportunities for playfulness, collaboration, and motivation (Kao et al., 2002), foster use of collectivist and positive language (Wise et al., 2017), and encourage emergent leadership styles (Sun et al., 2017).

## Design goals

BacToMars is based upon a research paper that explores how bioengineering can be used to facilitate manned exploration missions to Mars (Menezes et al., 2015). BacToMars allows children to create genetic programs for bacteria to sustain human life on the planet. Through collaboration with educators, we have identified specific learning goals for elementary school students (2nd-5th grade) to engage with bionengineering concepts: (L1) Introduce basic concepts of genetics, focusing on genes and DNA; (L2) Facilitate the design of genetic programs that include input and output; (L3) Introduce the foundations of biological engineering methods and scientific protocols to solve real-world problems; (L4) Demonstrate the principles of abstraction; and (L5) Engage players in creative problem-solving of critical challenges related to survival on Mars.

Our design goals for BacToMars were informed by these learning goals and influenced by theories of Constructionism (Papert, 1980) which view “microworlds” as fertile ground for children to cultivate ideas, test hypotheses, and construct new artifacts based on that learning: G1) Facilitate the development of inquiry skills through a hands-on playful experience where users can construct knowledge and apply creative problem-solving; G2) Provide feedback and guidance within the game; and G3) Present opportunities for collaborative learning.

## Design of BacToMars

The current version of BacToMars is a result of an iterative design process and close collaboration with both educators and children. Following, we describe the main design of the game.

### Goal of the game

Players are tasked with helping a team of astronauts survive on and escape from Mars after their biodome, supplies, and spaceship are destroyed in a dust storm. To do so, players are guided by the main game character, a biological-engineer astronaut, to design bacteria that produce various materials (products) by combining input and output BioBricks, visually represented by interlocking blocks. Input BioBricks make the bacteria consume readily-available resources on Mars, such as carbon dioxide, while output BioBricks produce particular products, such as oxygen. Some combinations are more effective than others.



**Figure 1.** The game space of BacToMars. In the first level (left), players are shown how to play the game. The final, multiplayer interface (center) adds complexity and requires collaboration to complete the game. Children played the multiplayer game at adjacent computers to encourage collaboration (right).

The game space is organized into two main areas, as shown in Figure 1: the Mars landscape with the astronauts’ biodome, natural resources, and product levels; and the workbench, where players can access resource and product BioBricks to engineer bacteria, view combination feedback, and see their score and character. Players must keep track of the product levels as they play so that the astronauts do not run out of any supplies. Figure 1 shows the game screen in a beginner level and an advanced level.

### Gameplay

We developed BacToMars as a multi-player collaborative game with a curricular supplement consisting of educational videos and minigames to explain the key concepts behind the game. Gameplay starts with a character selection screen, where players can create their character. Single-player scaffolding was integrated in the game, as shown in Figure 1. Players start by making oxygen using carbon dioxide, then are lead through more complex combinations. Once each player completes the scaffolding, all players are asked simultaneously whether they would like to collaborate. If they choose to collaborate, the Build a Launchpad level begins. Gameplay ends when



the team has successfully created a launchpad and spaceship. Players are then shown their final scores and team contributions. Throughout gameplay, players can view their individual score and character representation and that of their collaborators. Players work collaboratively in a single biodome to create products, and can view the product yield of all players so each may evaluate the effectiveness of each combination.

## Evaluation

### Procedure

The BacToMars game was tested during a 3-day informal bioengineering workshop. The research team observed  $N = 9$  children (5 girls, 4 boys) in 4<sup>th</sup> and 5<sup>th</sup> grade as they explored bioengineering content through digital and traditional learning activities such as physical games, picture books, and robotic construction. Children were divided into groups of three for the collaborative game and sat at adjacent computers, as shown in Figure 1. One group consisted of all girls, one of all boys, and one of mixed gender. In each group, children played the single-player scaffolding levels for approximately 10 minutes, and then continued to play the multiplayer extension for another 10 minutes. Researchers made qualitative observations, videotaped the interactions, and collected pre- and post-task questionnaires, which included questions about the key concepts, an attitudes questionnaire, and questions about their subjective enjoyment. We coded video transcripts for verbal content-specific themes.

## Results

### Multiplayer gameplay

When children encountered the prompt to either continue to play alone or play collaboratively, all of them chose to play with others and urged their teammates to choose that option. On average, groups played the single-player levels for about 10 minutes, and multiplayer levels for about 8 minutes. In all three groups, the total utterances in the multiplayer levels were greater than in the single-player levels. Both planning (discussion of tasks or roles) and narration (statements of actions or observations) dramatically increased from single-player to multi-player. Questions asked during gameplay were split into two groups: questions asked about how to play the game; and questions about concepts. Explanations were coded as players answering questions for each other. The number of positive interactions (statements of affirmation or excitement) increased between the single- and multiplayer levels. Competitive utterances, such as comparison of scores, also increased.

Usage of content key terms, such as “plasmid” or “bacteria,” were tallied for each group during single- and multi-player game play. In addition, children were asked to define these terms in their pre- and post- task questionnaires. None of the children in our preliminary evaluation used a key term during gameplay, however the percentage of correct definitions did increase in the post-task for five of the six key terms. We also assessed science attitudes before and after gameplay. Average responses for all children, and for boys and girls separately, increased after gameplay. Children were asked a series of free response questions about what they enjoyed most about the week. Multiple children highlighted that they enjoyed the collaborative game the most.

## Discussion

The multiplayer aspect of BacToMars facilitated engagement and collaboration, as demonstrated through increased utterances, planning and narration, and positive interactions. We saw an increase in correct definitions of key concepts after completion of the curricular component and gameplay, indicating that young children can indeed learn advanced concepts when presented with developmentally-appropriate curricula and tools. Attitudes scores improved for all children, but the increase in attitudes for girls as a group is promising. Overall, the design of BacToMars was effective at supporting children’s engagement, enjoyment, and learning. Our design of BacToMars demonstrates that collaborative games about real-world challenges are effective learning tools. Research on educational videogames can benefit from the current findings, indicating that providing open-ended, creative play experiences can inform children’s attitudes about learning content. Future work should focus on engaging children through a variety of digital media, including tangible interactions, and should focus on collaborative play as a way to foster bioengineering learning.

## Conclusion and future work

Through collaborative gameplay, BacToMars encourages children to place themselves in the role of a bioengineer in order to help a team of astronauts. In conjunction with the educational videos and minigames, BacToMars increased children’s knowledge of key bioengineering concepts. We plan to further develop curricula and novel interfaces to bring the burgeoning area of bioengineering to primary schools.



## References

- Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and instruction, 16*(3), 183-198.
- Auerbach, C., & Silverstein, L. B. (2003). *Qualitative data: An introduction to coding and analysis*. NYU press.
- Barone, J., Bayer, C., Copley, R., Barlow, N., Burns, M., Rao, S., Seelig, G., Popovic, Z., & Players, N. (2015). Nanocrafter: Design and Evaluation of a DNA Nanotechnology Game. In *FDG*.
- Bers, M. U. (2012). *Designing digital experiences for positive youth development: From playpen to playground*. Oxford University Press.
- Bers, M. U. (2017). *Coding as a playground: Programming and computational thinking in the early childhood classroom*. Routledge.
- Clements, D. H., & Sarama, J. (2003). Strip mining for gold: Research and policy in educational technology—A response to “Fool’s Gold”. *ACE Journal, 11*(1), 7-69.
- Common Core State Standards Initiative (2010). Common Core State Standards for Mathematics and English Language Arts. <http://www.corestandards.org/read-the-standards/>.
- De Freitas, S. I. (2006). Using games and simulations for supporting learning. *Learning, media and technology, 31*(4), 343-358.
- Druin, A. (2010). Children as codesigners of new technologies: Valuing the imagination to transform what is possible. *New Directions for Youth Development, 2010*(128), 35-43.
- Hoffmann, L. (2009). Learning through games. *Communications of the ACM, 52*(8), 21-22
- Kafai, Y., Telhan, O., Hogan, K., Lui, D., Anderson, E., Walker, J. T., & Hanna, S. (2017). Growing designs with biomakerlab in high school classrooms. In *Proceedings of the 2017 Conference on Interaction Design and Children* (pp. 503-508). ACM.
- Kao, L., Galas, C., & Kafai, Y. B. (2005). "A Totally Different World": Playing and Learning in Multi-User Virtual Environments. In *DiGRA Conference*.
- Loparev, A., Westendorf, L., Flemings, M., Cho, J., Littrell, R., Scholze, A., & Shaer, O. (2017). BacPack: exploring the role of tangibles in a museum exhibit for bio-design. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 111-120). ACM.
- Menezes, A. A., Cumbers, J., Hogan, J. A., & Arkin, A. P. (2015). Towards synthetic biological approaches to resource utilization on space missions. *Journal of The Royal Society Interface, 12*(102), 20140715.
- National Research Council (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.
- Okerlund, J., Segreto, E., Grote, C., Westendorf, L., Scholze, A., Littrell, R., & Shaer, O. (2016). Synflo: A tangible museum exhibit for exploring bio-design. In *Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 141-149). ACM.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc..
- Sandford, R., Ulicsak, M., Facer, K., & Rudd, T. (2006). Teaching with games. *COMPUTER EDUCATION-STAFFORD-COMPUTER EDUCATION GROUP-*, 112, 12.
- Steinkuehler, C. A. (2006). Massively multiplayer online video gaming as participation in a discourse. *Mind, culture, and activity, 13*(1), 38-52.
- Strawhacker, A., & Bers, M. U. (2015). “I want my robot to look for food”: Comparing Kindergartner’s programming comprehension using tangible, graphic, and hybrid user interfaces. *International Journal of Technology and Design Education, 25*(3), 293-319.
- Strawhacker, A., Sullivan, A., Verish, C., Bers, M. U., & Shaer, O. (2018). Enhancing children's interest and knowledge in bioengineering through an interactive videogame. *Journal of Information Technology Education: Innovations in Practice, 17*(1), 55-81.
- Sun, J., Jackson, J., Burns, M., & Anderson, R. C. (2017). Children’s Emergent Leadership and Relational Thinking in Collaborative Learning. Philadelphia, PA: International Society of the Learning Sciences.
- Verish, C., Strawhacker, A., Bers, M., & Shaer, O. (2018). CRISPEE: A Tangible Gene Editing Platform for Early Childhood. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 101-107). ACM.
- Wise, A. F., Antle, A. N., & Warren, J. (2017). Explanation-Giving in a Collaborative Tangible Tabletop Game: Initiation, Positionality, Valence and Action-Orientation.

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# Digital Badges for Capturing, Recognizing, Endorsing, and Motivating Broad Forms of Collaborative Learning

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**Abstract:** Traditionally, schools have measured, compelled, credentialed, and accredited *achievement*. The practices for doing so are opaque, analog, expensive, inefficient, and entrenched. This makes schools resistant to embodied, enactive, extended, and embedded collaborative learning. Digital badges can contain (a) specific claims about such broad learning, (b) web-enabled digital evidence supporting those claims, and (c) information about how that evidence was obtained. Badges can then circulate this information readily in social networks where they can gain additional meaning. This paper explores how CSCL goals might be served by using badges to shift towards capturing, recognizing, endorsing, and motivating *learning*, and doing so for a much broader range of learning than otherwise possible.

Open digital badges are a new kind of credential that were introduced in 2012 in an initiative of the MacArthur Foundation. The *Badges for Lifelong Learning* competition was introduced by the US Secretary of Education and was widely reported. The initiative supported 30 efforts to develop digital badges for diverse educational programs and the Open Badges metadata standards that allowed digital badges to become *interoperable* and *extensible*.

Despite significant interest among others, digital badges have received little attention in Learning Sciences venues (i.e., Davis & Bell, 2016; Hickey & Chartrand, 2018; Tran, Schenke, & Hickey, 2014) and apparently have never been represented in a CSCL venue. Some skepticism towards digital badges likely follows from their conflation with *gamification* (e.g., Duncan, 2011), *competency-based education* (e.g., Metzger, Lubin, Patten, & Whyte, 2016) and *extrinsic incentives* (e.g., Resnick, 2012). This paper argues that digital badges need not be used in these ways, and that doing so obscures their significant untapped potential for supporting the broader participatory and collaborative learning that is valued in the LS and CSCL communities, and supporting the embodied, enactive, extended, and embedded learning that is the focus of CSCL 2019. This is because badges can contain broad evidence of learning along with detailed information about how that evidence was obtained, and do so in a way that allows viewers who are interested and willing to interrogate this information

## Four potentially transformative functions of digital badges

This paper is organized around the four potentially transformative functions of digital badges. It illustrates these functions using a badge system that was designed within a “Big Open Online Course” on Educational Assessment that was completed by hundreds of students over three years. This badge system was designed to take advantage of key features of Open Badges while exploiting the potential synergy between badges and digital portfolios. With funding from Google and using Google *CourseBuilder*, the “Assessment BOOC” used *expansive framing* (Engle et al., 2012) to support participatory collaborative learning at scale.

### From measuring achievement to capturing learning

The first set of potentially transformative functions associated with digital badges concerns *assessment*. Much of the evidence that badges might contain is generated by typical classroom assessments, such as quizzes, performance assessments, portfolios, etc. While badges might also include scores from formal standardized achievement tests, scores on such tests typically can “speak for themselves” and therefore are ill-suited for badges.

### Capturing richer evidence of the context of the learning

The *Assessment Principles Expertise* badge, which one student earned by completing the second module in the BOOC included links for each of the three “wikifolio” activities that were completed, including the prompts for each element and response to each prompt (Endnote 1). This allows badge viewers to “drill down” into this information without getting lost; the information in the badge and the annotations on the hyperlinks help viewers know what they are clicking on and how it relates to the competencies asserted in the criteria of the badge. For the interested viewer, even more information about the learning context can be accessed from those links. All this information can make the actual “evidence” more meaningful to badge viewers who value this information.

### Capturing evidence of broader learning

The Expertise badge mentioned above states that the earner scored over 80% on the module exam. These were rigorous time-limited exams that included “best answer” items that were difficult to look up in the allocated time. Meanwhile, the linked wikifolios reveal both the prompt and the response to three reflections that provide evidence of *consequential engagement* (Gresalfi, Barab, Siyahhan, & Christensen, 2009). Arguably, this additional information provides stronger support for proficiencies claimed in the badge. In this way, badges are a promising response to the problem of CAMEO cheating (*Copying Answers from Multiple Existences Online*; Northcutt, Ho, & Chuang, 2016) that plague MOOCs. In situations where the value of the badge was very high, such nuanced evidence may be quite valuable. It is worth noting that several students at other universities were able to use their BOOC badges as evidence for earning “independent study” credits.

### Capturing evidence of collaborative learning

The first proficiency listed in the Expertise badge is *Productively discuss classroom assessment principles with professional peers*. Illustrating how badges address a crucial challenge in assessing collaborative learning, the badge provides further evidence of this collaborative competency *by the number and nature of comments on the individual wikifolios*. Rather than formally assessing representations of collaboration, these assertions and representations of collaboration allow viewers *for whom this evidence has value* to examine the evidence themselves and to do so in a manner that is commensurate with the viewers’ value of the claims and evidence.

### Capturing evidence from open learning pathways

Learners who earned all three module badges in the Assessment BOOC were issued an *Educational Assessment Expertise* “metabadge” that contained hotlinked images of the three module badges (Endnote 2). This is an example of an “open learning pathway” introduced by Otto (2017) and formalized in the most recent Open Badges 2.0 Specifications. Such arrays offer useful pathways *into* learning as well as *during* learning, by capturing evidence of accomplishment of smaller goals that are still meaningful.

### From credentialing graduates to recognizing learning

While related to the capturing aspect, digital badges also serve distinct functions associated with the *recognition* of learning. Recognition functions correspond more with credentialing practices associated with assigning grades and awarding certificates and degrees. Recognition functions are particularly relevant when using badges to catalyze broader transformations of educational ecosystems considering the broader functions of credentials (i.e., *human capital, screening & filtering, signaling, control, cultural capital, institutional, and credentialism*; Bills, 2003). The following recognition functions can be considered apart from the capturing, motivating and endorsing, which in turn helps reveal the complex but important interactions between these functions.

### Recognizing learning openly

Some have raised concerns over open recognition with badges and the corresponding lack of traditional security measures (e.g., Mathews, 2016). This is presumably because the transformative potential of open recognition is not readily obvious to many observers. In response, the *Bologna Open Recognition Declaration* asserted that “Open Badges, the open standard for the recognition of learning achievements has proved the power of a simple, affordable, resilient and trustworthy technology to create an open recognition ecosystem working across countries, educational sectors, work, social environments and technologies” (Open Recognition Alliance, 2016). The anthropological notion of *boundary objects* illustrates the potential of open recognition. Boundary objects are produced in one context but can be used in other contexts by other people, for different purposes. Consider, for example, that the same badges that an instructor might issue in a course can also be shared by the earner on their Facebook or LinkedIn account. The instructor might “stack” that badge into a learning management system (by recording the URL of the badge) and associate it with a grade and private feedback (information which must be strictly protected). But that same badge might also circulate publicly in the earners social networks where it gains “likes” and comments, which give the badge further and different meanings.

### Recognizing a broader range of competencies

Badges are well-suited for recognizing so-called “21<sup>st</sup> Century” competencies associated with networked digital learning. Such highly contextual competencies are difficult to assess and even harder to measure in standardized ways. The ability to recognize broader competencies has previously been ascribed to ePortfolios (e.g., Gibson & Barrett, 2002) and even earlier with portfolio assessment. Unfortunately, objective studies have shown that portfolios alone often fail to serve intended formative and summative functions (e.g., Lam, 2017). The obvious question is whether the combination of ePortfolios and digital badges has the potential to overcome the challenges of recognizing the broader range of CSCL competencies. Including threaded discussions contained in the BOOC

badges along with information about the context in which those discussions occurred make it possible to recognize collaborative learning in ways that otherwise would be quite difficult.

### Recognizing a broader range of proficiency of a competency

Traditional credentials are hard-pressed to recognize the range of proficiency for given competencies beyond grades, grade point averages, and honors achievements. For the same reasons that badges can recognize a broader range of competencies, badges can also recognize a broader range of proficiency for a specific competency. The BOOC module badges and the learning pathways discussed above provide one example of how digital badges facilitate the recognition of broader range of competency. This function was also exemplified by the way that earning a passing score on the final exam transformed the *Educational Assessment* badge into the *Educational Assessment Expertise* badge. This recognition potential is particularly relevant for highly contextual “21<sup>st</sup> Century” competencies. This is because an individual’s level of proficiency with these competencies is ultimately recognized in terms of the nature and number of contexts in which such competencies are demonstrated. Some viewers of the badge might find the number of comments on each wikifolio to be enough evidence of this competency; others might click on the links and examine discussions. This recognition function is particularly significant when combined with the endorsement functions described below.

### Recognizing opportunities for learning

Another important function of digital badges is helping *potential* learners recognize opportunities to learn. In the case of the Assessment BOOC, badge earners were strongly encouraged to share their badges over Facebook, LinkedIn, Twitter, and any relevant interest-driven professional networks; those badges invited viewers to submit their email addresses and place themselves on the distribution list. Additionally, clicking on the course URL on the first line of each badge took the viewer to the course homepage, which included a link that allowed new learners to enroll in the course. The course survey confirmed that some learners discovered the BOOC this way.

### From compelling achievement to motivating learning

Space limitations preclude full discussion of the many complex ways badges might motivate learning. To reiterate, some have characterized badges as “extrinsic incentives” which undermine intrinsically motivated learning. This rekindled debate over extrinsic incentives is discussed at length in a new handbook chapter (Hickey & Schenke, 2019). That chapter argues that: (1) digital badges are inherently more meaningful than grades and other credentials, (2) circulation in digital networks makes Open Badges particularly meaningful, (3) the negative consequences of extrinsic rewards are likely overstated, and (4) consideration of motivation and badges should focus primarily on social activity and secondarily on individual behavior and individual cognition.

### From accrediting schools to endorsing learning

A fourth set of transformative functions associated with digital badges concerns what is traditionally associated with *accreditation*, where external “third parties” review and verify the quality of schools and programs and the achievement represented by their degrees and credentials. Existing accreditation practices are analog, opaque and intransigent (Gallagher, 2016). Arguably, traditional accreditation is an obstacle to participatory and collaborative learning in many schools. Newly available “Endorsement 2.0” standards promise a shift towards more open and transparent *endorsement* of learning (Hickey & Otto, 2017). Two Assessment BOOC features illustrate what open endorsement practices might look like.

### Endorsing learning with peer endorsement

To encourage informal review of wikifolios by classmates, a *peer endorsement* feature was added to each assignment in the Assessment BOOC. Participants were asked (but not required) to endorse at least three of their classmates’ wikifolios for being “complete.” As shown in the Assessment Principles badge, these endorsements were tabulated on the module badge for each completed wikifolio assignment.

### Endorsing learning with peer promotion

Each wikifolio assignment asked (but did not require) students to promote one (and only one) of their peers’ wikifolio each week for being “exemplary.” Unlike peer endorsement, students were required to provide an endorsing statement describing what made the work exemplary. These promotions were also tabulated on the module badge, while the endorsing statements are displayed on the linked wikifolio. Students clearly valued the endorsements strongly and complained when course practices made it harder for them to earn endorsements. A search feature let participants locate widely promoted peer work completed by peers with similar professional roles.

## Discussion and future directions

This paper illustrated how a single digital badge system was used to capture, recognize, motivate, and endorse broad forms of conventional, participatory, and collaborative learning. We contend that these functions might be similarly useful for many other (but certainly not all) forms of CSCL. This seems particularly promising when coupled with the idea that the evidence contained in those badges could be readily examined in light of the claims made by those same badges in order to examine the effectiveness of the larger learning-assessment ecosystem. Innovators in the CSCL and LS communities and beyond are encouraged to consider adding digital badges to their efforts and exploring the transformative potential of the functions introduced here.

## Endnotes

- (1) <https://cabooc.appspot.com/badges/evidence?id=15102006>
- (2) [https://cabooc.appspot.com/badges/expert\\_evidence?id=11022008](https://cabooc.appspot.com/badges/expert_evidence?id=11022008)

## References

- Bills, D. B. (2003). Credentials, signals, and screens: Explaining the relationship between schooling and job assignment. *Review of Educational Research*, 73(4), 441-469.
- Davis, K., & Bell, A. (2016). *Co-designing a digital badge system: Supporting learners' science identities through participatory design*. Symposium presented at the International Conference of the Learning Sciences, Singapore.
- Duncan, A. (2011, September 15). *Digital badges for learning: Remarks by Secretary Duncan at the Launch of the MacArthur Foundation's 4<sup>th</sup> Annual Digital Media and Learning Competition*. Washington, DC: US Department of Education. Retrieved from: <https://www.ed.gov/news/speeches/digital-badges-learning>
- Engle, R. A., Lam, D. P., Meyer, X. S., & Nix, S. E. (2012). How does expansive framing promote transfer? Several proposed explanations and a research agenda for investigating them. *Educational Psychologist*, 47(3), 215-231.
- Gallagher, S. R. (2016). *The future of university credentials*. Cambridge, MA: Harvard Educational Press.
- Gibson, D., & Barrett, H. (2002). Directions in electronic portfolio development. *Contemporary Issues in Technology and Teacher Education*, 2(4), 556-573.
- Gresalfi, M., Barab, S., Siyahhan, S., & Christensen, T. (2009). Virtual worlds, conceptual understanding, and me: Designing for consequential engagement. *On the Horizon*, 17(1), 21-34.
- Hickey, D. T., & Chartrand, G. (2018, June). Recognizing competencies vs. completion vs. participation: Ideal roles for web-enabled digital credentials. In the *Proceedings of the biennial meeting of the International Conference of the Learning Science*, Volume 3 (pp. 792-799)
- Hickey, D. T., & Otto, N. (2017, February 13). Endorsement 2.0: Taking Open Badges and e-credentials to the next level. *EDUCAUSE Review*.
- Hickey, D. T., & Schenke, K. (2019). Open digital badges and reward structures. In K. A. Renninger, & S. E. Hidi (Eds.), *The Cambridge handbook on motivation and learning* (pp. 209-237). Cambridge MA: Cambridge University Press.
- Lam, R. (2017). Taking stock of portfolio assessment scholarship: From research to practice. *Assessing Writing*, 31, 84-97.
- Mathews, C. (2016, September 22). Unwelcome innovation. *Inside Higher Ed*.
- Metzger, E. C., Lubin, L., Patten, R. T., & Whyte, J. (2016). Applied gamification: Creating reward systems for organizational professional development. In D. Ifenthaler, N. Bellin-Mularski, & D.-K. Mah (Eds.), *Foundation of digital badges and micro-credentials* (pp. 457-466). Switzerland: Springer.
- Northcutt, C. G., Ho, A. D., & Chuang, I. L. (2016). Detecting and preventing "multiple-account" cheating in massive open online courses. *Computers & Education*, 100, 71-80.
- Open Recognition Alliance (2016). Bologna Open Recognition Declaration [Webpage]. Retrieved from <https://www.openrecognition.org>
- Otto, N. (2017, January 5). Open pathways connect badges to what you care about [Blogpost]. Retrieved from <https://www.concentricsky.com/articles/detail/open-pathways-connect-badges-to-what-you-care-about>
- Resnick, M. (2012, February 27). Still a badge skeptic [Blog post]. Retrieved from <http://hastac.org/blogs/mres/2012/02/27/still-badge-skeptic>
- Tran, C., Schenke, K., & Hickey, D. T. (2014). Design principles for motivating learning with digital badges: Consideration of contextual factors of recognition and assessment. In the *Proceedings of the 11<sup>th</sup> Biennial International Conference of the Learning Sciences*, Boulder CO (pp 1027-1031).

# Embodied collaboration to foster instrumental genesis in mathematics

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**Abstract:** As cognitive science reports joint action requiring tight intercorporeal coordination between two partners, we aim to evaluate the role of this coordination in computer-supported instrumental genesis for mathematics. In our dual eye-tracking design study we developed an embodied activity that potentially contributes to technologically extended problem solving in trigonometry. We tested three versions of the design: (a) individual sensorimotor enactment only, (b) individual and then collaborative enactments, and (c) individual enactment and then collaborative description followed by enactment. As our first case showed, the required sensorimotor coordination was developed but never used in the following problem solving when a student worked alone. In contrast, in both collaborative cases the relevant sensorimotor coordination became a part of instrumented action scheme. Future research is needed to investigate if intercorporeal coordination with the other is crucial for the transfer of sensorimotor coordination from their original source to instrumental activity in mathematics.

Following an embodied turn in cognitive science, the design study presented here is a deliberate attempt to design a computer-supported environment for trigonometry so as to make explicit and observable the embodied and extended mechanisms of mathematical learning. There is a long tradition of research on learning mathematics with technology that extends student's thinking processes, including research on the teacher's role in its introduction (e.g., Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010); and growing body of literature on embodied mathematical learning. However, the interaction in CSCL has rarely been promoted and studied from an embodied and extended perspective, especially when it comes to more sophisticated mathematics such as trigonometry. In the tradition of an embodied interactive action-based design genre (Abrahamson, 2014), we designed tasks that invite students to establish new sensorimotor coordinations and later enact them within instrumented trigonometry problem solving. This *design study focuses on* the necessity and the preferred form of collaboration with a more knowledgeable other in the progress from pure motor activity to mathematics.

## Theoretical framework

At the intersection of CSCL, E-approaches to cognition, and mathematics education, one can draw on multiple bodies of literature. Here we zoom in on embodied collaboration, computer-supported embodied design, and instrumental genesis as a prerequisite for technologically extended problem solving.

## Embodied collaboration

In line with sociocultural traditions, we assume a student and a more knowledgeable other form a *functional system* when solving a problem task, with actions and cognition contingently distributed between the partners (Newman, Griffin, & Cole, 1989). Cognitive science has distinguished multiple embodied mechanisms that maintain the operation of this *intercorporeal distributed system*, such as fine adjustment to the trajectory of the other's action (Schmitz, Vesper, Sebanz, & Knoblich, 2017), or fine-grained predictions of the other's movements (Vaziri-Pashkam, Cormiea, & Nakayama, 2017). In mathematics education we can find traces of *embodied coupling* as tutors monitor a student's actions: the tutor's eye-movements reveal tight coordination with the student's movements (Shvarts, & Abrahamson, under review). Alternatively, the role of more knowledgeable other in embodied collaboration might be seen in a reciprocal *multimodal revoicing* of a student that provokes gradual transformation from personal embodied experience to socially established mathematical objects (Flood, 2018). The versions of the computer-supported activity that were tested in this study were designed to distinguish the influence of embodied joint action from verbal description, thus stressing the role of intercorporeal functional system versus collaborative naming in the genesis of a mathematical instrument.

## Mathematical instrument and embodied instrumental genesis

In instrumental approaches to mathematics education an *instrument* is introduced as constituted from two sub-systems: an *artifact* and *instrumented action schemes*. A scheme is understood as "dynamic functional entity" in the complexity of its components such as "the goals and the anticipations, the rules of action, gathering of

information, control-taking and the operative invariants” (Trouche, 2004, p. 286). For example, if a child uses a spoon (the artifact) to make sound on drums or to hit a nail (instrumented action schemes), the observable *sensorimotor coordinations* are similar, but the schemes are different as the goals of actions differ. The process in which a learner appropriates an artifact for a specific type of tasks is called *instrumental genesis*. Clinical studies make obvious the emergence of new sensorimotor coordinations in instrumental genesis: manipulation with a stick immediately enlarges peripersonal space, a blind person literally senses through a white cane (see de Vignemont, 2018, for broader discussion). With an eye on embodied CSCL, we focus on involvement of previously elaborated sensorimotor coordinations into mathematical instrumented action schemes.

### Action-based design genre

Informed by embodied cognitive science, Abrahamson (2014) suggested a new genre of educational design for learning mathematical concepts with interactive technology, where a student is required to keep the screen green while moving her hands, thus developing new *sensorimotor coordinations*, traced in repetitive eye-movements in goal-oriented embodied activity (Duijzer, Shayan, Bakker, Van der Schaaf & Abrahamson, 2017). While at the beginning new coordination emerges as the solution of a motor problem, later it is transformed to mathematical conceptualization through collaboration with a tutor (e.g. Flood, 2018; Shvarts, & Abrahamson, under review). In this paper we question the necessity and investigate the form of this collaboration, in so doing we address the following *research questions*: How does collaborative versus solo performance influence the involvement of emergent sensorimotor coordinations into the future instrumental activity? How do perception, multimodal utterances and actions in a technological tutorial differ between embodied joint actions versus collaborative description of a student’s embodied experiences?

### Methodology and materials

For our design study we have chosen trigonometry as a mathematics topic that requires spatial articulation, thus providing us with an opportunity to investigate motor and sensory activity by videography and eye-tracking. Unit circle is an artifact that contributes to understanding the trigonometric functions as having the same value appearing twice in each period (e.g.,  $\sin \alpha = \sin(180^\circ - \alpha)$ ). The *instrumental genesis stage* consisted of a set of four sensorimotor problems with color feedback, belonging to an action-based design genre (Abrahamson, 2014). Each task led the students to an embodied discovery in establishing new sensorimotor coordination in accordance to task constrains. In the series the additional mathematical notations were progressively added. As can be seen from Figure 1, the promoted embodied discoveries were: (task 1) keeping the hands at the same level (*a* and *b*); (task 2) keeping the colored angles the same size (*c* and *d*); (task 3) keeping the measures of two angles to be  $180^\circ$  in sum (not depicted here), and (task 4) keeping projection on the y-axis at the same height (*e* and *f*). The *problem solving stage* consisted of four trigonometry problems (e.g.,  $\sin \alpha = \sin 3\alpha$ ). We hoped to see that the artifact used to solve the fourth motor-problem (Figure 1*d, e*) would next extend the students’ thinking and come to serve as the instrument for solving trigonometry equations.

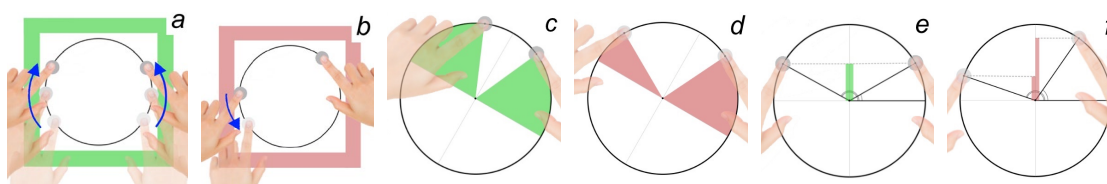


Figure 1. Figures *a, b* provide an idea of motor activity in task 1. Each pair of pictures represents two states: the target state with green feedback and incorrect state with red feedback.

This paper compares three versions of activity designs for undergraduate students learning. A graduate student in mathematics education program (Wes, all names are pseudonyms) took the role of more knowledgeable peer. Tim went through the motor problems of the instrumental genesis stage without any collaboration. For Rachel the individual sensorimotor practice was followed by a collaborative phase in which she performed the required embodied actions together with Wes (each one controlled one point and Rachel had to explain what to do). Diana, after her individual practice, had to answer the question about the rule that determines green feedback (the standard procedure for action-based design) and then also performed embodied joint action with Wes. Afterwards, all students went through the same problem solving stage. So, we trace three possible designs variations: *individual practice* (Tim), individual practice with the following *embodied joint action* (Rachel), individual practice with the following *collaborative description* of the rule and further joint action (Diana).

We used dual eye-tracking and videography to trace sensorimotor activity. In dual eye-tracking studies of CSCL often the interaction is limited to the speech channel and shared picture on the monitors, as remote



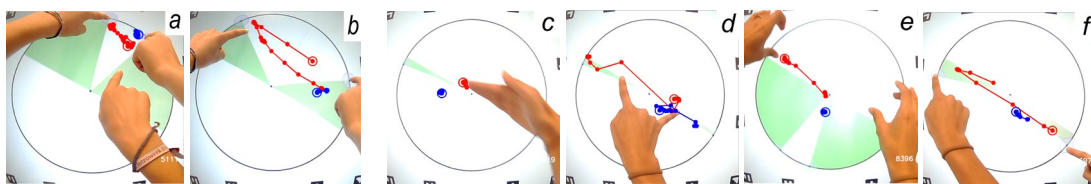
eye-trackers are used (e.g., Sharma, Jermann, Nüssli, & Dillenbourg, 2013). In this research we used two head mounted Pupil-Labs eye-trackers that were calibrated on the surface of an interactive whiteboard. Later gaze paths were aggregated in one video. A micro-ethnographical analysis was conducted with the focus on the intercorporeal coupling between participants and on differences in instrumental activity between the cases.

## Results and discussion

In accordance with previous findings (Duijzer et al., 2017), as students acquired fluent performance in each motor task, the iterative patterns of their eye-movements evidenced the emergence of new sensorimotor coordination. The eye-movements of the more knowledgeable peer as he was monitoring students' performance revealed tight coordination of his eye-movements with students' movements thus evidencing intercorporeal coupling between the tutor's perception and the student's action (cf. Shvarts & Abrahamson, under review).

### Stage 1. Collaboration on instrumental genesis

Although both Rachel (*embodied joint action*) and Diana (*collaborative description*) needed to explicate their individual performance, their utterances were remarkably different.



**Figure 2.** Rachel (a,b) and Diane (c,d,e,f) describe their embodied experience to Wes. The student's eye-movements are red, and those of the tutor are blue. On Figures a, b and d the right hand belongs to the tutor.

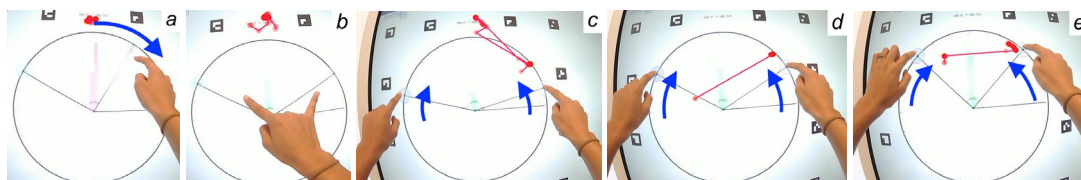
Rachel: Move that way (Figure 2a) ... and and... I need to think how to explain it <...>  
Just keep going that way, slowly <...> A bit slower [than me]

Diana: We wanna keep the angle ... between this line (Figure 2c). The middle line ... and our point, this angle, <...> we want them both to be equal (Figure 2d). <...> we want this angle between the middle line and our points to be the same (Figure 2e).

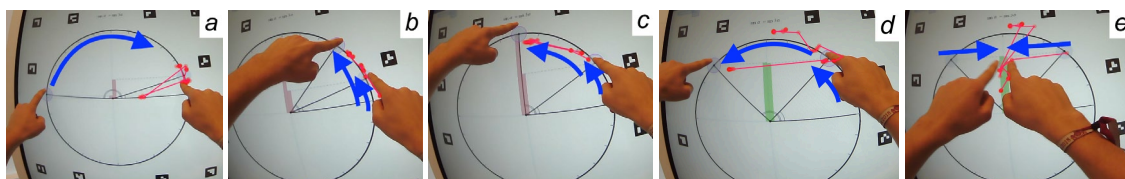
Rachel repetitively uttered “that way” and “slowly” and pointed to the target direction. These rather vague references were sufficient though to sustain successful joint action. Apparently, their natural ability to predict (Vaziri-Pashkam et al., 2017) each other's movements and adjust (Schmitz et al., 2017) to them provided sufficient ground for joint task-efficient performance. Diana on the other hand used mathematically relevant descriptions of angles, supplemented by iconic gestures. So in her case, the description request led to an elaboration of culturally meaningful references (cf. Flood, 2018). Both students traced the joint performance by repetitive eye-movements (Figure 2b, f), thus contributing to intercorporeal coupling within distributed system.

### Stage 2. Trigonometry problem solving

When they were asked to solve trigonometric equations, the usage of the digital artifact between the students trained in the individual (Tim) versus collaborative design versions (Diana and Rachel) was strikingly different.



**Figure 3.** Diana enacts the target sensorimotor coordination as she solves  $\sin \alpha = \sin 3\alpha$  equation. Eye-movements are in red. Blue arrows inserted to illustrate movements.



**Figure 4.** Tim invents a new instrumental action scheme as he solves  $\sin \alpha = \sin 3\alpha$  equation.



Diana and Rachel immediately engaged in the sensorimotor coordination that was established in the four embodied tasks of the instrumental genesis stage: They positioned two points on the circle so that the sinus value of two angles became equal (Figures 3a, b) and then moved the points, keeping them at the same level (Figure 3c, d, e) until one angle became 3 times bigger than another one. Tim on the contrary did not use the artifact in the proposed way. After some unsuccessful attempts he invented his own instrumented action scheme: He moved the points to track two angles so that one would be three times larger than the other (Figures 4b, c, d) until the sinus value of the two angles became equal (Figures 4d, e).

Problem solving processes were very similar among all students who worked on collaborative versus individual versions of the design beyond the cases presented here. So the established sensorimotor coordination being relevant for problem solving became part of the *instrumental action scheme* for the technological artifact only when it had been enacted earlier or discussed in collaboration with the other.

## Conclusions

In our design study we traced collaborative actions within an embodied computer-supported activity as well as dyads' multimodal utterances and eye-movements, and generated some novel hypotheses based on our results. We may expect individual *sensorimotor coordinations* as they emerge in a solution of interactive motor problems to be insufficient for instrumental genesis for mathematics. The comparison of the design versions suggested that a collaborative process is important for incorporation of the initial coordination into *instrumented action schemes* (Trouche, 2004): In both collaborative cases the students involved sensorimotor coordination, provoked by our embodied activities, in their technologically extended problem solving. In these cases, data revealed *coupling* between a student and a more knowledgeable other when the student and the other co-acted and when the other only observed the student's performance. The results contribute to understanding of embodied collaboration as forming an *intercorporeal distributed functional system*. Further research is needed to establish whether this intercorporeal coupling in joint action leads to the transfer of the initial embodied coordination to the mathematical domain, or whether a collaborative mathematical description of the student's experience is required. Unlike the explicit verbal description, the performance of embodied joint action did not require enculturated referencing and articulated iconic gestures. We propose that our design study contributes to understanding how embodied collaborative learning might lead to extended problem solving, and generates hypotheses that deserve investigation with a larger test group and the quantitative measures of gaze alignment.

## References

- Abrahamson, D. (2014). Building educational activities for understanding: An elaboration on the embodied-design framework and its epistemic grounds. *Int. Journal of Child-Computer Interaction*, 2(1), 1–16.
- de Vignemont, F. (2018). The Extended Body Hypothesis: Referred Sensations from Tools to Peripersonal Space. In A. Newen, L. De Bruin, & S. Gallagher (Eds.), *The Oxford Handbook of 4E Cognition*.
- Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom. *Educ. Studies In Mathematics*, 75(2), 213–234.
- Duijzer, C. A. C. G., Shayan, S., Bakker, A., Van der Schaaf, M. F., & Abrahamson, D. (2017). Touchscreen tablets: Coordinating action and perception for mathematical cognition. *Front. in Psychology*, 8, 144.
- Flood, V. J. (2018). Multimodal revoicing as an interactional mechanism for connecting scientific and everyday concepts. *Human Development*, 61, 145–173.
- Newman, D., Griffin, P., & Cole, M. (1989). *The construction zone: Working for cognitive change in school*. New York, NY: Cambridge University Press.
- Schmitz, L., Vesper, C., Sebanz, N., & Knoblich, G. (2017). Co-representation of others' task constraints in joint action. *Jour. of Exp. Psychology: Human Perception and Performance*, 43(8), 1480–1493.
- Sharma, K., Jermann, P., Nüssli, M.-A., & Dillenbourg, P. (2013). Understanding Collaborative Program Comprehension: Interlacing Gaze and Dialogues. In *Proceedings of CSCL*. Madison, WI, USA.
- Streeck, J., & Mehus, S. (2005). Microethnography: The Study of Practices. In K. L. Fitch & R. E. Sanders (Eds.), *Handbook of Language and Social Interaction* (pp. 381–404). Mahwah, NJ, LEA
- Shvarts, A., & Abrahamson, D. (under review) *Dual-eye-tracking Vygotsky: A microgenetic account of a teaching/learning collaboration in an embodied-interaction technological tutorial for mathematics*.
- Trouche, L. (2004). Managing the Complexity of Human/Machine Interactions in Computerized Learning Environments: Guiding Students' Command Process through Instrumental Orchestrations. *International Journal of Computers for Mathematical Learning*, 9(3), 281–307.
- Vaziri-Pashkam, M., Cormiea, S., & Nakayama, K. (2017). Predicting actions from subtle preparatory movements. *Cognition*, 168, 65–75.

# Collaborative Uncertainty Management While Solving an Engineering Design Problem

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**Abstract:** Uncertainty plays a crucial role in making engineering design decisions. It directly impacts both the design process and the final design output. It is important for learners to develop the skill of managing uncertainties effectively. However, there is a lack of research investigating how students manage uncertainties during a collaborative design process and how effective uncertainty management skills may be developed in the learners. In this paper, we present the results of a pilot study investigating how middle school students collaboratively manage uncertainties while solving an engineering design challenge. We also discuss issues related to the management strategies used and reflect on how these issues can be addressed using a computer-supported collaborative learning environment.

## Introduction

Engineering design problems are ill-structured and encompass uncertainties that arise due to the open-ended nature of the problems as well as the collaborative design process (Dym, Little, Orwin, & Spjut, 2009). In this paper, uncertainty refers to the cognitive feeling that encompasses subjective experiences of wonder, doubt or being unsure (Clore, 1992). The ways in which the uncertainties are managed collaboratively affect the overall design process and thus have implications for how and what students learn about engineering design (Jordan & McDaniel Jr, 2014). In this paper, we investigate how middle school students manage uncertainty while solving an engineering design challenge in a collaborative environment. We also discuss issues related to the management strategies used and reflect on how these issues can be addressed in a computer-supported collaborative learning environment aimed at developing learners' uncertainty management skills.

## Method

In this pilot study, we conducted an after-school robot design workshop for seventh-grade students in a metropolitan city in India. Five seventh grade students (three girls and two boys) participated in the study. We divided the students into two teams randomly. One team (Group A) consisted of two students (one boy and one girl) and the other team (Group B) consisted of three students (two girls and one boy). The workshop had two parts; first four hours consisted of basic training with the LEGO Mindstorms™ kit since students did not have any prior experience with it. In the next four hours, teams solved a design challenge competing with each other. Teams had to design a robot that cleaned at least two of the following materials- paper bits, LEGO™ pieces, water droplets, eraser dust, and pencil dust. They used LEGO Mindstorms™ kit and materials provided to them, such as mop and sponge, to construct the robot. Every construction material had an associated cost. The teams were asked to optimize the cost of their design.

We collected data from each team using audio and video recorders. We also conducted semi-structured interviews at the end of the design challenge and collected students' design artifacts and the workbooks given to them for taking notes and making sketches. We transcribed the video and audio data and noted the verbal conversations, gestures, interaction with objects, and gaze, in the transcript. Next, we analyzed the transcripts using the content analysis technique (Mayring, 2015). To ascertain the occurrence of uncertainty we used the coding scheme developed by Jordan et al. (2014), which focuses on the use of *hedgies*, *probability statements*, *hypotheticals*, *questions*, and *various nonverbal* indicators during student interaction. Next, we iteratively analyzed the uncertainty episodes to identify various management strategies based on our previous work (Kaur & Dasgupta, 2018).

## Findings

Teams reduced, suppressed or maintained the uncertainty during the design process. Strategies used by teams for reducing uncertainty were– *Analysis*, *Argumentation*, *Brainstorming*, *Experimentation and Trial & Error*, *Ask and Apply*, and *Observe and Replicate*. Students suppressed uncertainty by *ignoring* them. Strategies used by teams to maintain uncertainty was– *Delay Action*. Comparing the two teams, we found that during the entire design process, for group A, there were 31 episodes of uncertainty, whereas for group B, we found 40 episodes where the team faced uncertainty. We found differences in the way the two teams managed these uncertainties.

Group A used the *Ask and Apply and Ignore* strategy the most (23% each), followed by Experimentation and Trial & Error (19%). Group B used the strategy of *Analysis* the most (22%), followed by strategies like *Brainstorming* (20%), and *Argumentation* (17%). Use of strategies like *Delay Action* and *Ask and Apply* was negligible (2% each). We now share representative instances of how these strategies played out, and then discuss possible computer-supported solutions to scaffold these strategies.

## Analysis

This strategy includes actions like making sketches and diagrams, troubleshooting, and separating available information into parts. For example, consider the following episode:

*B1: We will have two motors like this, here is the sponge and the wipes [pointing to the sketch], and that brain [referring to the EV3 brick] will be dragging behind.*

*B2: I am still not clear...wouldn't it hurt the brick, we can put it on the top. And how will we attach that sponge and the wipes? And where are the wheels? How many do we need?*

*B1: We need four.*

*B2: Putting these on the sides [referring to sponge and wipes in the sketch] will not clean the trash completely. We also need to add a dustbin kind of thing to collect the trash.*

Here, group B learners B1 and B2 reflected on one of the alternatives sketched by them. They were figuring out how to attach different components of the robot (the motors, EV3 brick and cleaning materials) using the analysis strategy. While analyzing, the team identified issues with the design like the problem of dragging the brick, the problem with the sponge and wipes attached on the sides, etc. The strategy helped the team establish a function of garbage collection. It also gave rise to new uncertainties like where to put the EV3 brick, how to collect the garbage, and where to attach the sponge and wet wipes, thus expanding their problem space and opening opportunities to make their design even better.

## Argumentation

This strategy encompasses the process in which two or more engineers engage in a dialogue where arguments are constructed and critiqued. For example, consider the following episode:

*B1: Do we really need to make a bottom? I don't think so. [Referring to a support that team is trying to build to hold EV3 brick in the Robot].*

*B2: We need it because the surface will be uneven.*

*B1: No, because all the wheels we are using are of same height.*

*B2: But above the surface will be rough and the brick will keep falling down.*

*B1: We can do something, may be just tape it, because the bottom would be very costly.*

*B2: Ok. We can try it.*

Here, group B used the argumentation strategy for dealing with the uncertainty related to how to build sturdy but cheap support to hold the EV3 brick. The strategy likely helped in resolving conflicts and building consensus among the teammates. It also helped in making informed decisions and lead to clarification and reduction of doubts and misconceptions.

## Experimentation and Trial & Error

This strategy includes systematically testing option(s)/ ideas or engaging in Trial & Error method. For example, consider the following episode:

*A1: Should we just stick the wipe and sponge on the sides, or back or in front? Or should we just use sponge at the bottom and wipe at the back. I am not sure which will work better.*

*A2: Umm... I don't know, let's try them up.*

Here, in group A, while figuring out which design would help in cleaning the trash better, students started by testing their first idea, i.e., attaching sponge and wipes on the left and right side of the robot. To get the desired output, they used Trial & Error to check if anything worked. The team then tested another idea of using the sponge at the back. They did not test any further idea since they got a satisfying result.

## Brainstorming

This strategy refers to collaboratively generating ideas around a specific common problem. For example, consider the following episode:

*B1: We can fold the wipes.*

*B2: We can also cover the sponge with the wipes.*

*B1: We need a broom kind of thing and this [pointing to the cleaning wipes] will go wiping behind.*

*B3: Or a wipe followed by sponge. It will first do dry cleaning and then the wet cleaning.*

*B2: We can cut the wipes and the sponge to place it on both sides.*

Here, group B was faced with the uncertainty about how to use the additional cleaning materials given to them. They brainstormed different ideas which helped the team generate multiple ways of using the wipes and the sponge. This helped the teammates understand each other's perspectives and think of ways by which they can incorporate ideas of other team members. However, teams seemed to fixate on some particular ideas. For example, in this particular case, teams fixated on using all the materials provided to them. They wanted to use all the materials without thinking about other possible solutions that could serve the purpose better.

## Ignore uncertainty

This strategy includes actions like dismissing or paying no attention to the introduced uncertainty and moving forward without addressing them. For example, consider the following episode:

*A1: Our robot will clean everything.*

*A2: Should we use eraser dust? Won't it be difficult to clean it? It kind of...sticks to the floor.*

*A1: This is not important right now; we will be able to do it.*

Here, learner A2 of group A expressed the uncertainty about whether their design will be able to clean the eraser dust (one of the trash material). Learner A1 completely ignored this uncertainty by calling it unimportant. The uncertainty raised by the team member was regarding the constraints specified in the design problem. If this uncertainty had been addressed, the team may have realized that cleaning the eraser dust was not easy with the provided materials and this might have helped the team to further refine the design.

## Delay action

This strategy includes delaying action, decision, or evaluation. For example, consider the following episode:

*B1: Pass me the cost calculation sheet. I am worried that our robot will turn out a due to cost.*

*B2: Wait, let us first complete and then calculate, we have to make so many changes.*

*B3: Yeah, lets first program it and test it that is more important.*

Here, in Group B, B1 expressed her concerns regarding the cost of the robot. She wanted to calculate the cost to ensure that their budget was in control but the other two members asked her to do it later thereby delaying the action on it.

## Observe and replicate

It means observing the actions of other team members, other groups or an authority figure. Only group B used this strategy. For example, consider the following episode:

*B1: See, they have used the cage [structure to hold the EV3 brick].*

*B2: Yeah I think we should also just do it and start testing, we have no time left.*

We observed that when group B was struggling with the uncertainty about how and where to place the EV3 brick for a long time and failed to resolve it after many attempts; they went off to see the design of the other team and modified their design.

## Ask and apply

This strategy refers to asking for a solution from a teammate or an authority figure and then applying it directly. For example, consider the following episode:

AI: So, if you have to clean the dry dust, do we have to take it or we have to just move it aside?

Mentor: See that is your wish, anything works.

AI: So, even with the sponge we can just move it like this [Shows dragging action].

There were many instances like this one for group A where the team members preferred approaching an authority figure like a mentor instead of discussing it among themselves. However, for group B, there was a lot of discussion happening among the teammates and there were only a few instances where they preferred asking for a solution directly.

## Discussion

Students collaboratively managed the uncertainties using the management strategies mentioned in the above section. It was observed that students faced some issues while using these strategies which led to ineffective uncertainty management. For example, in the case of analysis and brainstorming, the dominance of certain team members led to unequal participation. A potential solution to this problem is to follow a structured way of collaborative turn taking or use of collaborative dialogue or negotiation tools (Jeong & Hmelo-Silver, 2016). Similarly, sketches played an important role in guiding discussions during analysis and brainstorming, but superficial sketches weakened their analysis as they missed important aspects to be analyzed. Majorly, these sketches lacked specifications like dimensions, size, materials, etc. and were incompletely labeled. Using collaborative and discussion-led sketching tools with reflective prompts can help in improving the quality of analysis. In the case of argumentation, it was observed that students' actions were not backed with appropriate reasoning. Using argumentation construction tools for helping students construct sound arguments might be a solution to this problem. Also, while brainstorming, teams got fixated on certain ideas which restricted them from further exploration. Engineering design tools like 6-3-5 Method, C-sketch method and the Gallery method (Dym et al., 2009) can help the teams expand the solution space while brainstorming.

Further detailed studies need to be conducted to understand different issues involved in the process of collaborative uncertainty management. Technological affordances, like the ones discussed above, can then be utilized to solve these issues and help learners manage uncertainties effectively.

## Conclusion

The preliminary results presented in this paper help us understand how middle school students manage uncertainty while solving an engineering design challenge collaboratively. Effective scaffolds for helping learners to manage uncertainties collaboratively can only be designed once we understand what problems and issues learners face during the management process. The work done in this paper is, therefore, an important step in gaining insights about what form and features can a computer-supported collaborative learning environment possess to ensure that learners are able to develop the skill of managing uncertainties effectively.

## References

- Clore, G. L. (1992). Cognitive phenomenology: Feelings and the construction of judgment. *The Construction of Social Judgments*, 10, 133–163.
- Dym, C. L., Little, P., Orwin, E. J., & Spjut, E. (2009). *Engineering design: A project-based introduction*. John Wiley and sons.
- Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help? *Educational Psychologist*, 51, 247–265.
- Jordan, M. E., Cheng, A.-C. J., Schallert, D., Song, K., Lee, S., & Park, Y. (2014). “I guess my question is”: What is the co-occurrence of uncertainty and learning in computer-mediated discourse? *International Journal of Computer-Supported Collaborative Learning*, 9(4), 451–475.
- Jordan, M. E., & McDaniel Jr, R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences*, 23(4), 490–536.
- Mayring, P. (2015). Qualitative content analysis: Theoretical background and procedures. In *Approaches to qualitative research in mathematics education* (pp. 365–380). Springer.
- Kaur, N. & Dasgupta, C. (2018). Types of uncertainty and collaborative uncertainty management strategies evidenced during the engineering design process. *International Conference on Computers in Education*, 175-180.

# Understanding Climate Change Through Collaborative Versus Individual Inquiry With Constructive or Example-Based Scaffolds

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**Abstract:** We investigated a constructive and an example-based scaffold when learning from dynamic visualizations about climate change. Learners collaboratively or individually generated a diagram that represented energy flow (constructive scaffold) or observed a peer learner generating the diagram (example-based scaffold). We hypothesized that collaborative learners would benefit more from the constructive than the example-based scaffold, but that the opposite would be the case for individual learners. Seventy-one university students were randomly allocated to conditions in the 2X2 between-subjects design. Climate change understanding was measured at pre- and posttest. Preliminary results supported our hypothesis. We conclude that the constructive scaffold elicited questions that led to deep engagement in the collaborative condition, resulting in better understanding. Individual learners possibly failed to recognize crucial concepts in the constructive condition because they had questions but nobody to discuss with. They profited more from the example-based scaffold which emphasized central concepts of climate change.

## Objective

The rationale for our study is that scaffolding effects are usually investigated without considering the social mode of learning. Dependent on whether learners study individually or collaboratively, specific types of scaffolds might be more or less suited. Our aim is to determine which properties of scaffolds elicit effective learning processes in individual, and which in collaborative settings.

## Theoretical and empirical background

Inquiry settings actively involve the learner in knowledge construction by engaging them in various epistemic activities such as making predictions, experimenting, evaluating evidence, explaining, revising predictions, discussing, and critiquing (Fischer et al., 2014; Linn & Eylon, 2011). Scientific models are suited to test predictions, to be evaluated, and revised (Schwarz et al., 2009). Due to technological affordances, scientific models can be implemented in inquiry settings fairly easily, as well as dynamically depict aspects of scientific phenomena that are otherwise not directly observable, allow experimentation that would not be possible in a classroom, and better represent the complexity of scientific phenomena. Thus, they show an advantage over static images in fostering coherent science understanding (McElhane, Chang, Chiu, & Linn, 2015).

Key to inquiry learning is learner guidance (Lazonder & Harmsen, 2016). Designers of scaffolds, however, are challenged with the aptly named “assistance dilemma” (Koedinger & Aleven, 2007): The fine line between providing too much or insufficient support. To be most effective, scaffolds ought to operate at what Vygotsky (1978) called the learner’s zone of proximal development (Tabak & Kyza, 2018). If a scaffold provides too much information, a learner has no room for autonomous inquiry or improvement. If a scaffold provides too little information, a learner might be overwhelmed with the task.

Research determining effective scaffolds usually investigates scaffolding independent of the social mode of learning. As known from worked example research, involving learners in problem solving before they processed domain concepts and problem structures, often results in the use of ineffective strategies. Learners should first learn with a worked example, from which domain principles and problem structures as well as solution strategies can be inferred, before engaging in less structured activities (Renkl, 2014). In example-based learning, “the apprentice observes the master demonstrating how to do different parts of the task” (Collins, Brown, & Holum, 1991, p. 2 online version). In other words, what usually happens “within” a problem-solver is externalized for observing learners. It seems, that properties of example-based scaffolds might be more suited for individual and less for collaborative learning settings.

Collaboration is a typical and critical feature of inquiry-based learning (Linn & Eylon, 2011). The effectiveness of collaboration depends on “the extent to which groups actually engage in productive interactions” (Dillenbourg, Järvelä, & Fischer, 2009, p. 6). For this reason, collaboration scaffolds have been designed to

support learners' productive interaction (Kollar, Fischer, & Slotta, 2007). These scaffolds, called collaboration scripts, are most effective when they prompt learners to build on each other's ideas (Vogel, Wecker, Kollar, & Fischer, 2017). Designing content scaffolds for collaborative settings should thus be effective, when they give learners opportunities to externalize their ideas, and build on each other's ideas. In general, properties of scaffolds for collaborative settings should promote learners to generate instead of process information.

Notably, the "generative" property of scaffolds that has been identified as ineffective for individual learning, might be the essential property in collaborative settings because it elicits questions which constitutes the basis for debating meaning, argumentation, consensus building, or other interactive activities that foster successful collaboration (Weinberger & Fischer, 2006). Building on each other's ideas or constructing ideas beyond the learning materials are at the top of the ICAP framework's hierarchy of deep cognitive involvement (Chi & Wylie, 2014), which aligns with the assumed mechanism. In individual learning however, it seems that active engagement, although lower on the ICAP's hierarchy, is essential for learners' success. Whereas individual learners might feel discouraged through constructive scaffolds and give up or skip over the understanding part, in collaboration settings understanding happens through constructing knowledge in interaction. In other words, collaborative learners would not benefit from the typical advantages of collaboration when using example-based scaffolds, as it might elicit less interaction.

## Research question and hypothesis

Learners creating a model, such as drawing a diagram, externalize crucial features and how features are linked, as well as underlying mechanisms, or relations (Schauble, 2018). A diagram activity thus scaffolds learning from a dynamic visualization. In the present study learners used dynamic visualizations to understand climate change in an online inquiry unit which they either completed collaboratively or individually. We compared two different scaffolds alongside the dynamic visualization and hypothesized:

The constructive scaffold fosters understanding climate change more effectively than the example-based scaffold when learners collaborate but the opposite is the case when learners study individually.

## Method

### Sample, design, and materials

German university students were recruited via advertisements to participate in the study, received a participation certificate, and were entered into a lottery to win one of eight 50€-Amazon gift cards. A priori power was calculated with G\*Power version 3.1 and the target sample size for detecting a medium sized effect (lower end of medium effect size according to Cohen  $f = .2$ ) with 80% power and a 5% alpha error probability is  $N = 199$ . Preliminary results reported in this paper refer to  $N = 71$  participants (44 females, 26 males, 1 other) with a mean age of 25.30 years ( $SD = 5.85$ ). Participants were randomly allocated to one of the four experimental conditions of the 2X2 between-subjects design. The two manipulated factors were scaffold (constructive vs. example-based) and study mode (collaborative vs. individual).

Participants learned about different types of energy, energy flow and transformation, how energy interacts with greenhouse gases and the ozone layer, and how this contributes to global warming in an online inquiry-learning unit with dynamic visualizations. Dynamic visualizations (NetLogo simulations) portray the entire process from solar energy entering the Earth's atmosphere, being absorbed by the Earth's surface, transforming into heat energy within the Earth's surface, being released as infrared radiation back into the Earth's atmosphere, and either exiting the Earth's atmosphere or being held back by greenhouse gases. In addition, dynamic visualizations address the role of the ozone layer, which is commonly but erroneously assumed to affect the rise of global temperatures (Andersson & Wallin, 2000).

### Scaffolds and study mode

Learners in the constructive scaffold condition created an energy-flow diagram (a type of concept map). Learners begin with an empty workspace and drag and drop icons that represent the physical system (e.g., the Earth) and choose from several types of energy when linking the icons (e.g., solar energy). Linking the icons shows the energy type and flow direction. Learners receive automated guidance which prompts them to further investigate the dynamic visualization if ideas are inaccurately represented. Learners in the example-based scaffold condition observed a modeling video, in which a peer learner creates the diagram, receives guidance and revises the diagram until energy flow is accurately represented.

In the individual condition, participants did not see each other's monitor display and worked alone. In

the collaboration condition, participants saw each other's monitor and collaborated throughout the learning unit.

## Procedure

Participants first completed a pretest including multiple choice, open response items and a diagram (20 minutes). After a quick explanation of how to navigate in the unit, they worked in the inquiry environment for 1.5 hours. Immediately after the unit, participants completed the same test as before and an additional transfer item.

## Understanding of global climate change

In this paper, we only report the outcome of the multiple choice test, consisting of 10 items with four answer options each. An example item is: "How do greenhouse gases influence global temperature?". The following answer options include the correct answer (a): a) Greenhouse gases contribute to an increase in global temperature as they absorb infrared radiation and send it back to the Earth's surface, b) Greenhouse gases contribute to an increase in global temperature as they absorb infrared radiation and send it back to the Earth's surface as heat energy, c) Greenhouse gases contribute to an increase in global temperature in a different way, d) Greenhouse gases do not interact with other types of energy and thus do not affect global temperature. All ten items were shown to participants in random order, as were the four answer options of each item. Each item included one correct answer, each correct answer was coded with 1 point resulting in a maximum of 10 points. Items were designed by a group of researchers and refined through cognitive interviews and feedback from subject matter experts. Reliability of both tests was low:  $r_{tt} = .28$  (acceptable) for pre- and  $r_{tt} = .60$  (acceptable) for posttest.

## Statistical analysis

The alpha level was set to 5% in all analyses. Statistical software used was SPSS24. Data from the collaborative condition was considered as hierarchical as individual learners were nested in dyads. To eliminate potential effects of particular learning partners on each other, we calculated the ICC for the collaborative condition. The ICC was close to 0 and statistically not significant which indicates that units in the same dyad did not resemble each other more than they resembled units from other dyads with respect to individual scores in the multiple choice test. Using individuals as unit of analysis is appropriate in this case. We tested differences in prior knowledge between all four conditions with a two-factorial ANOVA. Results showed that there were no systematic differences in prior knowledge before the study; no statistically significant difference between the scaffold conditions  $F(1, 67) = 0.02, p = .894, \eta_p^2 < .01$ , between the study mode conditions  $F(1, 67) = 0.2, p = .655, \eta_p^2 < .01$ , and no statistically significant interaction  $F(1, 67) = 0.17, p = .668, \eta_p^2 < .01$  (descriptive statistics in Table 1). It is therefore appropriate to not control for prior knowledge (Senn, 2013). Also, because the prior knowledge measure cannot be considered reliable.

## Results

A 2X2 ANOVA with factor 1 scaffold (constructive vs. example-based), factor 2 study mode (collaborative vs. individual), and knowledge about climate change as dependent variable showed that neither of the two scaffolds was more effective ( $F(1, 67) = 0.35, p = .558, \eta_p^2 = .01$ ), and neither study mode was more effective than the other ( $F(1, 67) = 0.8, p = .374, \eta_p^2 = .01$ ). In contrast, the interaction effect of scaffold and study mode was statistically significant,  $F(1, 67) = 4.22, p = .044, \eta_p^2 = .06$ . Descriptive statistics (Table 1) show that collaborative learners understood more with the constructive scaffold than with the example-based scaffold but that individual learners understood more with the example-based than with the constructive scaffold.

## Discussion and conclusion

Without a peer to discuss, individual learners might have resorted to weak strategies when trying to learn with the constructive scaffold. They might not have recognized crucial aspects of the dynamic visualizations by themselves. It was more beneficial to observe the modeling video (i.e., the example-based scaffold) because the demonstration of constructing a simplified model of energy flow and transformation that explicitly includes inaccurate ideas and their revision helped individual learners to recognize crucial aspects of the dynamic visualization and consequently understand domain principles (Renkl, 2014). Learners who have a peer to consult might (a) more easily master technical aspects of the modeling task (how to link icons) and (b) overcome challenging aspects by asking questions, verifying understanding, or debating meaning (Weinberger & Fischer, 2006). We assume that the constructive scaffold elicited high task engagement which reflects that learners were deeply cognitively engaged (Chi & Wylie, 2014). However, with the example-based scaffold the potential of collaboration might have been underutilized, as it elicited less questions and thus less interaction followed.

Conclusions are limited because results are based on a preliminary set of participants. Further, so far



only multiple choice items were used to measure understanding of climate change and a more valid picture of learners' understanding and the effects of the scaffolds will be obtained when open items and diagrams are included in the analyses. We will follow up on the idea that the constructive scaffold elicited more interaction than the example-based in the collaborative condition by analyzing video data of collaboration sessions.

Table 1: Descriptive statistics for multiple choice test across all four conditions at pre- and posttest

	Individual				Collaboration			
	$M_{pre}$	$SD_{pre}$	$M_{post}$	$SD_{post}$	$M_{pre}$	$SD_{pre}$	$M_{post}$	$SD_{post}$
Constructive Scaffold	4.64	1.14	7.64	1.87	4.64	1.28	8.79	1.12
Example-based Scaffold	4.52	1.4	8.67	1.46	4.86	2.41	8.21	1.76

## References

- Andersson, B., & Wallin, A. (2000). Students' understanding of the greenhouse effect, the societal consequences of reducing CO<sub>2</sub> emissions and the problem of ozone layer depletion. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 37(10), 1096–1111.
- Chi, M. T., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, 49(4), 219–243.
- Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American educator*, 15(3), 6–11.
- Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In N. Balacheff, S. Ludvigsen, & T. de Jong (Eds.), *Technology-enhanced learning* (pp. 3–19). Dordrecht: Springer.
- Fischer, F., Kollar, I., Ufer, S., Sodian, B., Hussmann, H., Pekrun, R., . . . Fischer, M. (2014). Scientific reasoning and argumentation: Advancing an interdisciplinary research agenda in education. *Frontline Learning Research*, 2(3), 28–45.
- Koedinger, K. R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review*, 19(3), 239–264.
- Kollar, I., Fischer, F., & Slotta, J. D. (2007). Internal and external scripts in computer-supported collaborative inquiry learning. *Learning and Instruction*, 17(6), 708–721.
- Lazonder, A. W., & Harmsen, R. (2016). Meta-Analysis of Inquiry-Based Learning: Effects of Guidance. *Review of educational research*, 86(3), 681–718.
- Linn, M. C., & Eylon, B.-S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*: Routledge.
- McElhaney, K. W., Chang, H.-Y., Chiu, J. L., & Linn, M. C. (2015). Evidence for effective uses of dynamic visualisations in science curriculum materials. *Studies in Science Education*, 51(1), 49–85.
- Renkl, A. (2014). Toward an instructionally oriented theory of example-based learning. *Cognitive Science*, 38(1), 1–37.
- Schauble, L. (2018). In the eye of the beholder: Domain-general and domain-specific reasoning in science. In F. Fischer, C. A. Chinn, K. Engelmann, & J. Osborne (Eds.), *Scientific Reasoning and Argumentation. The roles of domain-specific and domain-general knowledge* (pp. 21–43). New York, NY: Routledge.
- Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., . . . Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, 46(6), 632–654.
- Senn, S. (2013). Seven myths of randomisation in clinical trials. *Statistics in Medicine*, 32(9), 1439–1450.
- Tabak, I., & Kyza, E. A. (2018). Research on Scaffolding in the Learning Sciences. A Methodological Perspective. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), *International Handbook of the Learning Sciences* (pp. 191–200). New York and London: Routledge.
- Vogel, F., Wecker, C., Kollar, I., & Fischer, F. (2017). Socio-cognitive scaffolding with computer-supported collaboration scripts: A meta-analysis. *Educational Psychology Review*, 29(3), 477–511.
- Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education*, 46(1), 71–95.

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# Emergent Roles, Collaboration, and Conceptual Outcomes for Two Eighth-Grade Groups in CSCL Science Classes

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**Abstract:** When collaborating in groups, students may assume emergent roles as they interact over time. Emergent leadership can improve group functioning, but this depends on how leadership is supported by group members. We studied how roles emerged in two groups of eighth-graders participating in CSCL activities over a 12-week science unit. A leader emerged in each group, but through different processes. Group A showed greater distribution of contributions to decision-making and science talk than Group B, as well as greater conceptual gains on a content test. In contrast, Group B focused more on off-task talk than Group A. While our sample is too small to make causal claims, better distribution of contributions to talk and on-task participation seemed to positively impact collaboration and learning.

## Introduction

Collaborative activities help students to share perspectives, negotiate meaning-making, and deepen their understanding (Stahl, 2006). However, assigning students to groups does not mean that they will collaborate in productive ways (Dillenbourg, 2002). To support collaboration, scaffolds, such as scripts, can help students set groups norms and interact in productive ways (Mercer & Dawes, 2008; Wang, Kollar, & Stegmann, 2017). Some scripts include roles that are intended to foster collaborative meaning-making (De Wever, Van Keer, Schellens, & Valcke, 2010; Strijbos & De Laat, 2010). Scripted roles assign responsibilities to group members, which can improve students' accountability, interdependence, equity in contributions, collaboration, and learning (De Wever et al., 2010; Strijbos & De Laat, 2010). However, scripted roles have some limitations. Rigid roles constrain students' self-regulation (Wang et al., 2017), and students may deviate from scripts (Hoadley, 2010). This latter issue points to a need to understand how roles emerge with and without scripts.

To understand emergent roles, we can examine how students working in groups take on responsibilities over time, and, in turn, how these responsibilities constrain students' interactions (Mercier, Higgins, & da Costa, 2014; Sarmiento & Shumar, 2010). For example, students taking on leadership roles may direct the group's intellectual or organizational progress (Mercier et al., 2014), with or without support from others (Strijbos & De Laat, 2010). Leaders may also attempt to control others' participation or use of shared resources (Jones & Issroff, 2005). Yet, other students may seem to abdicate their responsibilities (e.g., free-riders; Strijbos & De Laat, 2010). How students take on roles, whether scripted or emergent, has implications for the efficiency and structure of group collaboration and can shape how learning processes unfold (Spada, 2010; Strijbos & De Laat, 2010). Further, emergent intellectual leaders can help groups to successfully complete tasks (Mercier et al., 2014). In our study, we aimed to understand how roles emerged in two groups as they participated in a CSCL science unit. Our research questions were: *how did roles emerge via group discourse over the 12-week unit, and what effects did roles have on students' conceptual outcomes?* These questions have implications for supporting learning processes in CSCL contexts that encourage student to set their own group norms.

## Methods

This study investigated how two groups of eighth-grade students (4 students per group,  $N = 8$ ) collaborated during a 12-week, design-based CSCL science unit. Both groups had the same teacher, but in different classrooms of an urban middle school in the U.S. Midwest. During the unit, students designed compost bioreactors that decomposed quickly and odorlessly while promoting microbial activity. Two CSCL activities informed students' designs. Students collaboratively brainstormed questions and conducted research using an e-textbook over four sessions. Students also used a simulation to explore decomposition in compost over four sessions. While the teacher determined the groups, no scripts or other scaffolds for collaboration were provided.

We collected video data from the first and last sessions with the e-textbook and the simulation for each group (558 min). Our goal was to analyze how students' discourse and control of resources shaped role formation over time. To analyze groups' discourse, we developed a coding scheme for students' decision-making and science talk (Lemke, 1990) after viewing videos of group work. Our first category, *Decision-Making Talk*, included the following codes: (i) asking for decisions; (ii) making conceptually-directed decisions; (iii) making task-related decisions; (iv) accepting a decision; (v) repeating a decision; (vi) questioning a decision; (vii) offering

an alternative; and (viii) controlling resources. Our second category, *Science Talk*, included the following codes: (i) reporting observations or results; (ii) conceptual discussions; and (iii) metacognitive reflection on group knowledge. We also included a category for *Off-Task Talk*.

The first two authors established inter-rater reliability with 10% of the full data set (717 turns of talk, Cohen’s kappa = .843). The first author coded the remaining data (except teacher-student talk and inaudible talk) for a total of 5,504 turns of talk. We next calculated frequencies of students’ coded discourse and divided each student’s total by the group’s total for each code. We used these proportions to compare students’ talk over time and identify roles in groups. We also compared the two groups’ talk using *z*-score tests of homogeneity.

Finally, we compared student’s pre- and post-unit scores from a researcher-designed content test. Due to small group sizes, we compared relative percent gains within groups, rather than conducting statistical tests.

## Findings

To understand roles, we analyzed how each group member contributed to group discourse, especially decision-making and science talk. Group A contributed 2,407 turns of talk. Mala contributed the most to (40.0%), followed by Sylvia (28.0%), Rose (27.3%), and Melinda (4.7%). Table 1 below shows each student’s contributions to decision-making and science talk over the four activities, with darker shading indicating higher contributions.

Mala contributed the most to conceptual (70.7%) and task-based (55.1%) decision-making during three of four activities. She also offered alternatives (36.2%) and controlled resources (38.7%) more than her group members. Sylvia and Rose also contributed to decision-making, especially during Activity 3 (see Table 2). Sylvia contributed the most to asking (41.0%), accepting (35.6%), and questioning (37.5%). Rose repeated decisions as often as Mala (32.7%), but she also contributed the most to off-task talk (33.5%). Melinda contributed the least to each kind of talk. Regarding students’ science talk, Mala contributed the most to conceptual discussion (44.2%), followed by Sylvia (26.1%), Rose (25.1%), and Melinda (4.7%). Mala also contributed the most to metacognitive reflection (51.8%), followed by Rose (27.1%), Sylvia (20.0%), and Melinda (1.2%). Thus, Mala contributed the most to conceptual and metacognitive talk in Group A.

As Mala contributed the most to decision-making and science talk overall, we identified her as the *conceptual and task leader* in Group A, with support from other members (see the excerpt below Table 1). However, Sylvia and Rose made considerable contributions to the group’s discourse, especially during Activity 3. Sylvia acted as the *decision evaluator* by asking for, questioning, and accepting others’ suggestions, with some support from Rose. In contrast, Melinda acted as a *quiet learner* in her group. Melinda contributed little to group discourse, but we observed she used the simulation on her own to conduct additional experiments as Mala, Sylvia, and Rose discussed earlier experiments. We also noted that students tended to focus their gaze on shared resources (e.g., the computer) or each other during discussions, which we interpreted as active participation.

Table 1: Group A’s decision-making and science talk over four activities

Student	Decision-Making Talk				Science Talk			
	Activity 1	Activity 2	Activity 3	Activity 4	Activity 1	Activity 2	Activity 3	Activity 4
Mala	0.420	0.488	0.290	0.446	0.461	0.524	0.242	0.491
Sylvia	0.283	0.218	0.430	0.329	0.238	0.154	0.401	0.242
Rose	0.268	0.218	0.269	0.189	0.248	0.264	0.338	0.218
Melinda	0.029	0.077	0.011	0.036	0.053	0.058	0.019	0.048

Mala:	Who is your group leader? All right, me.
Rose:	Mala.
Sylvia:	Group leader – do we even have one?
Rose:	Yeah, Mala.
Sylvia:	Wouldn’t that be [the teacher]?
Rose:	No, it would be one of us.
Mala:	I’m the leader today.

For comparison, Group B contributed 3,097 turns of talk. Christy contributed the most (34.3%), followed by Josh (27.3%), Lydia (21.2%), and Luis (17.2%). Table 2 below shows each student’s contributions to decision-making and science talk over the four activities, with darker shading indicating higher contributions. Christy contributed the most to conceptual (80.0%) and task-based (60.3%) decision-making during the four activities. She also asked (50.0%), accepted (51.4%), repeated (43.8%), and offered more alternative (55.0%) decisions. Josh questioned decisions (46.7%) and controlled resources (38.7%) more than other group members. Lydia and

Luis contributed less to decision-making than Christy or Josh. Regarding students' science talk, Christy contributed the most to conceptual discussion (52.3%), followed by Josh (28.1%), Lydia (10.1%), and Luis (9.5%). Christy also contributed the most to metacognitive reflection (70.0%), followed by Lydia (20.0%), Josh (10.0%), and Luis (0.0%). Thus, Christy contributed the most to conceptual and metacognitive talk in Group B.

As Christy contributed the most to decision-making and science talk, we identified her as the *conceptual and task leader* in Group B. Group B, however, seemed to accept her leadership differently than in Group A. While other members of Group A actively supported and/or questioned Mala's ideas, the members of Group B accepted Christy's role as leader by abdicating responsibility. Group B seemed content to let Christy "do all the work" (see the excerpt below Table 2). Group B also demonstrated frequent off-task talk or activities, such as braiding hair. Josh provided limited support for Christy's decision-making by questioning others' decisions. However, Lydia and Luis mostly acted as *free-riders* in the group (Strijbos & De Laat, 2010).

Table 2: Group B's decision-making and science talk over the four activities

Student	Decision-Making Talk				Science Talk			
	Activity 1	Activity 2	Activity 3	Activity 4	Activity 1	Activity 2	Activity 3	Activity 4
Christy	0.508	0.546	0.612	0.569	0.487	0.491	0.561	0.444
Josh	0.161	0.303	0.259	0.235	0.223	0.362	0.311	0.270
Lydia	0.195	0.118	0.082	0.118	0.140	0.098	0.054	0.159
Luis	0.136	0.033	0.047	0.078	0.151	0.049	0.074	0.127

Christy: What the heck?  
 Josh: What the heck, nah nah. We haven't even got this done yet. We haven't even got this done yet. We're all working while you're just talking so...  
 Christy: What the...?  
 Luis: And *you're* stressing out.  
 Lydia: Josh, she's doing all the work.

Thus, one student in each group emerged as a conceptual and task leader. However, the dynamics in which leadership emerged differed between groups. In Group A, Sylvia and Rose actively negotiated Mala's ideas. However, in Group B, Christy was the primary decision-maker and contributed the most science talk. To illustrate differences, we compared groups' talk using *z*-score tests of homogeneity. We found that Group A contributed significantly more decision-making talk than Group B (37.6% vs. 12.1%,  $z = 22.2$ ,  $p < .001$ ). Also, Group A contributed significantly more science talk than Group B (38.9% vs. 20.2%,  $z = 15.3$ ,  $p < .001$ ). However, Group B contributed significantly more off-task talk than Group A (69.5% vs. 30.6%,  $z = 28.7$ ,  $p < .001$ ). Thus, Group A seemed to demonstrate more productive collaboration than Group B.

We also compared students' learning outcomes as assessed on a content test. We calculated percent gains by subtracting pre-test scores from post-test scores. In Group A, all four students showed conceptual gains on the post-test (ranging from 15.4% to 37.5%, with an average gain of 25.7%). Sylvia improved by 37.5% on her post-test (41.9% to 79.4%). Rose improved by 25% (50.0% to 75.0%), as did Melinda (66.2% to 91.2%). Mala improved by 15.4% (66.9% to 82.4%). Yet, in Group B, only two students showed conceptual gains on the post-test (ranging from -2.9% to 25.0%, with an average gain of 7.2%). Josh improved by 25.0% on his post-test (59.6% to 84.6%) and Lydia improved by 6.6% (58.1% to 64.7%). However, Luis had a 2.9% decrease on his post-test (66.9% to 64.0%). Christy had scored 100% on her pre-test, and she again scored 100% on the post-test (0.0%). Thus, Group B demonstrated lower conceptual gains on the post-test than Group A.

## Discussion and conclusion

Our goal was to understand how roles emerged during CSCL activities in a 12-week science unit, and how these roles may have shaped students' conceptual outcomes. From our analysis of group members' contributions to decision-making and science talk over time, we found that one student in each group assumed a leadership role. Mala (Group A) and Christy (Group B) contributed the majority of conceptual and task-based decision-making, as well as conceptual discussion and metacognitive reflection. Thus, Mala and Christy acted as intellectual and organizational leaders in their respective groups (Mercier et al., 2014). However, we observed differences in how other group members accepted this leadership. Mala's group members seemed to accept her leadership while still engaging in constructive critique of her ideas (Mercer & Dawes, 2008). However, Christy's group members accepted her leadership because it meant they could contribute less. Consequently, Group A seemed to collaborate

more effectively than Group B, as members of Group A engaged in more decision-making and science talk, and significantly less off-task talk, than Group B.

Although members of Group A did not contribute equally to conceptual discussions or metacognitive reflection, they all showed conceptual gains on their post-tests. Even the quiet student, Melinda, appeared to benefit from her group's conceptual and metacognitive talk, as shown by her higher post-test score (the second highest score of students in both groups, with the exception of Christy). However, in Group B, only Josh and Lydia showed conceptual gains on their post-tests. This is partially explained by Christy's maximum score on both pre- and post-tests. However, Luis appeared to do *worse* on the post-test. Luis did not show the same benefit as Melinda, likely explained by his tendency to engage in off-task talk.

While acknowledging that our sample is too small to determine causality, our findings indicated that distributed, active participation in CSCL activities (in discourse or attention) may be more important than emergence of a leader in supporting collaboration and conceptual gains in each group. Each group included an emergent leader (Mala, Christy), along with one student who contributed little to group decision-making (Melinda, Luis). However, the less-verbal students showed marked differences in their participation and outcomes. Melinda seemed to pay attention to her group's activities; conducted experiments as other students discussed concepts; and demonstrated conceptual gains on her post-test. Luis, however, participated in off-task talk and activities, and actually did worse on the post-test than pre-test. His lack of participation reflected a larger trend in Group B to engage in "free-riding" (Strijbos & De Laat, 2010), as members of Group B seemed content to let Christy complete their work. Correspondingly, Group B demonstrated overall lower conceptual gains compared to Group A.

This study's implications relate to how the assumption of roles, as evidenced in group discourse, shapes collaboration and learning within groups. Intellectual leaders can help groups to successfully complete tasks (Mercier et al., 2014), but how leaders are accepted may also affect the group's conceptual outcomes. While a student in each group assumed leadership, this leadership did not always promote productive collaboration (Dillenbourg, 2002). Thus, some scripting of roles may support student's participation in shared meaning-making (De Wever et al., 2010; Spada, 2010). However, since students do not always enact roles as intended (Hoadley, 2010), we must understand how groups establish roles and norms for collaboration over time (Mercer & Dawes, 2008; Sarmiento & Shumar, 2010) to inform the ways in which we integrate scaffolds for setting group norms (Wang et al., 2017) and intervene at key points to redistribute roles and reshape collaboration.

## References

- De Wever, B., Van Keer, H., Schellens, T., & Valcke, M. (2010). Roles as a structuring tool in online discussion groups: The differential impact of different roles on social knowledge construction. *Computers in Human Behavior, 26*(4), 516-523.
- Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In *Three worlds of CSCL* (pp. 61-91). Heerlen: Open Universiteit Nederland.
- Hoadley, C. (2010). Roles, design, and the nature of CSCL. *Computers in Human Behavior, 26*(4), 551-555.
- Jones, A., & Issroff, K. (2005). Learning technologies: Affective and social issues in computer-supported collaborative learning. *Computers & Education, 44*(4), 395-408.
- Lemke, J. (1990) *Talking science: Language, learning, and values*. Norwood, N.J.: Ablex.
- Mercer, N. & Dawes, L. (2008). The value of exploratory talk. In N. Mercer & S. Hodgkinson (Eds.), *Exploring talk in school* (pp. 55-71). London: Sage
- Mercier, E. M., Higgins, S. E., & Da Costa, L. (2014). Different leaders: Emergent organizational and intellectual leadership in children's collaborative learning groups. *ijCSCL, 9*(4), 397-432.
- Sarmiento, J. W., & Shumar, W. (2010). Boundaries and roles: Positioning and social location in the Virtual Math Teams (VMT) online community. *Computers in Human Behavior, 26*(4), 524-532.
- Spada, H. (2010). Of scripts, roles, positions, and models. *Computers in Human Behavior, 26*(4), 547-550.
- Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. Cambridge, MA: MIT Press.
- Strijbos, J. W., & De Laat, M. F. (2010). Developing the role concept for computer-supported collaborative learning: An explorative synthesis. *Computers in Human Behavior, 26*(4), 495-505.
- Wang, X., Kollar, I., & Stegmann, K. (2017). Adaptable scripting to foster regulation processes and skills in computer-supported collaborative learning. *ijCSCL, 12*(2), 153-172.

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# Examining How Scientific Modeling Emerges Through Collective Embodied Play

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**Abstract:** Previous studies demonstrated that embodied play in a mixed-reality environment can be an entry point for young children to learn about scientific modeling. However, it's still unclear how specific features of play orient students towards scientific modeling and thus science learning. We investigate how the organization of an activity where students pretend to be bees to learn about how bees pollinate might direct their attention either to treating these activities as play or to exploring the underlying rules about how bees behave in the real world in a manner more akin to modeling. We describe three activities where students appear to have engaged in different kinds of play and explore how their actions and teachers' orientation produced either playful rules or scientific accounts. The implications of this work will support teachers and researchers in organizing embodied play activities that help students engage with scientific concepts.

## Introduction

Play as defined by Vygotsky (1978) is the combination of two key features: an imaginary situation and a set of rules, which allows students to explore the explicit rules of the social world by engaging in the imaginary situation. While play is often accepted in out-of-school settings, it has been rarely treated as a powerful learning tool in classrooms. Nonetheless, scholars have argued that there are ways that play can help with science learning. For example, when used to articulate ideas about how the world works, play can be viewed as a form of inquiry (Youngquist & Pataray-Ching, 2004). Based on Lesh and Deorr's (2003) definition, a scientific model contains "elements, relations, operations, and rule governing interactions that are expressed using external notation systems." Both play and scientific models are rule-based activities. In play, students can explore and negotiate the rules to make the play meaningful to themselves; while in modeling, the rules refer to the relationships between objects in the natural world. Therefore, we argue there is real potential to use play as an entry point for learning scientific modeling (Enyedy, Danish, Delacruz, & Kumar, 2012) because play helps students orient towards the implicit rules of a social situation or phenomena. However, not all play activities automatically lead students to engage in the target content. Therefore, in this work we explore how teachers' organization of play activities in the form of prompts and materials may lead students to engage either solely with fun aspects of the play context, or with scientifically normative rules more akin to modeling. Specifically, we focus on how the students orient their play either toward fun, nonscientific features, or to normative scientific accounts during their interaction in the Science through Technology Enhanced Play (STEP) project (Enyedy, Danish, & DeLiema, 2015).

## Design

This work builds on the Science through Technology Enhanced Play (STEP) Project, which is a Mixed Reality (MR) environment to support young children learning science concepts through sociodramatic play. When students move in the classroom, Microsoft Kinect cameras track their motion and feed it into a computer simulation, which depicts their movements as bees in the meadow. The STEP environment provides the imaginary context for students (pretending to be a bee), so that students can explore the rules of the phenomena (how bees collect nectar) through their embodied play (See Figure 1). Our prior work has demonstrated that this general approach was quite successful in helping students understand how honeybees collect nectar. The current implementation took place over 8 days. Our present analysis focuses on activities from Day 6 and Day 8, when students engaged with a range of materials to explore how bees that are foraging flowers in search of nectar have pollen stick to their bodies and thus unintentionally support pollination.

## Method

## Participants and data source

In the STEP project, participants (n=48) were from a first and second grade classroom at a public elementary school in a small city in the midwestern United States. Each classroom was teacher-assigned into two groups and participated in eight 45-minute lessons. Each teacher led two groups of students from their own classroom, and the researchers were present with the teacher to facilitate the conversation. Here we present an illustrative case study from two days (Day 6 and Day 8) when one group of second graders (n =13) engaged in the embodied activities to learn about the procedure of pollination. Day 6 was the first day we started to introduce the concept of pollination to the students. Students were given stickers and blocks as tools to demonstrate the procedures of pollination. Then they switched to interact with the STEP environment to continue exploring the rules of pollination. Day 8 was the last day students participated in the activity, and they did an activity with blocks again to demonstrate the pollination procedure, but this time they were not given stickers.

## Data analysis

We used Interaction Analysis (Jordan & Henderson, 1995) in both contexts to investigate the organization of play on these two days. From our experience in the classroom, we were particularly struck by how distinctly different the two activities were for the same group, and only moments apart. Therefore, we made a note to begin our analysis with these two sessions, and then after reviewing the entire corpus of video we identified Day 6 as a valuable contrast point. We looked at all 3 activities across the 4 groups and found similar interaction patterns. Therefore, we identified one group for further analysis, and to serve as an illustrative case study of these interaction patterns. Our goal in analyzing these three activities is to present general patterns in how students' activity was organized. We focused on how the students interacting with peers and material, and response to the teachers impacted the organization of play in a way that oriented students to either non-scientific "rules" or to normative "rules" that accounted for how honeybees pollinate.

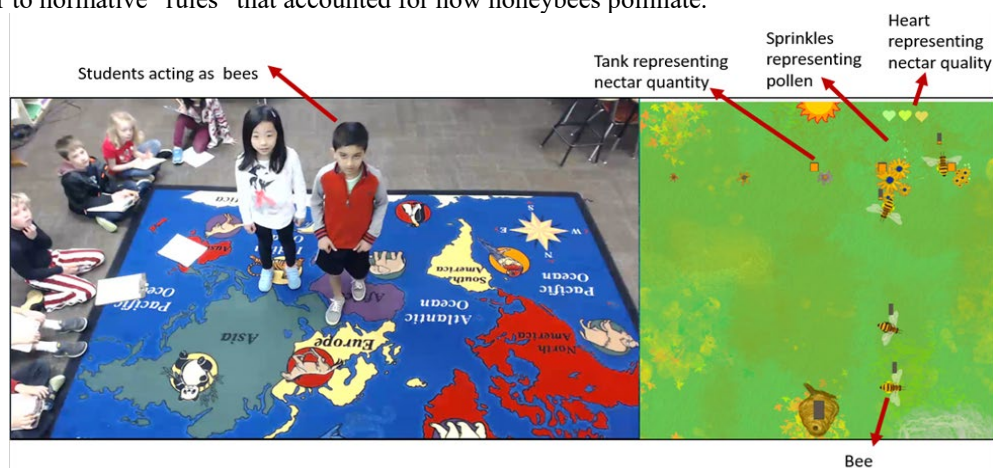


Figure 1. The students interacting with STEP (left) and the projected simulation on shared screen (right).

## Findings

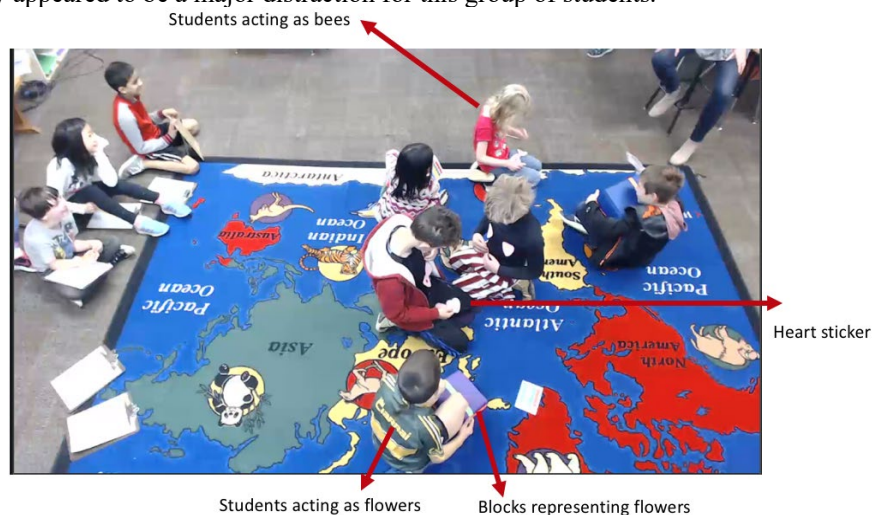
To explore how the organization of play led students to focus on different kinds of rules (non-scientific or scientific), we focused on how students pick up teachers' prompts given in the activities and the way students then interact with each other and the materials as they continue to co-construct their play experience with each other and the teacher. To explore how these interactions led students to science learning, we also focused on whether the students were engaged in the implicit or explicit rules of science phenomena or other less scientific rules. Based on these interactions, we categorized the three activities into three types of play 1) free play, where students appear to have been oriented toward non-scientific rules or fun; 2) intermediate play with rules, where students were interacting with some of the scientific rules due to the STEP environment; 3) more scientifically normative play, which is more akin to modeling, where students themselves identified the scientific rules.

## Free play

We named this activity free play, because even though the teacher intended for it to be oriented towards modeling and making sense of the science, students engaged in the imaginary situation as being bees and focused on rules of getting stickers. Students were divided into three groups: flowers, bees and observers.



Students who pretend to be flowers were sitting on the floor holding a block with heart stickers that represented nectar; they were also given round stickers representing pollen. These students were given the task to give out the stickers to represent pollination. Their peers were told to pretend to be bees and get nectar from the flowers, while observers were told to write and draw what they saw happening (See Figure 2). This activity had previously been quite productive for helping students recognize how pollen sticks to bees who were collecting nectar. However, in the current iteration, the bee group started to reach out their hands asking for “stickers” rather than waiting. This led all the students to orient more towards the sticker passing process, which was exacerbated when one student “slapped” his sticker onto a peer in an exaggerated manner, which led to laughter and then repeated acts of rambunctious sticker requests and passing. The observers primarily laughed at this, rather than observing how pollen was collected. As a result, the intended, implicit rule of “demonstrate how bees pollinate flowers *accidentally*” became “getting stickers as pollen in a funny way”, and the students did not focus on the “accidentally” aspect. The prompts given by the facilitators attempted to re-focus the students’ attention on the scientific rules of pollination and were not taken up by the students. Students ultimately focused primarily on getting the stickers in the most laughter-inducing manner, and the teacher ultimately decided to cut the activity short and attempt to re-focus the students’ attention on the scientific rules in subsequent activities. We thus decided to re-orient students toward attempting to model how real bees behave and chose not to re-use the stickers as they appeared to be a major distraction for this group of students.



**Figure 2.** Students doing free play and exchanging stickers.

### Intermediate play with rules

Intermediate play with rules is the activity right after the free play sticker activity on Day 6 that is described above. In this activity, students were interacting with the STEP simulation. In STEP, the rule of the scientific phenomena is pre-set in the simulation: 1) bees get pollen “sprinkled” accidentally when they collect nectar in the simulation, and 2) pollination only happens on the same species of flower, which is represented as two or more flowers in same color in the simulation. In this activity, students were split into two groups: an embodied group that were pretending to be bees and interacting with the simulation, and an observer group, that was given paper to take notes

Students’ embodied action showed that they started to explore the flower with high quality and quantity nectar in the simulation and they would respond to the facilitators’ prompt to move on to other flowers unlike the prior activity. The facilitator prompts appeared to have helped orient students toward the underlying scientific rules of the imaginary situation by orienting the students-as-bees to the aspects of the phenomena that would lead them to new flowers (nectar supplies). The teacher comments also helped students to disentangle the symbolic supports within the simulation from the phenomena they described. For example, after visiting several flowers iteratively, students noticed that the dot trail that the simulation uses to show them where pollen was carried created a clearly visible “line.” The teacher asked whether the bees were following the “line” and why they would care about the “line”? The students were able, in response to these prompts, to note that the bees were pursuing nectar, but this led to a repeated visit to certain flowers and hence the line, and ultimately, pollination. Thus, the rules built in to the simulation scaffolded students’ action to be “accidentally” getting pollen and helped the students re-orient away from aiming to collect pollen (stickers), to aiming to collect (simulated) nectar as bees would.



## Scientific normative play

In Day 8 students were engaged in a play activity with blocks that represented flowers when tracked by the STEP software, and they were asked to demonstrate the procedure of pollination. One intention of this was to challenge students to re-represent and thus focus on what they had noticed within the STEP MR environment. Students were split into two groups, one group pretended to be bees, and the others were observers. For this time, the students were interacting with the blocks, responding to the teachers' prompt, and came up with their own ideas to represent the "accidentally" aspect of the pollination rule. A common occurrence was that students would exaggeratedly bump their foot into a flower while pretending to drink nectar with their mouth. The teacher then asked what they were doing and the students clarified that they were showing how the bees "accidentally" bumped the flower and thus collected pollen. When students visited multiple flowers of the same color, they further highlighted, in response to teacher prompts, that this is how bees supported flowers of the same species in receiving pollen, again by accident as they pursued nectar sources. In this more scientifically normative play, students became the ones to demonstrate the explicit rule of scientific phenomena, and they were able to use objects given in the space as a symbol of the real scientific rule. Their embodied interaction between the bees and blocks mirrored the explicit rules of pollination. The prompts given by the teachers cued students' explanations, and students were able to give an accurate explanation of pollination to their embodied action.

Across the three activities, we found the interaction shifted from engagement in play with implicit rules of being bees but focusing on stickers in a fun manner, to being oriented toward nectar by the pre-built rules in the STEP environment and later having students themselves represent the rules using the materials in the space to demonstrate the scientific model. In the first activity, we see how the typically fun nature of play can sometimes intrude into classroom play when students focus on their own rules. However, a focus on how these rules are made salient to students helped us to easily adapt and re-focus. In this case, we shifted to using the STEP environment to help make the implicit rules more salient. In other activities, we were able to pause and help the students re-orient towards the underlying scientific rules. Student learning can also be seen in how they are able to take responsibility for enacting the rules of the target phenomena, and ultimately used those rules to guide their actions in the final activity. Here, though, we saw that while the students were oriented towards those rules, teacher prompts were often necessary to help make them visible to the teacher and the other students.

## Significance

By investigating the interaction during these three types of play, we saw that the STEP environment serves as the transitional stage for students to use play to produce a scientific model, and that this type of simulation with pre-built rules also served as a form of pivot for students to connect play to modeling of a scientific phenomenon. Teachers' prompts were important not just for helping the students to focus on the scientific rules, but also in helping students to articulate how and when they were representing those rules for their peers. Play remains a powerful entry point into scientific modeling. However, this work shows how play facilitators can benefit from orienting toward which rules students are attending to in order to support students in using play as a form of modeling in ways that continue to build on the imaginary situation while orienting them towards rules that they are continuing to uncover in their inquiry.

## References

- Enyedy, N., Danish, J. A., Delacruz, G., & Kumar, M. (2012). Learning physics through play in an augmented reality environment. *International journal of computer-supported collaborative learning*, 7(3), 347-378. Authors. (2015).
- Enyedy, N., Danish, J. A., & DeLiema, D. (2015). Constructing liminal blends in a collaborative augmented-reality learning environment. *International Journal of Computer-Supported Collaborative Learning*, 10(1), 7-34.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, 4(1), 39-103.
- Lesh, R. A., & Doerr, H. M. (2003). *Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching*. Routledge.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.
- Youngquist, J., & Pataray-Ching, J. (2004). Revisiting "play": Analyzing and articulating acts of inquiry. *Early Childhood Education Journal*, 31(3), 171-178.

# See the Collaboration Through the Code: Using Data Mining and CORDTRA Graphs to Analyze Blocks-Based Programming

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**Abstract:** This paper describes an exploratory study that leveraged data mining, qualitative analysis, and Chronologically-Ordered Representations of Discourse and Tool-Related Activity (CORDTRA) diagrams to identify and analyze key moments in students' collaborative app building during a 12-week computing curriculum. Our analysis showed that two key practices emerged: 1) Students leveraged their past work and tutorials to support their app development, both on their own and with peers; and 2) Students largely developed their own parts of group apps without feedback from peers or referencing prior work. We discuss how patterns revealed in this mixed-methods approach affected how students constructed code, with an eventual goal of identifying how these patterns shaped students' final projects.

## Introduction

Since Papert's early work with Mindstorms, collaboration has been an important part of computing education (Resnick, Ocko & Papert, 1988). While numerous studies have shown that collaborative approaches, such as pair programming, can effectively support collaborative learning in computing education (Preston, 2005), there are questions around how collaboration is enacted by different groups and over various scales of time (Kafai et al., 2012; Lewis & Shah, 2015; Goel & Kathuria, 2010). Further, it is challenging to assess collaboration in computing education, as collaborative processes occur both on screen and physically between collaborators. Much of the research about collaboration in computing education focuses on the end product of students' work or their perceptions of collaboration, rather than students' collaborative practices and how these practices support the work students are doing (Williams et al., 2002). While there has been some research aimed at revealing the effectiveness of collaboration during real-time interactions of students (Fields et al., 2016; Litts et al, 2017), the majority of this research has largely been conducted during short lab-based activities (e.g., Grover et al., 2016). As such, there is a gap in our understanding of how collaboration in computing education plays out over sustained periods of time. In response, we must analyze students' collaborative practices over longer periods of time. However, as noted by Wise and Schwarz (2017), there are significant challenges in conducting rich qualitative analysis of students' engagement in longer activities. When students engage in collaborative activities over weeks, or even months, how can researchers select moments in time for cohesive, meaningful analysis? In response to this challenge, this paper describes an exploratory approach for combining data mining and qualitative methods to identify key moments in students' collaborative app development, as a means for understanding how students collaboratively make use of their own knowledge and that of their peers. Two questions guided our work:

- 1) Within a long-term programming project, how can we effectively identify key moments in students' group projects for analysis?
- 2) How can qualitative analysis shed light onto the knowledge-seeking and collaborative practices students engage in when these moments arise?

Below, we discuss our multidimensional approach for conducting analysis of collaboration within the context of a high school computing class. We discuss the patterns that emerged, their importance for understanding collaboration in computing education, and next steps for applying these analyses.

## Methods

This study involved 22 students (21 male, 1 female) in a large urban high school in the North Eastern United States. The school is one of the most diverse schools in the US (25% Asian, 23% Hispanic, 20% Black/African American, and 29% White), and 61% of the students are eligible for free or reduced lunch.

Using a computational action approach (Tissenbaum, Sheldon & Abelson, 2019), the students took part in a 12-week curriculum in which they used MIT App Inventor – a blocks-based programming language that allows students to build fully native Android mobile apps without needing to learn the syntax of code – to develop apps that had direct impacts in their community. For this study, students built apps aimed to help clean and bring awareness to pollution issues of a large river running through their city. Students spent the first eight weeks of the curriculum learning about App Inventor and developing starter apps as an introduction to the system and the ways they could develop apps with real-world applications. During the final four weeks, students worked in pairs or

triads to design and build their own apps. This version of App Inventor was specially designed to allow students to collaboratively develop group apps in real-time on multiple computers, rather than having to take turns (e.g., as in pair programming). This provided a unique opportunity to understand how students collaborated and developed their apps when each student was free to work on their own sections. For the purposes of this study, we only analyzed the apps that groups built during the final four-week period.

Log data was collected each time a change was made to a group's project. This data included: (i) which student made the change, (ii) which element (i.e., block) was changed, (iii) the element's beginning and ending location on the screen (i.e., if and where it was moved), and (iv) the timestamp of the event. Screen and voice recordings were also captured for each student who gave informed consent using *Screencastify* (a Chrome browser extension). *Screencastify* was embedded within our special instance of App Inventor so that it launched when students logged into App Inventor. It also automatically uploaded recordings to our secured server, along with start and stop timestamps and students' login IDs, when students logged out or closed the browser window. By syncing the screen recordings with App Inventor, we ensured that timestamps in the log files exactly matched timestamps in the screen recordings.

Using the log files, we implemented a data mining approach that provided timestamps for each episode of students adding particular blocks (e.g., a block to create a list, open a new screen, store data to a database, or implement a map function) into their app for the first time. We were interested in those instances because they marked times for further investigation of why students decided to add a particular block. We also planned to examine how students figured out how to use the block in their app. Using data mining to determine these moments helped us to reduce the time-consuming (and error prone) process of manually watching and coding screen recordings of students' work, as critical incidents of students' collaboration.

Once the episodes of students' app building were identified using the data mining approach above, we triangulated this data with the screen and voice recordings to examine students' work immediately before and after the student added the new block. We used a combination of inductive and deductive coding to develop 12 codes for students' interactions in App Inventor around these episodes (Table 1). We began coding students' work starting at two minutes before the block was added in order to capture relevant discussion or coding students may have engaged in prior to adding the block. We coded for at least two minutes after the block was added. In cases where the students continued to work with the block or elements connected to it, we continued to code the video until students moved on to a new task. In some cases, two or more blocks were added during the same episode. In these cases, we considered the event as continuous and coded them together. To allow finer-grained analysis and visualization of student work, we segmented each episode into discrete 15-second blocks. We included event codes if they happened any time during the 15-second block. Each code was only marked once, regardless of how many times it happened during the 15-second block. We coded a total of eleven episodes (mean duration 15.22 minutes). These episodes were chosen as they were the ones that contained the identified events and all group members consented to have their voices recorded (which was needed to analyze the collaborative discourse).

Table 1. Event codes for video analysis of student app building

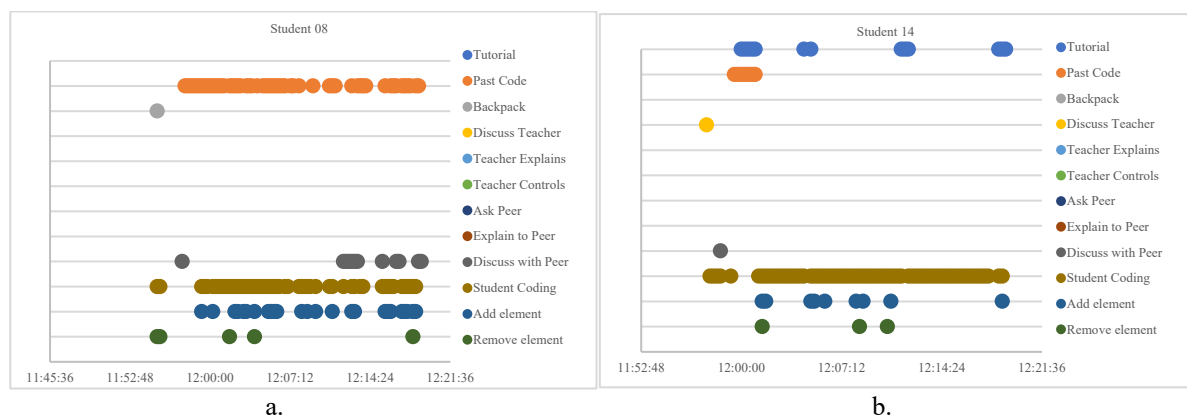
<b>Coded Event</b>	<b>Description</b>	<b>Coded Event</b>	<b>Description</b>
<b>Tutorial</b>	Student looked at a tutorial from a previous exercise	<b>Past Code</b>	Student looked at code from a previous project or exercise
<b>Backpack</b>	Student used the backpack (a way of storing and retrieving code across projects)	<b>Discuss with Teacher</b>	Student discussed their work with the teacher
<b>Teacher Control</b>	Teacher takes control of the student's computer	<b>Ask Teacher</b>	Student asks the teacher for help
<b>Explain to Peer</b>	Student explains how something works in their app	<b>Discuss with Peer</b>	Student discusses how they might do something in their app
<b>Ask Peer</b>	Student asked a peer how to do something in their app	<b>Student Coding</b>	Student is building/coding their app
<b>Add Element</b>	Student adds an element (i.e., a coding block or a button) to their app	<b>Remove Element</b>	Student removes an element from their app

Event codes were added by the two authors. The two authors independently coded 20% of the data to establish intercoder reliability. Across all twelve codes, the combined intercoder agreement was 96% (Cohen's kappa = .852). The two authors coded the remaining data separately.

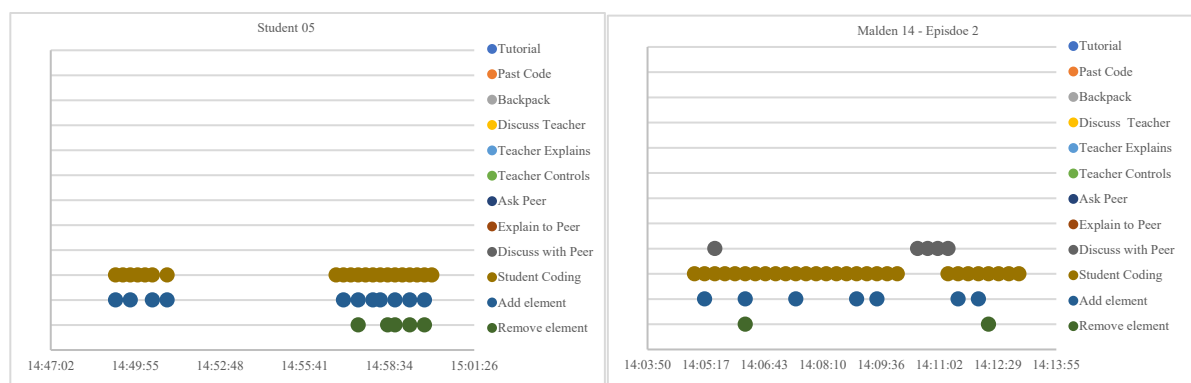
In order to better understand the multiple processes involved as students collaboratively developed their apps, we plotted a timeline of event codes using Chronologically-Ordered Representations of Discourse and Tool-Related Activity (CORDTRA) diagrams (Hmelo-Silver, Chernobilsky & Jordan, 2008). CORDTRA diagrams are particularly useful for these kinds of activities, as they combine log data with fine-grained event coding in a visualization that allows for more holistic analysis than purely text-based coding schemes (Hmelo-Silver et al., 2008). Below, we discuss our findings on students' collaborative practices and tool use when introducing new elements to their apps.

## Results

Across the 11 episodes, a few patterns emerged. One pattern was that of students revisiting past work as a reference on how to implement a new block in their app (see Figure 1). Students moved back and forth between the app they were currently building and earlier exercises and tutorials they had completed during the first eight weeks of the curriculum. In a similar episode (not shown here), student went back and re-used whole pieces of code from their backpacks in their new project. In these cases, students would sometimes talk with their peers to clarify what they were doing; in other episodes, they largely worked alone. Across both examples in Figure 1, the students were observed doing some variation of “copy and paste.” In the tutorial and past-code cases, students used the same, or very similar, names for variables and labels, even if they did not fit their current apps. Similarly, when the students re-used code snippets from the backpack, they focused on removing errors, rather than creating appropriate names for their variables or blocks. When errors occurred, students tended to engage in “guess and check” debugging (i.e., semi-randomly changing variable names) rather than focused debugging. This seems to indicate that they students were focused more on *making the apps work* than understanding *how the apps work*.



**Figure 1a.** an example of a student looking at past code and discussing with a peer;  
**Figure 1b.** a student using past code and past tutorials, but largely working alone.



**Figure 2a.** An example of a student lacking a debugging strategy.  
**Figure 2b.** An example of lulls in student work after a successful coding strategy.

Another pattern that emerged was that of students rarely, if at all, revisiting past code as a means of supporting their app building. Instead, students attempted to figure out codes on their own or through discussion with their group members. In this pattern, we found some important differences between students working on

their own compared to when they talked with their peers. When students did not talk with their peers, we observed that students seemed to aimlessly test problem-solving strategies without a clear debugging strategy. This was punctuated by long gaps in their coding, in which students did little (see Figure 2a). In this episode, the student was trying to get maps to work, but he used the wrong element (a canvas drawing element). Eventually, the student simply removed many of the elements and blocks without resolving the issue. In the second example (Figure 2b), the student was able to implement the code (i.e., change screen) without any significant complications. The only break in coding (at 14:11:02) was to discuss work their peer was doing. However, it is worth noting that after successfully completing this code, the student did no additional work for over 10 minutes.

## Discussion

This paper is an exploratory attempt to combine data mining, qualitative analysis, and chronological visual representations of students' interactions as they developed their own learner-driven mobile applications. While only a first step in our analysis, this multi-dimensional approach provided insights into key moments in students' app development, problem-solving strategies, and collaboration. While some clear patterns emerged, a critical next step is to analyze the groups' final projects and examine how code developed during these episodes manifested itself in final products. For example, do students re-use or discuss past code in their final projects? Do any of these patterns result in more functional apps? If so, using similar mixed-methods approaches may help us provide necessary help to students in real-time by providing context- or goal-specific scaffolds, such as suggesting that students revisit prior projects for similar blocks of code. Understanding students' collaborative practices in computing education also helps us to bridge collaboration across coding on-screen and in the physical world.

## References

- Fields, D. A., Quirke, L., Amely, J., & Maughan, J. (2016, February). Combining big data and thick data analyses for understanding youth learning trajectories in a summer coding camp. In *Proceedings of the 47th ACM technical symposium on computing science education* (pp. 150-155). ACM.
- Goel, S., & Kathuria, V. (2010). A novel approach for collaborative pair programming. *Journal of Information Technology Education: Research*, 9, 183-196.
- Grover, S., Bienkowski, M., Tamrakar, A., Siddiquie, B., Salter, D., & Divakaran, A. (2016, April). Multimodal analytics to study collaborative problem solving in pair programming. In *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (pp. 516-517). ACM.
- Hmelo-Silver, C. E., Chernobilsky, E., & Jordan, R. (2008). Understanding collaborative learning processes in new learning environments. *Instructional Science*, 36(5-6), 409-430.
- Kafai, Y. B., Fields, D. A., Roque, R., Burke, W. Q., & Monroy-Hernandez, A. (2012). Collaborative agency in youth online and offline creative production in Scratch. *Research and Practice in Technology Enhanced*.
- Lewis, C. M., & Shah, N. (2015, July). How equity and inequity can emerge in pair programming. In *Proceedings of the eleventh annual International Conference on International Computing Education Research* (pp. 41-50). ACM.
- Litts, B. K., Lui, D. A., Widman, S. A., Walker, J. T., & Kafai, Y. B. (2017). Reflections on Pair E-Crafting: High School Students' Approaches to Collaboration in Electronic Textiles Projects. Philadelphia, PA: International Society of the Learning Sciences.
- Preston, D. (2005). Pair programming as a model of collaborative learning: a review of the research. *Journal of Computing Sciences in colleges*, 20(4), 39-45.
- Resnick, M., Ocko, S., & Papert, S. (1988). LEGO, Logo, and design. *Children's Environments Quarterly*, 14-18.
- Tissenbaum, M, Sheldon, J. & Abelson, H. (2019). From computational thinking to computational action. *Communications of the ACM*.
- Williams, L., Wiebe, E., Yang, K., Ferzli, M., & Miller, C. (2002). In support of pair programming in the introductory computer science course. *Computer Science Education*, 12(3), 197-212.

# Towards Automatic and Pervasive Physiological Sensing of Collaborative Learning

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**Abstract:** We present a collaborative learning study contextualized within Project based Learning. The main aim of our contribution is to use the physiological data such as heart rate, skin temperature, electrodermal activity and blood volume pressure to quantify the learning experiences of the collaborating teams. We propose an automatic method to extract collaborative measures and study their relationship with the perceived performance, usefulness and satisfaction from the collaborative sessions from various student groups in a university degree course. We aim to contribute towards automatized, pervasive and more generalizable sensing of collaborative learning. Our results show that the synchrony in automatically extracted physiological states correlates positively with perceived performance and satisfaction of teams.

## Introduction and background

The proponents of Project Based Learning (PBL) suggest that there are some advantages to it. For example, students in PBL learn better and they engage more actively in learning than normal instruction (Green 1998), students show more reflection on the knowledge gain (Preuss 2002) and there is a gradual decrement in the requirement of a step-by-step instruction (Lenshow, 1998). We present a study from a collaborative PBL course in a university. Our aim is to provide objective measures to capture the self-reported learning experiences of the students in a collaborative scenario such as performance, usefulness and satisfaction. In the present contribution the objective measures come from a wearable wristband that records the heart rate, electro dermal activity, skin temperature and the blood volume pressure of the participants in each student group. In this paper we would collectively refer to these data streams as *wristband data*. With the advancements in the wearable technologies, off-the-shelf devices have made the physiological sensing easier for the researcher than in the past. There have been many studies carried out to explore the relationship between the physiological data and learning outcomes (Pijeira-Díaz et al 2016), collaboration quality (Chenal et al 2013).

We propose three fundamental shifts. First, we move from the invasive devices such as eye-tracking, EKG, EEG to pervasive wristbands. Second, we move from semi-automatic to completely automatic extraction of collaborative segments. Finally, the third shift is from the emotional/semantic sensing of collaborative scenarios to semantic-less sensing of the collaborative scenarios to achieve a greater generalizability of research outcomes. The main contribution of this study is the use of physiological data to define collaborative measures and using them to quantify collaborative learning experiences. Through this contribution, we address the following research question: “*how the groups’ physiological state affects the learning experiences of the collaborators?*” We define the physiological states using the features extracted from the four collected data streams, i.e., heart rate (HR), blood volume pressure (BVP), electro dermal activity (EDA) and skin temperature (TEMP). We hypothesize that the *synchrony of the physiological state among the collaborators would affect their learning experiences*. To compute the synchrony of the physiological states, we employ previously used methods to compute the synchrony in the collaborative eye-tracking data in various CSCL scenarios called cross-recurrence (Jermann and Nuessli, 2012; Schneider et. al., 2016).

Wearable devices are now widely available and affordable and it has become possible to monitor more subtle phenomena, such as the quality of social interactions, students’ mental health and learning engagement (Wang et al., 2018). In terms of measuring collaborative learning gains, Pijeira-Díaz et al (2016) conducted a study with high school students to study the relation between collaboration will, learning product, learning gain and Empatica and eye-tracking data. The main features used by Pijeira-Díaz et al (2016) were the direction of change, direct difference and linear relationship among the different data streams. On the other hand, Chenal et al (2013) used skin temperature and skin conductance with eye-tracking and electrocardiographs (ECG) to assess collaboration quality (measured by grounding, emotion management, conflict resolution, consensus building) using correlation-based features. Blanchard et al (2012) used EEG, GSR and skin temperature to explain the CL process with the focus is on individual analyses. Sottolare et.al. (2012) proposed to measure engagement, workload, motivational level and emotional state using physiological data while interacting with an Intelligent Tutoring System with a special focus on emotions/affective states.

Most of these methods employ eye-tracking, EEG or ECG equipment which hinder the pervasiveness of the devices used (Pijeira-Díaz et al, 2016). Others used human labelling as one of their methods that hinders the

automatization of the process (Chenal et. al, 2013). A few other either focused on the individual measurements or they focused on the emotional awareness during collaboration, making the results generalizable in the similar given contexts only (Sollilare et al., 2012). In this contribution, we use only the wristband data, no human labelling, unsupervised segmentation of individual data and a collaborative measure to study the relation between collaborative physiological sensing and learning experiences during collaborative sessions.

## Methodology

To capture fine-grained physiological data during a learning experience, we designed an in-the-wild study. The study took place in a regular university course called *Customer Driven Project*. This is a master-level class where groups of 5-7 students work on a software engineering project with a real customer. During the semester, groups have their internal group meetings, meetings with the customer representative and class sessions with their advisor. The role of the advisor is to meet the groups once every week for an approximately 30 minutes to discuss with the group about the progress and objectives of their project.

We recruited a total of 31 university students (12 female and 19 male) aged between 21 and 53 years old (mean = 24.01, S.D. = 5.87). Participants were recruited using convenience sampling from the pool of a major European university. Participants were CS majors and taking the respective course as part of their CS degree. Participants were given a 30 Euro gift card upon completion of the study. In the beginning of each class session, the participant wore the wristband, and attended the class as usual. At the end of the class, each participant completed a questionnaire that was designed (based on the literature) to capture student's learning experience. The class lasted for approximately 30 minutes.

We used surveys (7-point Likert scale) gathered students' learning experience. The survey concerned factors adopted from prior studies, particularly on how students perceived the following three notions: 1) Satisfaction (Gray & Diloreto, 2016), 2) Usefulness (Sánchez & Huero, 2010) and 3) Performance (Kuvaas, 2006). Participants wore the Empatica E4 wristband on their non-dominant hand and four different measurements were recorded: 1) heart rate (HR) at 1 Hz, 2) electro dermal activity (EDA) at 4 Hz, 3) body temperature (TEMP) at 4 Hz, and 4) blood volume pulse (BVP) at 64 Hz.

## Wristband data pre-processing

Physiological data, comprising of HR, EDA, BVP, and Temperature, are affected by many biases based on the age, gender, time of the day, physical and medical conditions of the participants. Therefore, it is necessary to remove these biases. We normalize the time series of these data streams for every individual participant using the mean of the first minute of their data. All segments of data will have the same average bias per person, hence when we normalize the data with the first segments of data the biases present in all the segments gets cancelled out. Next, the noise mostly contains the occasional outlier due to the error in the measurement or the repositioning of the wristband by the participants. We use a spline smoothing to remove occasional outliers from the data.

## Wristband data feature extraction

We first segmented the data into chunks of 30 seconds each. Then we define the following measures from each of the four data streams (HR, EDA, BVP, and Temperature). *Histogram based*: we compute the basic statistics from the histogram such as: mean, standard deviation, maximum, median, skewness, and kurtosis. *Auto Correlation*: we compute the first N autocorrelation coefficients using the segmented data, the choice of N is based on the AIC value of the autoregressive model. *Frequency domain*: we transform the data from temporal domain to frequency domain using a Fast Fourier Transform, and then take first M coefficients.

## Clustering

We use a simple K-means clustering algorithm to obtain 5 clusters. Once again, the number of clusters (5) is determined based on comparing the different number of clusters and the corresponding value of inter-cluster separation. The inter-cluster separation is defined as a ration of the average distance between the point for each cluster and the average distance between the centroids of the clusters. The centroids of the clusters are calculated as the average of all the points in a cluster. We chose the value that maximizes the inter-cluster distance. We can see that the inter-cluster distance is not changing significantly after five clusters. Once we have assigned each segment a cluster number, we then create a time series of cluster values for each participant in every group. Each cluster is indicative of a certain physiological state of the participant. One can use these sequences of states to explain the collaboration processes, outcomes or experiences. The next subsection provides the details of how we used this sequence of states to define collaborative measures to explain the group experiences.

## Cross-recurrence (CR)

It is widely used in the theory of dynamical systems to compute the temporal co-occurrence of states of two dynamical systems (Eckmann et. al., 1987). In CSCL this measurement has been used to explain collaborative processes using dual eye-tracking data (Schneider et. al., 2016; Jermann and Nuessli, 2012). In the context of our analysis, each student can be considered as a dynamical system and the physiological data from a given time window represents the state. Thereby, CR analysis can be used to measure how much and when two subjects have similar physiological states. The principle of CR is detailed in Nüssli (2011).

## Results

*Cluster Analysis:* Using the method described in the previous section, we obtained five clusters from the features computed with BVP, HR, EDA, TEMP. Once we obtained the clusters, we chose top 12 features (with largest effect sizes, Figure 1) to explain the clusters in terms of the physiological data.

*Cluster 1* (n = 550): This cluster is comprised of the segments with high auto-correlation coefficients for TEMP and BVP. This indicates that TEMP and BVP during such segments have stable TEMP and BVP values, since the auto-correlation coefficients are positive and high for both TEMP and BVP.

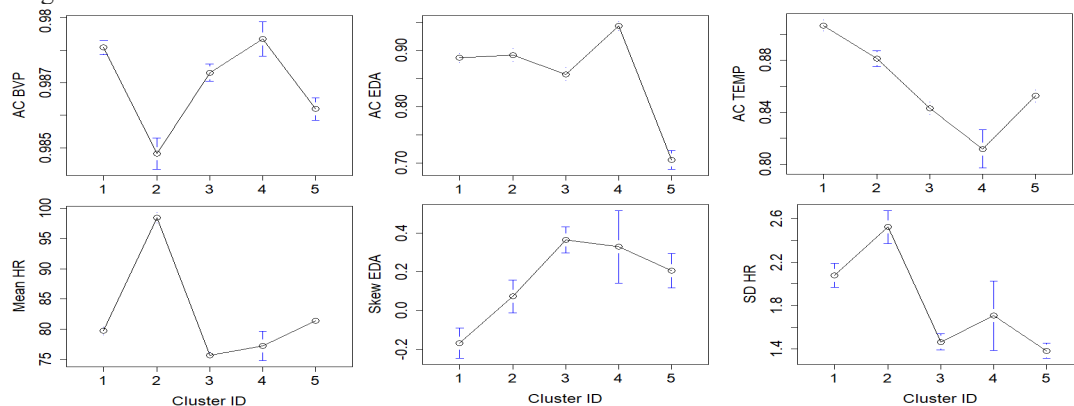
*Cluster 2* (n = 519): Segments in this cluster are characterized by low auto-correlation coefficients for BVP and high mean and variance for HR. This indicates that the heart rates during these segments are high with a lot of fluctuations. Moreover, since the auto-correlation coefficients for BVP are lower in this case than the other clusters, this shows that there is a considerable variability in the BVP of participants for such durations as well.

*Cluster 3* (n = 889): This cluster has the segments with highly skewed EDA and low mean and variance for HR. This indicates that such segments had high EDA levels and low but stable heart rates for the participants.

*Cluster 4* (n=133): This cluster has segments which show low auto-correlation coefficients for TEMP but high auto-correlation coefficients for EDA and BVP. This indicates that the EDA and BVP have low variation during such periods, but this is not the case for TEMP.

*Cluster 5* (n = 826): Segments in this clusters show low auto-correlation for EDA and low variance for HR. This indicates that the heart rates are stable during these moments, but not the EDA.

*CR analysis:* We observe a positive and significant correlation between the CR and the perceived performance of the group (Pearson cor. = 0.56, p = .02). We also observe a positive and significant correlation between the CR and the perceived satisfaction of the group (Pearson cor. = 0.56, p = .02). However, we did not observe any significant correlation between the perceived usefulness of the group and the average CR of physiological states.



**Figure 1.** The clusters as defined by the top 12 features (largest effect sizes). These 12 features are: three auto-correlation coefficients for TEMP, EDA, and BVP, mean and variance of HR and the skewness of EDA.

## Discussion and conclusion

We present results from a project-based learning study, where we recorded the physiological data (electro dermal activity, heart rate, blood volume pressure, and skin temperature) of the participants. We then defined five different physiological states using the features from the data. Next, we computed the cross-recurrence of these states among the participants. Finally, we show the correlations between the cross-recurrence and the groups' average learning experiences (satisfaction, performance, and usefulness). Each cluster we obtained from the features of the physiological data collected represents a certain physiological state. For example, a state with high variability in HR and EDA might hint towards argumentation during the collaboration (Cluster 2); while the stable episodes with TEMP, EDA and BVP might indicate agreement (Clusters 1 and 4). Cross-recurrence among the participants in a group depicts the physiological synchrony among them. We observe that this synchrony is positively and significantly correlated to the groups' perceived satisfaction and performance. One plausible reason



for this might be the fact that having similar physiological states over time indicates similar activities done by every member in the group and hence every one of them had higher ratings for satisfaction and performance. On the other hand, groups with low physiological synchrony might have subgroups within them, and the different subgroups might have different perceptions for performance and satisfaction, this could result in lower average ratings for these two variables. The lack of correlation between the perceived usefulness and the physiological synchrony among the peers could be because of the usefulness could be a construct which is not clearly linked to the physiological data; clearly more experimentation is required to disambiguate these two reasons. The Cross-recurrence can also be used as a temporal measure of synchrony. This provides the possibility to use wearable sensing to automatically capture students' physiological states early in the collaborative sessions. This generates new opportunities for wearable technologies to quantify the learning experiences. Temporal CR of the physiological states might provide early feedback to both students and teachers. Thus, it makes possible to get early warnings of disruptions in collaborations and allows students and teachers to take proactive remedial actions.

Empatica E4 devices are accurate, unobtrusive and require low maintenance; thus, facilitating ubiquity. Eye-tracking glasses are wearable solutions, but there is a cost to accuracy correlation (more accurate off-the-shelf solutions are expensive). Eye-tracking glasses require low maintenance but have certain degree of obtrusiveness. Considering EEG, wearable solutions are available, but they are uncomfortable and obtrusive; EEG is also noise prone and low-cost solutions provide low accuracy and low data resolution. With our results, we show new trends of the shift the three directions (see Introduction). First, we show that unsupervised clustering methods have a potential to be used instead of human labeling of collaborative episodes. Second, we show that synchrony of semantic-less physiological states correlates with the learning experiences. Finally, the third shift towards more pervasiveness, we show that it is possible to quantify collaborative learning experiences using only the wristband data and using similar methods to that from collaborative eye-tracking studies.

## References

- Blanchard, E., Chalfoun, P., & Frasson, C. (2007). Towards advanced learner modeling: discussions on quasi real-time adaptation with physiological data. In Seventh IEEE International Conference on Advanced Learning Technologies (pp. 809-813).
- Chanel, G., Bétrancourt, M., Pun, T., Cereghetti, D., & Molinari, G. (2013). Assessment of Computer-Supported Collaborative Processes Using Interpersonal Physiological and Eye-Movement Coupling. In Proceedings of Humaine Association Conference on Affective Computing and Intelligent Interaction (pp. 116-122).
- Eckmann, J. P., Kamphorst, S. O., & Ruelle, D. (1987). Recurrence plots of dynamical systems. *EPL*, 4(9), 973.
- Gray, J. A., & M. Diloreto. (2016). "The Effects of Student Engagement, Student Satisfaction, and Perceived Learning in Online Learning Environments." *NCPEA International Journal of Educational Leadership Preparation* 11 (1): 98–119.
- Green, A. M. (1998). Project-based Learning: Moving Students through the GED with Meaningful Learning.
- Jermann, P., & Nüssli, M. A. (2012). Effects of sharing text selections on gaze cross-recurrence and interaction quality in a pair programming task. In Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work (pp. 1125-1134). ACM.
- Kuvaas, B. (2006). Work performance, affective commitment, and work satisfaction: The roles of pay administration and pay level. *Journal of Organizational Behavior*, 27, 365–385.
- Lenschow, R. J. (1998). From teaching to learning: A paradigm shift in engineering education and lifelong learning. *European Journal of Engineering Education*, 23(2), 155-161.
- Nüssli, M. A. (2011). Dual eye-tracking methods for the study of remote collaborative problem solving.
- Pijera-Díaz, H. J., Drachsler, H., Järvelä, S., & Kirschner, P. A. (2016). Investigating collaborative learning success with physiological coupling indices based on electrodermal activity. In Proceedings of the sixth international conference on learning analytics & knowledge (pp.64-73). ACM.
- Preuss, D. A. (2002). Creating a project-based curriculum. *Tech Directions*, 62(3), 16.
- Sánchez, R. A. & Huero, A. D. (2010). Motivational factors that influence the acceptance of Moodle using TAM. *Computers in Human Behavior*, 26, 6, 1632–1640.
- Schneider, B., Sharma, K., Cuendet, S., Zufferey, G., Dillenbourg, P., & Pea, R. (2016). Using mobile eye-trackers to unpack the perceptual benefits of a tangible user interface for collaborative learning. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 23(6), 39.
- Sottolare, R. A., Brawner, K. W., Goldberg, B. S., & Holden, H. K. (2012). The generalized intelligent framework for tutoring. Orlando, FL: US Army Research Laboratory–Human Research & Engineering Directorate.
- Wang, R., Wang, W., daSilva, A., Huckins, J. F., Kelley, W. M., Heatherton, T. F., & Campbell, A. T. (2018). Tracking Depression Dynamics in College Students Using Mobile Phone and Wearable Sensing. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 2(1), 43.

# Scaffolding Inclusivity Through Making: A Preliminary Analysis of Diverse Learners' Meaning Making Through Complex Systems

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**Abstract:** This project builds upon a body of work that interrogates the socio-material affordances of maker tools and integrates socioculturally responsive approaches for the inclusion of diverse learners in makerspaces. We provide a preliminary interaction analysis, which explores how racially and linguistically diverse learners engage in learning with complex systems through tools and language during bidirectionally responsive design activities.

## Introduction and background

This project builds upon a body of work that interrogates the socio-material affordances of maker tools and integrates socioculturally responsive approaches for the inclusion of diverse learners in makerspaces (e.g., Richard & Kafai, 2015; Richard & Giri, 2019). Specific to this iterative, multi-stage, design-based research project is its purposeful integration of different contemporary digital and physical content creation tools (i.e., multiple interfaces), which each invite unique socially-mediated proclivities and uses and are scaffolded through the curriculum to invoke collaboration. In this way, we integrate work on bidirectionally responsive design (BRD), which proposes purposefully integrating diverse, contemporary maker tools in ways that encourage the design of simultaneously physically and digitally interactive projects (Richard & Kafai, 2015). BRD models authentic design practices found in computing professions, and involves purposefully utilizing simplified digital (eg. Scratch) and physical (eg. the Lilypad Arduino, the Makey Makey) programming, design and fabrication toolkits to create cohesive, integrated systems with simultaneous digital and physical feedback. In BRD, the focus is not specifically on how to use the tools, but is instead on the assemblage of complex and seemingly disparate systems in collaborative ways. As a result, learners engage in complex systems thinking, across a variety of computational systems, and social systems, as they work together to create a shared artifact. Our past work also finds that both the purposeful integration of maker tools that invoke different skill sets (e.g., the Lilypad Arduino, which utilizes sewing to create wearable circuits) and the promotion of an inclusive learning environment positively shapes counter-stereotypical collaboration practices and roles across gender and cultural backgrounds.

Specifically, this work extends upon frameworks related to understanding learning with complex systems (Richard & Giri, 2019). For example, multimodal learning theories propose that learners engage more deeply with instructional materials when they are provided different auditory, visual and textual representations (e.g., Meyer, 2003). However, until recently, most of this work did not consider tangible and integrative dimensions, such as those that could be fostered through BRD. Likewise, by participating in authentic interdisciplinary design practices (i.e., engineering design, coding, project management, etc.), learners are engaging in meaningful complex systems design practices (e.g., Lu et al, 2007). We further propose that the use of language itself provokes and invites another level of complex systems engagement – that of linguistics. The study was guided by sociolinguistic approaches to code switching (e.g., Lin, 2008). Lin (2008) identified three main categories of code shifting: (1) ideational (providing contextual understanding of content through lived experiences, including language); (2) textual (signaling topic shifts); and (3) interpersonal (appealing to shared cultural values).

In other words, in this paper, we focus on the ways that socioculturally inclusive learning can be fostered through “embodied, enactive, extended, and embedded learning,” in line with this year’s theme. We examine how first-time makers, who are both linguistically and culturally diverse, attempt to create both collaborative and individual multimodal projects, facilitated through multi-interface design, as part of the fifth iteration of this multi-year design-based research project, by exploring two teams of students. In our preliminary interaction analysis, we focus on detailed narrative summaries of interactions, guided by our central research question: How do racially, ethnically and linguistically diverse learners engage in collaborative meaning making through BRD?

## Methods

### Participants and setting

Participants were six (N=6) high school students, ranging from 14-18 years old, who were participating in a six-week TRiO summer program, which serves low-income youth from rural, high-poverty areas, in a rural part of the Northeastern United States. (All participant names have been changed to protect confidentiality.) Over 100 youth were enrolled and could register for classes of interest within the STEM and ELA curriculum. The setting

of this study was a STEM course entitled “Computer Coding,” which focused exclusively on Scratch in prior years and added the maker activities this year. All but one student spoke fluent Spanish and all indicated they were first time “makers.” Four students identified as Hispanic/Latinx, one as Black/African American, and one as both. Two primary instructors, both Black women, led class activities: one, a graduate student (author Whittington), taught the first three weeks of the course, which focused on Scratch coding, and the other, a professor (author Richard), taught the integrated making, coding and design course (the BRD curriculum) during the last three weeks. Three male graduate students, two White American and one Nepalese (including authors Giri and Ashley), provided hands-on instructional assistance along with the professor.

### Course design (summary)

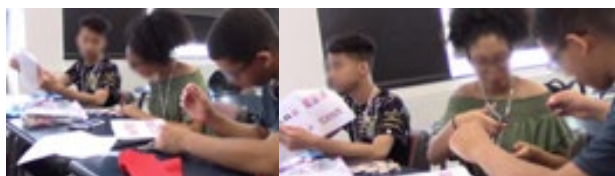
The BRD curriculum, iteratively designed by Richard, focuses on student-centered, constructionist, project-based learning (see Richard & Giri, 2019). This particular workshop lasted three weeks, four times a week at 2 hours a session. During the first few sessions, students learn concepts around circuitry, electronics and fabrication through short, expository videos and lectures with rich visual and textual representations, which is followed closely by hands-on activities to explore the concepts learned. Throughout the workshop, students learn how to use all of the digital and physical tools to code, design, fabricate and sew. During the last four sessions, learners first engaged in design thinking activities, negotiated final project designs with 1-2 others, and collaboratively created their integrated, multi-interface project, taking on different roles.

### Data sources and analysis

We recorded audio/video observations using two wide-angle and two close-up cameras. Instructors engaged the students throughout the course in think aloud prompts in order to monitor their progress and engage the students’ metacognitive strategies. We focus on a subset of data, which was transcribed, translated and analyzed, utilizing microanalytic techniques (Derry, et al., 2010). The microanalysis allowed us to review the video data through multiple lenses, including micro, meso and macro interactions. We provide first-stage findings using analytic induction (Derry, et al., 2010) on a subset of salient vignettes identified by the four authors.

### Findings

We focus on two detailed narrative summaries as vignettes. The first centers on learning interactions amongst three bilingual, native Spanish speaking students in the class, as they navigate through learning how to create a bidirectionally responsive project. The second centers on the one native English speaker, an African American female student, and her partner, a young woman who identifies as both Latinx and African American, as they design their final multi-interface design project together.



**Figure 1.** (a) Ricki asks a question about project 3; (b) Lisa and Juan playfully cut thread together.

### Vignette 1: Language use as learning with complex systems

Lisa (16), Juan (15) and Ricki (17) (All participant names have been changed to protect confidentiality.) are either finalizing or beginning their 3rd projects, individually, which combine all of the systems together (e-textiles, the MakeyMakey and Scratch) to create bidirectionally responsive designs. Juan, Lisa, and Ricki are sitting next to each other, working on their own projects. They are having a conversation in Spanish for two minutes about an unknown person while they work. Soon after, Ricki, looking confused, asks Lisa a question softly, in Spanish, which cannot be discerned (fig 1a). Lisa looks at his project and replies in English: “Oh that’s for your thumb. You’re supposed to do that.” Ricki’s facial expression is visibly shocked, “Really?”

Lisa [*in English*]: “...keep reading the thing” [*She motions to the instructional pamphlet (figure 3a), which Ricki has not taken out of his Ziploc bag from the prior class. Ricki pulls it out and begins to look over it quickly, and says something inaudible to Lisa.*]

Lisa: [*in English*]: “Yes it does just keep reading it”. [*Lisa points to a particular part of the handout.*]

Lisa: “Mira, ahí. ¿Tú me estabas diciendo mentira?” (“*Look, there. Are you lying to me?*”) [*Ricki continues softly in Spanish, seemingly confused.*]

Lisa [*in English*]: “You never know.” [*Ricki goes back to reading the instructions.*]

The three continue to work on their projects. Ricki is quietly reading through the pamphlet when Juan turns to Lisa who has a pair of scissors (fig 1b):

Juan: “Dame la tijera pa [sic] atrás.” (“Give me back the scissors.”) [*Lisa holds the scissors up. Instead of taking them, Juan holds up a piece of non-conductive thread.*]

Juan: “Dale” (“There”) [*Lisa proceeds to cut the thread right in the middle.*]

Juan: “No era ahí.” (“It wasn’t there.”) [*Juan playfully shakes his head to indicate Lisa has cut the wrong spot. Lisa laughs.*]

Lisa [*in English*]: “You said there, and then I did that.” [*She points with the scissors in the center of the thread.*] “...and you didn’t say no.” [*Juan laughs and says he was playing. Ricki looks to see what Juan and Lisa are doing then looks back at the handout. He turns to Lisa and asks an inaudible question.*]

Lisa: “¿Que te pasa?” (“What’s wrong?”) [*Ricki whispers something Spanish, seeming exasperated.*]

Lisa [*in English*]: “I don’t know.” (*with surprise*) [*Ricki gets up with an expression of disappointment.*]

Lisa: “Es que tú le preguntabas” (“You asked them.”) [*Ricki goes to one of the instructors for help.*]

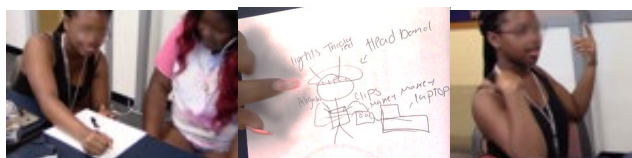


Figure 2. (a) Drawing preliminary interactions; (b) Ebony points to the diagram; (c) Priscilla demonstrating.

## Vignette 2: Engaging in complex systems design through collaboration

The second vignette focuses on Priscilla (14) and Ebony (16), who are working on their collaboratively designed final project. The vignette begins during the final week, when the two are beginning to plan out their bidirectionally responsive final project. They start drawing out the interactions (fig 2a, b), and the professor comes over to ask them specifically about the Scratch interaction, having overheard some of the confusion, “So think about the Scratch interaction. What’s going to happen in Scratch? Priscilla, what are you thinking of?”

Priscilla replies: “Um, we touch-” [*pointing to her shoulders where the left and right physical buttons would be attached (fig 2c)*] “-It’s going to move left to right. And then the lights are going to blink.”

Professor: “And Scratch?”

Ebony: “In Scratch the game will go left to right because we are doing a catch game so our basket will be left to right-” [*touching her shoulders*] “-and touch...what’s it-?”

Priscilla: “...conductive tape.”

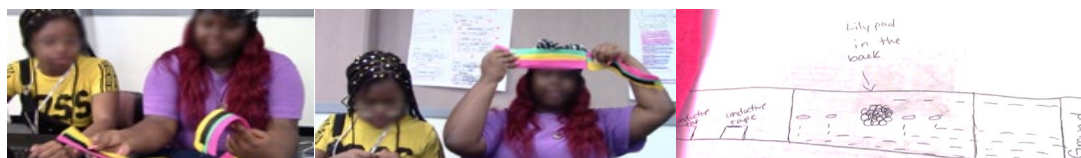


Figure 3. (a) Priscilla and Ebony showing how they added the Velcro; (b) Ebony demonstrating the headband; (c) the final detailed diagram of the headband e-textile circuit.

The instructors leave Ebony and Priscilla to continue working on their storyboarding and project fabrication. The next part of the vignette begins during the next class session, when they have already hot glued three rectangular pieces of felt and have attached Velcro to make it adjustable. Ebony shows the project to one of the instructional assistants, explaining the adjustable design of the headband, depending on head size (see fig 3a, b). Priscilla also explains that you could wear it around your waist. Ebony adds that they are “going to sew the LEDs but we are going to finish programming first.” She shows that the LEDs are going to be placed in the front. Ebony asks Priscilla where the ground should be. Priscilla suggests that it could on one end of the headband.

Ebony shows that they are going to have alligator clips on the side where the ground is and then clip the alligator clip to the conductive tape (ground). The instructional assistant reminds them to finish drawing out their designs.

About 20 minutes later, Ebony has finished drawing the diagram, and proudly explains their design to one of the instructional assistants (figure 3c): “Okay so, we have sort of an idea like how to do it... We're gonna put our, our LED's on the front and our Lilypad in the back with the piece felt covering it. So, when you put it on your head-” [makes a gesture of wearing the headband] “-you feel it, but you don't really feel it. You can feel the felt... So, we're gonna cover it with felt, we're gonna sew it on, and then we're gonna sew all our LED's from the back [of the headband]. And we'll go for each LED, we will go down and over, down and over, so our lines don't cross like this-” [showing lines crossing her fingers on her diagram (figure 3c)] “-Down and over. Down and over-” [showing the dotted lines going down from the LEDs and running parallel on the diagram] “-And then we'll have conductive tape right here [points to the conductive tape on the far left of figure 3c] “-that will go from our alligator clips to our Makey Makey.” They both continue working on the project, and before the class session is over, Ebony is sewing the Lilypad to the back of the headband. The course assistant asks about their experience working in groups. Priscilla replies, “I like working with her,” and Ebony adds “It's fun.” He then asks how they have split up the work. Ebony replies, “[Priscilla] does the coding.” To which Priscilla responds, “[Ebony] does the sewing,” and Ebony further clarifies that they are “going to work on the Makey Makey together.”

## Discussion and conclusion

We purposefully selected vignettes that cover overarching areas of significance for understanding how learners engage in collaborative meaning making with and through complex systems. The second vignette is a more traditional example of how diverse learners engage in collaboration and complex systems understanding through BRD. Specifically, Ebony, who missed several prior classes, and Priscilla, who demonstrated an aptitude for coding, were able to complement each other's strengths in service of their final design. By working iteratively, they were able to bring their shared understanding of the physical (e-textile) and digital (Scratch) systems together. We argue that the complexity of interactions and engagement add another important layer to understanding inclusive collaboration. The first vignette evidences prevalent categories of code switching. For example, the learners employ Lin's ideational category, when Lisa provides targeted support for Ricki, who has only recently learned English. She would provide certain scaffolding in Spanish, but also encourage him to seek out resources independent of her, where he would have to apply English. An added category we identified is the use of action with code switching. For instance, both Ricki and Juan actively handed-off materials or projects to Lisa; in Juan's case, it is in service of Lin's textual category (i.e., off-topic camaraderie), and in Ricki's case, it is primarily to aid his understanding. We argue that learners are utilizing complex linguistic and gestural systems to better engage with intricate material, which extends prior work on BRD for fostering complex systems engagement (Richard & Giri, 2019). In sum, we find support that, at baseline, it is important to provide more inclusive learning opportunities, such as those that account for multilingual entry points; however, such learning opportunities would also benefit from designing for purposeful collaborative engagement. The overall implications of this preliminary analysis suggest that providing meaningful, yet student-centered activities allow learners to actively help each other through complex learning tasks, often in ways that they may be uniquely able to scaffold.

## References

- Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., ... & Sherin, B. L. (2010). Conducting video research in the learning sciences. *J of the Learning Sci*, 19(1), 3-53.
- Lin, Angel M. Y. (2008). Code-switching in the classroom: Research paradigms and approaches. In K. A. King, & N. H. Hornberger (Eds.), *Encyclopedia of language and education* (pp. 273-286). New York: Springer.
- Lu, S. Y., ElMaraghy, W., Schuh, G., & Wilhelm, R. (2007). A scientific foundation of collaborative engineering. *CIRP*, 56(2), 605-634.
- Mayer, R. E. (2003). The promise of multimedia learning. *Learning & Instruction*, 13(2), 125-139.
- Richard, G.T. & Kafai, Y.B. (2015). Responsive Make and Play: Youth Making Physically and Digitally Interactive and Wearable Game Controllers. In A. Nijholt (Series Ed.), *More Playful User Interfaces* (pp. 71-93). Springer.
- Richard, G.T. & Giri, S. (2019). Digital and Physical Fabrication as Multimodal Learning: Understanding Youth Computational Thinking When Making Bidirectionally Responsive Projects. *ACM Trans on Comp Ed*, 19(3): 17:1-17:35

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# Exploring Group' Design Thinking Patterns in a Principle-based Knowledge-Building Environment

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**Abstract:** This study adopted a principle-based knowledge-building pedagogy to engage groups in four design-thinking modes (i.e., observation, synthesis, ideation and make prototypes) in an online environment. Participants were 38 college students enrolled in an “Introduction to Living Technology” course at a Taiwanese university. They were randomly assigned to eight groups. Each group discussed their design ideas in a computer-supported collaborative knowledge-building environment - called Knowledge Forum (KF) - to collaboratively design a product. Data includes students' design discussion in KF and analysis focused on online knowledge-building activities and groups' design-thinking modes. In general, knowledge-building activities cultivated students in design-thinking modes during the design process as a group. Specifically, the extent to which groups sustained online engagement and the advancement of their group knowledge had a major impact on their design performance. Ways of applying knowledge-building principles to foster effective design processes are discussed.

## Introduction

An important strand of research in design education explores how to foster students' design thinking so that they can be effective knowledge workers (Bereiter, & Scardamalia, 2014; Scheer, Noweski, & Meinel, 2012). This includes research on providing more effective and productive online learning environments. To date, current studies have introduced design thinking not only in professional design practices and in different disciplines, but also identified the process to foster design thinking. However, there have been relatively few studies dedicated to improving researchers' and educators' understanding on how to foster students' design skills using online learning environments or the design of pedagogically effective online activities (Taheri, Unterholzer, & Meinel, 2016).

Innovative instruction studies have proved that principle-based knowledge building pedagogy and technology enabled elementary students to engage in collaborative design projects to make visible their invisible design knowledge, in the form of notes written in shared online environment called Knowledge Forum (KF) (Kangas, Seitamaa-Hakkarainen, & Hakkarainen, 2013). These earlier studies have demonstrated the value of KF as a knowledge-building environment in which students can develop their design ideas. Nonetheless, no study has focused on the relationship between groups' collaborative activities and the development of design-thinking modes in online knowledge-building environments (e.g., KF). The current study is designed to adopt principle-based knowledge building pedagogy to guide students' design work in KF. Our research question was brought out: What are the groups' sequential behavior patterns of design thinking in a knowledge-building environment?

## Method

### Classroom context and participants

Educational reforms in Taiwan are shifting from teacher-guided, outcome-based education to learner-centered, maker-based, technology-integrated education. Based on that, increasing emphasis focused on cultivating students as design-oriented thinkers and knowledge practitioners. Nonetheless, there is a few courses provided to engage students in such innovative and design-oriented learning environment. In the present study, we employed principle-based knowledge-building pedagogy to engage students in online communities to develop design ideas and sustain idea improvement. The participants were 38 undergraduate students aged 18 to 22 years, from a national university in Taiwan. They enrolled in an elective course titled “Introduction to Living Technology” for a semester. At the start of the course, the participants were randomly assigned to eight small groups (G1 to G8) with four or five members each.

### Instructional design

The course had two separate parts, one based on lectures given by an instructor and the other on a student-directed design project (for 14 weeks). The groups were allowed to freely choose project topics based on their interests (i.e., shoes, glasses, cotton swab, e-book projector, VR and its application, parking lot, raincoat). The design projects were taken places in an online environment with the goal to help students develop design modes of

thinking through knowledge-building activities.

Groups' design work was explicitly guided by two knowledge-building principles: "community knowledge, collective responsibility" and "improvable ideas" (Scardamalia, 2002). The first principle states that participants should work collectively to advance the group's knowledge. The main KF activities, such as notes generated and read, essentially reflect the extent of students' online engagement. The second principle, "improvable ideas", asserts that ideas are improvable and that collective advancement of knowledge depends on sustained, creative work with ideas as a group. Students are encouraged to identify design topics that interest them and then to contribute their initial design ideas in the form of notes in KF. The important point is the production and refinement of ideas (i.e. knowledge advancement activities) that leads to the evolution of group knowledge, and therefore optimizes their design work.

## Data collection and analyses

The data of this research was based on groups' design work in an online environment called KF, which is designed on the basis of knowledge building principles so the KF supports the principle-based knowledge building pedagogy.

### Analyses of knowledge-building activities

Knowledge building activities include engagement and knowledge advancement. Engagement data was directly retrieved from embedded analytical tool of KF. We summed up number of notes generated and read. In contrast, knowledge advancement in the online community was assessed by counting their built-on (i.e., connected) notes in the KF database and by coding these notes into six levels of cognitive understanding suggested a revised version of Bloom's taxonomy (see Anderson et al., 2001). Using the six cognitive levels from remembering to creating, along with exemplary verbal concepts to indicate knowledge advancing efforts (such as interpreting, designing, etc.), a score of 1 to 6 was assigned. Two researchers independently coded data and Cohen's kappa coefficient computed was 0.87 ( $p < 0.001$ ).

### Analyses of design-thinking modes

During the design process, students were introduced to four design-thinking modes (i.e., observation, synthesis, ideation, prototype creation) to help them design products (Plattner, 2010). Groups' design processes were further coded in six categories in our study: (1) discarded idea: the ideas were left without further discussion (e.g., S35: This cannot work, let's abandon the idea.); (2) social talk: they shared an understanding or emotional response toward a thing (e.g., S8: I agree! This is a good way to try.); (3) observation: they "observe" emerging problems in their daily life and then choose a topic that interested them (e.g., S2: Police officers might be well-trained, additional function to their shoes would give them another way of protecting themselves); (4) synthesis: they "synthesized" all the problems in which they were interested into a set of core problems on which they wanted to do further work (e.g., S5: I think that our design could focus on different functions for different duties or tasks, for example...); (5) ideation: they "ideated" every possible solution to the core problems (e.g., S1: I think that the electricity to be used for shocking should be controlled to just cause minor cramp); (6) prototype creation: they summarized and developed a "prototype" (in concept only, due to time constraints) based on promising ideas they had identified (e.g., S30: Our design could include...). Using notes as the unit of analysis, two researchers independently coded data into above mentioned six coding schemes, with Cohen's kappa coefficient computed to be 0.90 ( $p < .001$ ).

### Analytical strategies

In order to answer our research question, we calculated KF activity scores using z-scores based on the sum of online engagement activity (including the numbers of notes contributed and read) score and online knowledge advancement score (number of built-on notes and their quality scores). Next, scores for KF activities were calculated using a two-stage cluster analysis with knowledge engagement and advancement as two principal indicators: (1) first using hierarchical clustering analysis to determine the cluster number on the basis of dendrogram; (2) second using k-mean cluster analysis on the identified cluster number. Last, we examined groups' design-thinking performance using behavior sequential analyses to ascertain design patterns (i.e., discarded idea, social talk and four design-thinking modes, i.e., observation, synthesis, idea generation and prototype creation) for each cluster.

## Results

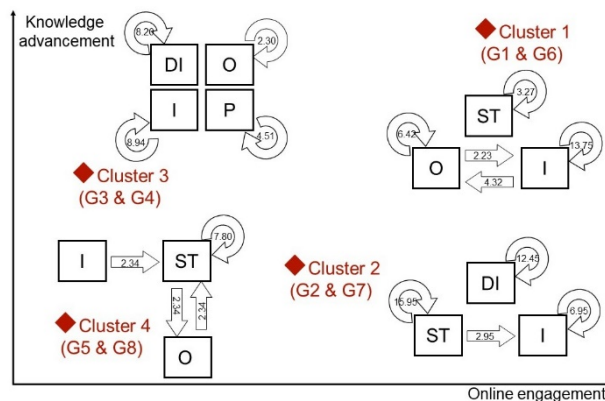
### Group design-thinking performance in a knowledge-building environment

The online engagement of the 38 participants contributed 399 notes ( $M = 10.5$ ,  $SD = 7.16$ ), read 2728 notes ( $M =$



71.79,  $SD = 79.23$ ). The knowledge building advancement counted 181 built-on notes ( $M = 4.76$ ,  $SD = 4.90$ ) and the mean score of built-on notes was 1.69 ( $SD = 0.60$ ). Cluster analysis was employed to measure students' online engagement and knowledge advancement activities (using z-scores). The four clusters which emerged according to the online behavior they represented, Cluster 1 (groups 1 and 6), Cluster 2 (groups 2 and 7), Cluster 3 (groups 3 and 4), Cluster 4 (groups 5 and 8).

We conducted the sequential analysis on the six design behaviors - discarded idea, social talk, observation, synthesis, ideation and prototype creation as exhibited by the four clusters of groups. The adjusted residual z-score greater than 1.96 indicates that a statistically significance ( $p < .05$ ) of the continuity of specific initial behavior is followed by a subsequent behavior in the design process (Bakeman & Gottman, 1997). As a result, the design behavioral patterns of each cluster is shown in Figure 1.



**Figure 1.** Clusters distribution and design behavioral transition.

Note: DI = discarded idea, ST = social talk, O = observation, I = ideation, P = prototype creation.

The above analyses show an integrating of cluster and sequential analyses of groups' design behavior patterns within the knowledge-building environment. Cluster 1 exhibited high frequencies of online engagement activities and knowledge advancement activities and thus had the best overall design performance as reflected in the sum of their design patterns. Via sequential behavior analysis, we found that groups in Cluster 1 tend to involve in the iterative social talk, observation and ideation. Moreover, they might worked back and forth between observing problems and generating solutions.

Cluster 2 showed that their online activity was dominated by online engagement activities at the expense of knowledge advancement activities and as a result, their design behavioral transition were mainly on iteratively discarding ideas, talking and ideating. As a result, some ideas come after their talking such that group 2 contributed a lot of information, but the information was not being further refined via reflection and elaboration to advance knowledge.

Cluster 3 did better than Cluster 2 at knowledge advancement activities; however, there was relatively little online engagement. This overemphasis on the former is clearly evidenced by the quality of their reflective efforts to advance knowledge through iteratively discarding useless ideas, observing designed problems, proposing possible ideas and making prototype. But their design behavior could not be transited. For example, group 4 worked iteratively on their initial design ideas but did not try to enrich or diversify their initial pool of ideas in order to broaden their ideas solutions.

Lastly, Cluster 4 clearly had the lowest frequencies of online engagement activities and knowledge advancement activities. For example, the groups in Cluster 4 were mainly focus on social talks. As a result, they were not able to decide their design topics. Even though their social talks and observation activities are bi-directionally influencing each other, their social talks were not helpful for observing problems.

## Discussion and future directions

The purpose of this study was to investigate whether working in a computer-supported collaborative knowledge-building environment, in this case KF, improves students' design-thinking capability. Students were guided by two knowledge-building principles to encourage them to engage in interactions in an online environment (i.e., "community knowledge, collective responsibility") and advance knowledge (i.e., "improvable ideas"). They involved in design projects to collaborate with group members. To summarize, the findings suggest that the performance of the different clusters would need different, customized guiding principles to further facilitate KF



activities and achieve an appropriate balance between them, in order to improve different groups' design performance. For example, we found that many students struggled with particular modes of design thinking and so it might be helpful to design some customized instructional scaffolds to smooth the transitions from one design-thinking mode to another, such as "I observe", "I emphasize", may help novice designers to concretize design ideas and consolidate the complex design process. To facilitate further development of design ideas, it is perhaps necessary to encourage groups to make a fast prototype creation that requires the participants to explain how the prototype would meet users' needs. In addition, setting up more specific and well-defined design goals in each design-thinking mode may be useful.

Moreover, this study showed that groups that demonstrated better knowledge engagement and more knowledge advancement activities also tended to have better and smoother design behavioral transition as indicated by behavioral sequential analyses. In other words, balanced online engagement and knowledge advancement activities in a knowledge-building environment have important effects on students' design-thinking capability.

Instructional implication for future studies should select appropriate pedagogical principles to shape a productive learning environment. This study employed a principle-based knowledge building pedagogy by using two explicit principles and found that providing students with guiding principles helped create an effective knowledge-building environment in which both online engagement and knowledge advancement activities were valued. We found that in an open, collaborative knowledge-building environment that encourages production of ideas and makes it easier to connect ideas to each other, online activities such as contributing, reading and building on notes have to be engaging enough if they are to advance a group's knowledge. For example, groups who find it difficult to move from one design-thinking mode to another might benefit from an additional guiding principle "rise above" (see Scardamalia, 2002, for detail). This principle that highlights group members collectively working towards higher-level understanding of problems, may be useful for guiding the groups to focus on the task at issue, and thus to help enhance group members to enhance their thinking skills. In summary, design thinking is emerging as one of the key thinking competency for the 21<sup>st</sup> century. To facilitate students' development of design thinking, pedagogical models that with appropriate use of knowledge building principles are urgently needed. Future research into these issues is in progress.

## References

- Anderson, L. W., Krathwohl, D. R., Airasian, P., Cruikshank, K., Mayer, R., Pintrich, P., ... & Wittrock, M. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy*. New York. Longman Publishing.
- Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis*. Cambridge university press.
- Bereiter, C., & Scardamalia, M. (2014). Knowledge building and knowledge creation: One concept, two hills to climb. In *Knowledge creation in education* (pp. 35-52). Singapore: Springer.
- Kangas, K., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2013). Design expert's participation in elementary students' collaborative design process. *International Journal of Technology and Design Education*, 23(2), 161-178.
- Plattner, H. (2010). *Bootcamp bootleg*. Palo Alto, CA: Stanford Institute of Design.
- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp.67-98). Chicago: Open Court.
- Scheer, A., Noweski, C., & Meinel, C. (2012). Transforming constructivist learning into action: Design thinking in education. *Design and Technology Education*, 17(3), 8-19.
- Taheri, M., Unterholzer, T., & Meinel, C. (2016). Design Thinking at Scale: A Report on Best Practices of Online Courses. In *Design Thinking Research* (pp. 217-235). Springer International Publishing.

# Perspective Taking in Participatory Simulation-based Collaborative Learning

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**Abstract:** This experimental study examined participatory simulation-based collaborative learning in a teaching training setting. A virtual-reality (VR) supported, embodiment integrated learning system is constructed to enable collaborative and contextualized teaching practices by university teaching assistants. A total of 40 teaching assistants participated in a 4-hour teaching training session, during which they were randomly assigned to a VR-supported and a live simulation group. Participants reported significantly higher teaching self-efficacy after the training. The VR participatory simulation better promoted the post-session, lab-teaching knowledge test performance than the live simulation. ‘Bicentric’ perspective taking embedded in VR-based interactions facilitated both experiential and vicarious learning. Yet a concurrent hybrid presence framed by the virtual and physical collocation of participants exerted an over-reliance on individual autonomy in VR simulation-based collaborative learning.

## Introduction and literature review

Simulation refers to the imitation or representation of dynamic features and structural elements of a real-world system, entity, phenomenon, or process (Frasson & Blanchard, 2012). A *participatory simulation* extends and integrates a real-world representation with participatory and collaborative role-play—‘diving into’ the simulated space and directly engaging with the simulated system or phenomenon (Colella, 2000; Ackermann, 2012).

According to Piaget (2005) and Ackermann (2012), both perspectives of “diving in” and “stepping out” are important for deeper understanding. By “diving into” a variety of situations and becoming part of the phenomenon, the learners are connected and sensitive to variations in the environment in reacting to their actions. By “stepping out” of the situations or momentary withdrawal from immersion in the experience, the learner then gets the chance to *reflect on* their experience from a distance to form more abstract, symbolic insights and achieve “reflexive abstraction.” Through shifting between “diving-in” (egocentric) and “stepping-out” (exocentric) perspectives, learners are able to differentiate and coordinate different viewpoints to discover foundational rules governing the phenomenon (Ackermann, 2012; Dede, 2009).

Although such an integrative, “bicentric” frame of reference is argued to support the mastery of complex, multidimensional information (Dede, 2009), the design and research of a bicentric perspective in simulation-based collaborative learning is lacking. Prior research of participatory simulations predominantly studied the single “diving in,” immersive experience, focusing on a simulation with surrounding projection or a pervasive play experience. To extend prior research, this current examination is aimed to explore the design and learning effectiveness of a participatory simulation that: (a) integrates both perspectives in its interactivity, and (b) enables the shifting between immersive role-playing and “stepping-out” observation of the simulated phenomenon by blending a virtual and a physical learning space.

## Virtual reality for participatory simulation with a bicentric perspective

The nature of virtual reality is defined as “Immersion-Interaction-Imagination” by Burdea and Coiffet (2003). Virtual reality (VR) enables and integrates a 3D immersive user interface, multimodal and real-time interactivity, participatory narrative, and persona construction that promotes imagination creativity. VR also allows the user to view and interact with a virtual object, space, or phenomenon from egocentric and exocentric perspectives. These salient features of VR make it a promising platform of collaborative, participatory simulation with dynamic perspective taking. A recent meta-analysis of the effectiveness of virtual reality-based instruction on students’ learning outcomes in K-12 and higher education indicated that virtual worlds were effective in improving learning outcome gains (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014).

Although isolation from the physical environment is considered immersive, it is not a prerequisite for the situated immersion (Witmer & Singer, 1998). It is argued that one’s immersion in a virtual space does not require the total displacement of attention from the physical locale, because typically attention is divided

between the physical world and the mental world of imaginations, memories, and other cognitive activities. In other words, individuals experiencing a virtual space can concurrently attend to aspects of the virtual space and events in their physical environment.

### Simulation-based teaching training

Teaching is complex problem solving that requires contextualized information representation and multimodal interpersonal interactions. Cruickshank (1986) summarized four levels of strategies in teaching training: (a) concrete-real – in-field and clinical experiences of student teaching; (b) concrete-modeled – simulated teaching experiences, such as role-playing, microteaching, and simulation; (c) vicarious – observations of others teaching live in classrooms or on tape, and (d) abstract – learning from lectures, case studies and discussions. Teaching training in university has traditionally relied on abstract instructional strategies. The need for training to bridge the gap between abstract and concrete-real experiences of teaching is critical for future university instructors (DeChenne et al., 2012).

The use of virtual reality to promote simulation-based teaching training is just emerging (Ke, Lee, & Xu, 2016). In a recent qualitative, observatory study, Quintana and Fernández, (2015) reported that VR can provide a virtual space to simulate teaching challenges and hence act as a pedagogical tool for the collaborative teaching training program. Gregory and Masters (2012) conducted a study on using SecondLife-supported VR for pre-service teachers to practice teaching. The study reported that VR-based simulation and role-playing made pre-service teachers “think in complex and creative ways by assisting them in considering multiple perspectives on a topic” (p.427). Gregory and Masters (2012) called for future research on designing VR training to serve as a complementary part for teachers with both real-life and virtual accesses.

### Methods

By investigating a VR-supported, participatory simulation in comparison with the live simulation in the collaborative learning setting, this study aimed to address the following research questions: *To what extent will the VR-supported participatory simulation, compared with the live simulation, support teaching practices and knowledge development?* An experimental, pretest-posttest control group design was adopted. Both quantitative and qualitative data on participatory simulation-based collaborative learning were collected.

### Participants

Forty university teaching assistants were recruited from the chemistry department in a land-grant university in United States. These participants included 22.5% females and 77.5% males, with 50% of them not having teaching experience and 37.5% being non-native English speakers. Twenty one participants were randomly assigned to the VR-supported simulation group while the other 19 were assigned to the live simulation group. Both groups participated in a 4-hour, synchronous training session in a physically co-located setting, with the VR simulation group staying in a computer lab and the living simulation group being in a chemistry classroom.

### Simulation-based collaborative learning environments

#### VR-supported participatory simulation

In the VR simulation-based learning setting, participants were physically seated in the computer lab and participated in collaborative role-play through a 3D, VR-supported simulation. Using OpenSimulator, a virtual campus was designed to simulate daily teaching scenarios, such as *lab teaching*, *recitation*, and *assignment tutoring*. Participants were assigned into two sub-groups. Within each sub-group, participants shifted the roles of instructor and student in the teaching scenarios, following a semi-structured protocol that outlines the backdrop mission, structure, and planned procedure of the collaborative roleplay. Each participant was provided a randomly-assigned, role-play notecard describing a specific learner or instructor profile with exemplary scripts. Every participant wore headsets during the training session, and there were dividers in between their seats. They did reflective group debriefing via VR voice and text chats at the end of each teaching simulation.

Using Microsoft Kinect and a middleware that interfaced Kinect with the OpenSimulator platform, the VR-based teaching simulation enabled participants to project and embody real-time body movements and gestures onto their avatars in the virtual world. Specifically, it enabled embodied gesturing in virtual lecturing.

Implementing VR-supported simulation in a physical co-located space would create a hybrid space that allows trainees to engage in collaborative role-play in a virtual space through virtual avatar embodiment, while maintaining a real-world identity to do reflective and vicarious (or observational) learning of their virtual-world performance. VR simulation also supports the sifting between the first and third person points of view during the interaction and navigation. *We hypothesized that the hybrid, virtual-physical learning space as well as the*

bi-centric interaction interface of the VR simulation would offer trainees a dynamic “diving-in” and “stepping-out” perspective taking during participatory simulation-based learning.

### Live participatory simulation

In the live simulation-based learning setting, participants were physically seated in a typical chemistry classroom. Facilitated by an experienced teacher trainer, they performed collaborative role-play—acting and shifting being the instructor or student in simulated teaching scenarios. The structure and protocol of simulation-based collaborative learning activities in the live simulation setting were similar to those in the VR simulation group, except that all activities were performed face to face in a physical space—an actual classroom.

### Data collection

All Participants received a teaching knowledge test and a teaching self-efficacy survey before and after the study session. The teaching knowledge test was developed based on the existing graduate teaching training materials of the chemistry department, and encompassed 12 lab-teaching story problems (Cronbach's  $\alpha=.88$  in this study) and 4 recitation/tutoring story problems (Cronbach's  $\alpha=.61$ ). Each problem presented a scenario narrative and asked participants to select all applicable problem solutions in a checklist. Each item is scored on the number of correct answers selected. The STEM Graduate Teaching Assistant (GTA) teaching self-efficacy survey by DeChenne, Enochs, and Needham (2012), validated in prior research on GTA teaching training, was adopted in the study. The survey consists of 15 five-point Likert scale items (Cronbach's  $\alpha=.95$  in this study).

Participants' learning interactions in the two simulation-based learning settings are observed, screen captured, and voice recorded. A semi-structured group interview was conducted at the end of the study session, focusing on exploring participants' perceptions of their learning experiences.

### Data analyses

We conducted descriptive statistics and pairwise t-tests with the pre- and posttest results to examine the potential changes in participants' teaching knowledge and self-efficacy before and after the study session. We then did ANCOVA analyses to investigate whether there was a difference between the two modes of participatory simulation in supporting participants' teaching knowledge and self-efficacy development. We also performed a qualitative thematic analysis with the qualitative data to examine salient themes that depict the attributes and the nature of simulation-based collaborative learning in the two simulation settings. The qualitative findings provided descriptive evidence and explanation on the features of the two participatory simulation environments and their impacts on participants' collaborative learning processes.

## Findings

### Modes of participatory simulation on teaching knowledge

A one-way ANCOVA was conducted to compare the effect of simulation modes on the post-session lab-teaching scores of participants in the VR and live simulation conditions, with the participants' pre-session scores as the co-variate. There was a borderline significant effect of the simulation modes on the lab teaching scores,  $F(1, 33)= 3.48, p=.07$ , partial  $\eta^2=.10$ . The VR-supported participatory simulation group ( $M_v=28.80$  out of 43,  $SE_v=5.38, n=20$ ) scored higher than the live participatory simulation group ( $M_l=24.63, SE_l=6.14, n=16$ ).

The ANCOVA on the effect of simulation modes on the post-session recitation/tutoring scores of participants in VR and live simulation conditions also indicated a significant result,  $F(1, 37)= 23.54, p<.001$ , partial  $\eta^2=.39$ . Differently, the live participatory simulation group ( $M_l=7.47$  out of 17,  $SE_l=1.65, n=19$ ) scored higher than the VR-supported participatory simulation group ( $M_v=5.81, SE_v=2.20, n=21$ ) in the post-session recitation/tutoring knowledge test.

### Modes of participatory simulation on teaching self-efficacy

A one-way ANCOVA was conducted to compare the effect of simulation modes on the post-session teaching self-efficacy scores of participants in VR and live simulation conditions, with the participants' pre-session scores as the co-variate. There was not a significant effect of the simulation modes on the teaching self-efficacy scores,  $F(1, 34)= 0.15, p=.71$ . The pairwise t-test comparing the teaching self-efficacy of all participants ( $n=37$ ) before and after the training session indicated a significant result,  $t(36)=-2.76, p<.01, d=-.31$ . Participants scored higher in the teaching self-efficacy responses after the session,  $M_{pre}=63.24$  out of a total of 75,  $SD_{pre}=7.73$ ;  $M_{post}=65.03, SD_{post}=8.21$ .

### Qualitative findings

Two salient themes governing the features of VR-supported participatory simulation in relation to collaborative learning processes and outcomes emerged from the qualitative data: (a) experiential and vicarious learning enabled by a bicentric interaction interface, and (b) inconsistency and heterogeneity in resource or effort allocation across the hybrid learning spaces. We observed that more than 50% of the role-playing or learning interactions in the VR-based simulation involved participants' shifting points of view; the frequency of enacting ego- and exocentric perspective alternation during the interactions tended to be positively associated with both prior teaching experience and the post-session teaching knowledge performance. An interpretation is that dynamic perspective taking embedded in the VR interactions facilitated both "diving-in" experience and evaluative observation of each other's teaching practices.

On the other hand, a concurrent hybrid presence framed by the virtual and physical collocation of participants in the VR simulation was associated with a reliance on individual autonomy in coordinating one's simulated and real-world personae during collaborative role-playing. As a result, participants showed differing level or pacing in allocating their attentional resources in between VR-based collaborative role-playing and "stepping-out" reflection/observation. Their attention allocation to the collaborative role-playing also fluctuated based on the contextual demand, with the "diving-in" input obviously reduced in teaching scenarios that prioritize lecturing or concept explanation (e.g., recitation/tutoring). The inconsistent and inequivalent individual learner involvement in collaborative role-play created frustration and may have moderated the experience of immersion and interactivity in VR simulation-based learning. In comparison, the live simulation participants demonstrated a similar and consistent level of engagement in collaborative role-playing.

## Implications and significance

The study findings generally support the feasibility and effectiveness of a VR-supported participatory simulation that enables dynamic perspective taking in the collaborative learning of a complex task. The study indicates an interaction between the design of perspective taking and learner autonomy in collaborative role-play. It will help to inform not only the approach of concrete, modeled teaching training in an accessible manner, but also design strategies in relation to perspective taking, interactivity, and immersion that enhance simulation-based collaborative learning.

## References

- Ackermann, E. (2012). Perspective-taking and object construction: Two keys to learning. In Y. B. Kafai & M. Resnick (Eds.), *Constructionism in practice* (pp. 39-50). New York, NY: Routledge.
- Burdea, G. C., & Coiffet, P. (2003). *Virtual reality technology*. Hoboken, NJ: John Wiley & Sons.
- Colella, V. (2000). Participatory simulations: Building collaborative understanding through immersive dynamic modeling. *The Journal of the Learning Sciences*, 9(4), 471-500.
- Cruikshank, D. R. (1986). Instructional alternatives available for use in professional education. In E. Doak (Ed.), *Simulation and clinical knowledge in teacher education: Prologue to the future* (pp. 10-20). Knoxville, TN: University of Tennessee, College of Education.
- DeChenne, S. E., Enochs, L. G., & Needham, M. (2012). Science, Technology, Engineering, and Mathematics Graduate Teaching Assistants Teaching Self-Efficacy. *Journal of the Scholarship of Teaching and Learning*, 12(4), 102-123.
- Dede, C. (2009). Immersive interfaces for engagement and learning. *Science*, 323(5910), 66-69.
- Frasson, C., & Blanchard, E. G. (2012). Simulation-based learning. In *Encyclopedia of the Sciences of Learning* (pp. 3076-3080). Springer US.
- Gregory, S., & Masters, Y. (2012). Real thinking with virtual hats: A role-playing activity for pre-service teachers in Second Life. *Australasian Journal of Educational Technology*, 28(3).
- Ke, F., Lee, S., & Xu, X. (2016). Teaching training in a mixed-reality integrated learning environment. *Computers in Human Behavior*, 62, 212-220.
- Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education*, 70, 29-40.
- Piaget, J. (2005). *The psychology of intelligence*. Abingdon, UK: Routledge.
- Quintana, M. G. B., & Fernández, S. M. (2015). A pedagogical model to develop teaching skills. The collaborative learning experience in the Immersive Virtual World TYMMI. *Computers in Human Behavior*, 51, 594-603.
- Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7(3), 225-240.

# Using A Virtual Design Studio to Support Collaborative Studio Instruction

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**Abstract:** This study explored artifact-driven online collaboration methods within a virtual art studio context. A collective case study (Stake, 1995) methodology was used to investigate a virtual design studio (VDS). The purpose of this study was to explore how two different studio art classes used a VDS environment to engage in studio practices and online critique processes. Through data analytics and thematic analysis, this study investigated how students collaborate during the critique process in a VDS environment. The results are supported in three ways: (1) VDS technology afforded viewing and the critique of artifacts, (2) the VDS failed to support dynamic peer collaboration, and (3) students sought technology alternatives to engage in deeper discussion. These findings aim to increase the effectiveness of VDS and expand the methods of online student collaboration.

**Keywords:** virtual design studios, online collaboration, online discourse

## Introduction

A virtual design studio (VDS) is one platform in which students can post artifacts (artwork), critique/collaborate, facilitate sharing of design information, and support integration regardless of place and time (Broadfoot & Bennett, 2003). A critique is a strategy used to evaluate students' work and work in progress to discover potential ways to proceed (Hetland et al., 2013). A critique is a creative and collaborative process that is linked to the principles of effective learning and has been identified in the learning sciences (Sawyer, 2012).

Studio-based learning (SBL) is a method used in arts-based education that allows learners to use feedback from peers to refine their work and it is through that interaction that students can foster a sense of creative discovery, exploration of ideas, and critical discussions (Vyas et al., 2012). Students are encouraged to not only produce artifacts but also to critically respond to others' artwork (Halverson & Sheridan, 2014). A group of students can achieve more together than they could individually (Barrett, 2000). A typical interaction involves both the instructor and students providing feedback to a piece of artwork, as well as the artist responding. This is a continual dialogue between an instructor and peers. Due to evolving technology, studios that leverage a virtual design environment are a relatively new phenomenon; therefore, it is important to investigate the affordances and constraints of this new offering and to examine how the proliferation of the online environment impacts the student learning experience in the arts discipline. As classroom learning environments inevitably transition to more online environments, unanswered questions of practical and theoretical significance are worth discussion: How can a critique effectively translate into an online environment? What will be lost or gained in this process?

The creative process and collaborative critique are linked to the principles of effective learning and have been identified in the learning sciences (Sawyer, 2012). Given the research on SBL, this study explored how two case studies used a VDS for studio practices, specifically the collaborative nature of participating in a critique. By embedding a collaborative activity, like a critique, into the structure of a course, encourages students to view it as a necessary step in the process of creating quality work (Ruff, 2010). This research investigated how technology impacts the collaborative critique process in a virtual studio environment. Specifically, this study aimed to investigate: How does technology provide opportunities or barriers to student collaboration in a virtual environment?

## Methods

This study builds off of a pilot study that was conducted in the spring of 2016. The goal of the pilot study was to explore strategies to leverage this technology in an effort to support critiques and collaboration practices. The pilot study was integral in the design of the VDS and helped to determine what "worked" and what did not in the VDS.

This study ran in fall 2017 and employed a qualitative collective case study (or multiple case study) design (Creswell, 2013; Yin, 2003) to describe and explain how learners in two asynchronous studio-based classes utilized a VDS. This collective case-study (Stake, 1995) builds off the pilot and focused on two different courses from a Digital Multimedia Design (DMD) program at a university in higher education to explore the pedagogical beliefs and implications for SBL in two asynchronous learning environments.

## The participants and case study setting

Participants included 17 undergraduate students (ages 18-44). This first case examined a course which introduces students to the concepts, skills, language, and principles of practice in art and design, communication, and information sciences. Ten students consented to be a part of the study. The second case study analyzed a course that provides an introduction to how computer hardware and software can be used to produce works of art and design to be exhibited electronically or in print. Seven students consented to be a part of the study. The analyses focused on two assignments for each case study that included studio-based instruction and a critique of artwork. Students were taught a critique method to provide feedback called the critique sandwich, in which students provided a compliment, followed it up with a possibly negatively comment, and ended the critique with a positive statement. Furthermore, these assignments required students to go through a process of ‘propose–critique–iterate,’ where students provided feedback to help refine an artifact (Brocato, 2009, p. 179) for final submission. This practice is similar to the characteristics of the four studio hallmarks: demonstration-lecture, students-at-work, critique, and exhibition (Hetland, 2013).

## Learning design and environment

The learning environment from this study focused on the participation and experiences of conducting a critique in the VDS. This VDS is a component of a larger online platform called eLearning Management System (ELMS). The ELMS platform was developed using Drupal, an open source educational technology platform used for building and sustaining innovative online courses. In ELMS there are two virtual environments: (1) course pages and (2) the VDS. Courses pages, which were separate from the VDS, displayed specific information about assignments and course content. This study concentrated on the VDS. Students were taught how to use the system and were required to use it for all class assignments and to critique peers (see Figure 1).

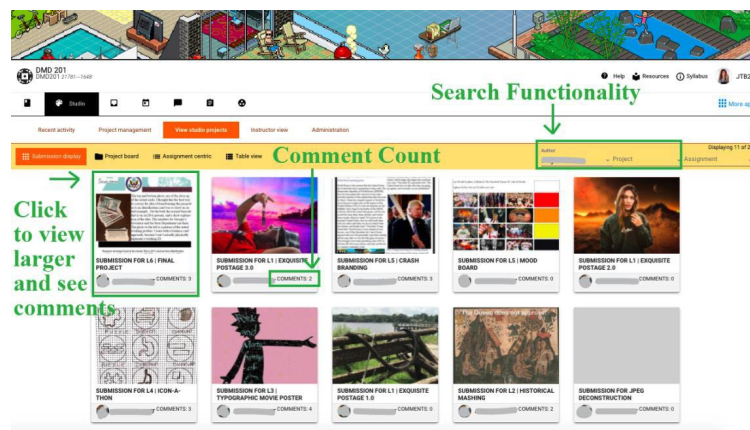


Figure 1. The VDS Homepage that Shows a Galley of Student Artwork.

## Data sources and analysis

Data sources included: (a) data/user analytics, (b) transcripts of discourse and student artifacts (artwork) posted on ELMS, (c) online interviews, and (d) background information surveys. Interviews were transcribed and interactions on the virtual studio were documented and interpreted. There were two types of data analysis: (1) data analytics to examine critique completion and response rates and (2) thematic analysis of participant interviews. Both of these methods were collected to discover trends in participation and engagement in the VDS.

## Findings

Technology is what mediates the collaborative environment between students since there are no synchronous communication components. The findings are categorized in three ways: technology affordances (what the VDS allows students to accomplish from the participants' perspective), technology failures (concern with the technology and issues using/navigating the VDS), and technology alternatives (other critique methods).

## The VDS technology afforded viewing and critiquing artifacts

The functionality of ELMS allowed participants to complete critiques and provided an environment that enabled dialogue, conversations, and critique of peers' works. As one participant discussed, the asynchronous aspect of the VDS was beneficial because of the flexibility: "I do the bulk of my homework and stuff during my downtime

at work or on my breaks.” The VDS allowed her to access the studio from anywhere and still participate in class in spite of her busy work schedule. Another student stated that the being asynchronous allowed more time to reflect on peers’ work: “[...] I have time to think about it. I mean I don't always have to answer right away, but it's nice [...] and maybe sit with it, and kind of have the wheels turning.” The asynchronous nature of the case studies allowed for flexibility and reflective practice (Schön,1987), which is essential to SBL. Students in both case studies completed critiques, provided feedback to peers, and were able to progressively iterate toward a solution. In both case studies, student perceptions were overall favorable. One participant interviewed described the ease of using the VDS to review her peers’ feedback: “It was it was nice because you know [...] right on the side of your work, you can see [...] in a list of all the people's response [...] it was definitely helpful.” The layout of the VDS allowed participants to easily search for and view peers’ work. The VDS homepage allowed students to view active projects, identify who needed a critique, and view recent submissions.

### Asynchronous technology failed to support dynamic peer collaboration

The technology used for the VDS had limitations. During a critique, students were required to respond to at least two people or a set group. When examining student participation, students only provided an initial response, rarely responded to peers’ critiques, and rarely extended beyond the required amount (see Table 1). The technology in this study did not promote the levels of student interactions intended, and the majority of students simply went through the motions, completing activities because they were required to as part of a grade. Students in face-to-face studio environments typically thrive off peer collaboration and learning (Kvan, 2001), but in this collective case study, participants did not contribute to a back-and-forth communication process. Instead, communication was one-directional, meaning it was student-to-student or instructor-to-student, with no response back.

Table 1: Participation Averages

	Mean # of Critiques per student	Mean Word Count for each critique	Mean # of Replies
Case Study 1: Assignment 1 N=10	2	197	0
Case Study 1: Assignment 2 N=10	2	562	0
Case Study 2: Assignment 1 N=7	3	113	0
Case Study 2: Assignment 2 N=7	3	162	1

The asynchronous nature of the VDS further impacted the critique; typically critiques involve the discussion of and sharing of ideas in order to develop design projects (Kvan, 2001). However, in this case, the VDS environment did not meet all of the students’ needs in order to foster the appropriate levels of collaboration. For example, one participant indicated that not being in a face-to-face environment was a barrier in forming a sense of a connection with peers: “[...] I didn't ask anyone any questions because [...] there's a disconnect between everybody [...] because it's not like a classroom where you could just turn to your left and right, and form any type of rapport.” The asynchronous nature of the VDS isolated students and led to limited discussion and debate among peers, both of which are important aspects of the signature pedagogy (Cennamo & Brandt, 2012). Participants reported that more direct notifications (or pings) when others provided a critique would have been helpful to promote engagement and lessen isolation. Further investigation of the tools and technology in conjunction with social interactions should be explored in an effort to increase the discussion aspect of the VDS that was limited in this study.

### Students sought technology alternatives to engage in deeper discussion

Participants in both case studies reported that they wanted to engage with their peers, but the VDS environment was not allowing them to adequately do so. One participant from the first case study discussed how she did not complete a critique in ELMS: “I did kind of my own personal experiment on one after I wasn't getting a lot of feedback. And I took it to Facebook....and many of my friends ripped me apart and helped me build it to something better...” In the second case study, participants reported that they utilized other technology to communicate and collaborate. For example, one participant described in the interview that he wanted to directly communicate with a peer and could not: “[...] I sent them a message outside and saying like 'hey - you want to see your idea in action? This is kind of what I did with it.' [...] And then they commented on it and critiqued it a little bit [...]



through our canvas message.” This student used Canvas (the University LMS), not ELMS (the VDS), to communicate with peers for a critique. The notion that students were critiquing by using technology not provided in the class suggests that multiple technologies and methods for supporting discussion around artifacts were needed.

## Conclusions and implications

This study provides perspectives on utilizing a VDS in SBL courses. One underlying objective of this study was to investigate the characteristics of a VDS that allow students to experience a successful critique process in a virtual environment. By analyzing two asynchronous SBL courses, we were able to examine the beliefs and practices associated with facilitating a critique in a VDS. The findings suggest that students recognized the affordances of being asynchronous and that the VDS was effective in allowing students to participate and conduct critiques. In both case studies, participants saw value in being online as it allowed for flexibility in students’ schedules and wider availability, meaning students could be located anywhere, yet still participate in collaborative work (Bradfoot & Bender, 2012).

The findings revealed insight into the prevalence and growth of online education models and provide implications for a redesign of the structure of the course requirements of a studio-based course. Consistent with other studies on a VDS, continuous dialogue is a central component of critique and typically involves students engaging in dialogue with the artist (Vyas et al., 2013). A response to an initial critique, which is equally as important to the critique process, involves aspects such as answering questions and posting new ideas. However, this environment lacked the continuous dialogue component of a critique. It was found that due to the strict course requirements and procedures, the dialogue became largely one-directional and involved only a small number of students. Course requirements should have less rigid peer critique requirements and should promote the idea of responding to peers to initiate continuous dialogue.

Furthermore, due to the lack of interactivity and responses, participants, sought out alternative forms of technology to conduct critiques when the immediate environment was not meeting their needs. This lack of interactivity leads to the idea that a focus should be placed social presence in the online experience (Whiteside, 2015) in order to promote a level of collaborative discourse in SBL. Building relationships in online courses are important for students to connect and engage with each other (Whiteside, 2015) and to the studio pedagogy in order to encourage connections in the iterative design process (Cennamo & Brandt, 2012). Further exploration is needed to synthesize and develop methods to use in online critiques and promote student collaboration.

## References

- Broadfoot, O., & Bennett, R. (2003). Design studios: Online? Comparing traditional face-to-face design studio education with modern Internet-based design studios.
- Brocato, K. (2009). Studio based learning: Proposing, critiquing, iterating our way to person-centeredness for better classroom management. *Theory into practice*, 48(2), 138-146.
- Cennamo, K., & Brandt, C. (2012). The “right kind of telling:” Knowledge building in the academic design studio. *Educational technology research and development*, 60(5), 839- 858.
- Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th edition). Thousand Oak, CA: Sage.
- Hetland, L., Winner, E., Veenema, S. and Sheridan, K.M. (2013) *Studio thinking 2: The real benefits of visual arts education*. 2nd ed. New York: Teachers College Press.
- Kvan, T. (2001). The pedagogy of virtual design studios. *Automation in Construction*, 10(3), 345-353.
- Sawyer, R. K. (2012). Learning how to create: Toward a learning science of art and design. In *Proceedings of the 10th International Conference of the Learning Sciences (ICLS 2012)* (pp. 33-39).
- Stake, R. E. (1995). *The art of case study research*. Sage.
- Vyas, D., van der Veer, G., & Nijholt, A. (2013). Creative practices in the design studio culture: collaboration and communication. *Cognition, Technology & Work*, 15(4), 415-443.
- Whiteside, A. L. (2015). Introducing the Social Presence Model to Explore Online and Blended Learning Experiences. *Online Learning*, 19(2), n2.
- Yin, R. K. (2003). Design and methods. *Case study research*.

# Maggie Mars: Theatrical Modeling and the Phenomenological Understanding of Solar Systems

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**Abstract:** In this manuscript we report on initial findings from the first implementation of a four-cycle design study that seeks to synergize computational modeling and narrative theater to support students' phenomenological understanding of solar systems. We develop the notion of the theatrical model as a low-overhead, high-expressivity alternative to typical computational modeling approaches. We then analyze the lifespan of one theatrical model as a case study to show how its collaborative creation and interpretation both reflect characteristic computational modeling practices and suggest new resources for modeling.

## Introduction

Embodiment supports the development of computational thinking through syntonetic links between human learner and computational agent (Papert, 1980). Recently, learning environment designers have used this syntoneticity to support students' construction and use of embodied computational models to study dynamic, complex systems (Colella, 2000; Wilensky & Reisman, 2006; Brady, Holbert, Soylu, Novak, & Wilensky, 2015). Outside the classroom, embodiment is an important modeling tool for structural biologists, who conduct "body experiments" to understand the dynamics of protein folding (Myers, 2012). In this paper, we present a kind of modeling activity—theatrical modeling—that leverages the power of syntoneticity by combining theater and multi-agent computation in the context of solar systems modeling. We believe that theatrical modeling is especially useful for the study of perspectival aspects of solar systems using what Bollen and van Joolingen (2013) call a "*phenomenological way of modeling*" (p. 213, italics in original).

## Theoretical framework

We ask: how might theater and computational modeling be coordinated in a collaborative learning environment to promote students' development as scientific modelers of solar systems? To answer this question, we build on work in computational modeling to develop the concept of the *theatrical model*. We believe embodiment is conducive to computational thinking because of human-agent *syntoneticity* (Papert, 1980). We also draw from Wilensky and Reisman (2006), who analyzed how students construct embodied computational models of complex systems, like firefly populations, to understand emergent phenomena such as the synchronization of the fireflies' flashes. These works highlight syntoneticity as an embodied, perceptual resonance between a single learner in physical space and a single agent in representational space (e.g., the LOGO turtle or the NetLogo firefly). There is a related body of research considering how computationally enriched embodied activities (e.g., participatory simulations) enable groups to model emergent phenomena in complex systems (Wilensky & Stroup, 1999; Brady, Weintrop, Anton, & Wilensky, 2016; Colella, 2000; Brady, Holbert, Soylu, Novak, & Wilensky, 2015). This work extends the idea of syntoneticity to groups of learners modeling complex systems.

We believe, however, that there is a categorical difference between the complex systems modeling (e.g., of a firefly population) and phenomenological modeling (e.g., of a solar system). This important difference is in *how* the target phenomenon emerges. For the firefly population, synchronization emerges as a global aggregation of local, single-agent behaviors. This contrasts with solar systems, where phenomena such as day and night emerge through the interaction of only *some* of the many bodies. In this case, we believe that embodied perspective taking is an even more crucial "phenomenological connector" for enabling students to model perspectival aspects of solar systems (cf. Soylu, Holbert, Brady, and Wilensky, 2017).

With this background, theatrical modeling was conceived as a low-overhead modeling environment that could blend science with art to support both quantitative scientific modeling and qualitative narrative expression. Theatrical models involve a script, a performance, and a recording all geared toward a modeling question. We construe the *script* as a modeling artifact that mediates between the computational and the theatrical: it defines the stage as a performative and co-ordinate space and assigns roles and behaviors to actors using codified stage directions and narrative lines. Throughout the modeling process, the development of the script parallels the development of the group's epistemological and affective stances toward the phenomenon. In these ways the script both organizes and is shaped by each group performance in much the same way that a computational model evolves over time. Theatrical models are similar to what Myers (2012) calls "body experiments," which

are part of the daily and mundane work of learning and conducting inquiry in science.... As improvised articulations they can be reenacted, revised and refuted mid-gesture. They can be repeated, but always with a difference. What's crucial here is that these animations do not fix the temporal flow of a process: their temporality is elastic. (p. 171)

In much the same way, theatrical modelers and their onlookers can use the performance as a temporally elastic tool for exploring and communicating ideas about solar systems and their experience as *part of* the model. In a theatrical model, human bodies become celestial bodies, human eyes become perspectival sensors, and human experiences become scientific evidence.

## Methods and data

We developed a three-week unit on solar systems, emphasizing a phenomenological understanding of patterns (like day/night cycles). The 15-day sequence of lessons culminated in students working in groups of three to video record a theatrical model of an imagined solar system that addressed two questions: (1) How do planets move through the solar system? and (2) What are some consequences or implications of that motion? Students first wrote a narrative script to be read aloud as the group enacted the model. They then used a head-mounted GoPro camera to record their enactment. In total, 7 models were recorded. On the last day of the unit, Ms. Rogan facilitated an activity in which students viewed two of the videos, reenacted each of them to address questions that arose in discussion.

We collected student artifacts (e.g., written scripts and video recordings) as well as video and audio recordings of the whole classroom. First, we prepared a detailed transcript of the whole-class video and audio data using Inqscribe. We then used NVivo to code the transcript and students' scripted theatrical models. We were looking specifically for instances of students using theater as modeling: these included making claims related to both quantitative and qualitative aspects of the model, bids to re-run or change the parameters of the model, taking the perspective of actors within the model, and using the model to generate new questions. The research team met weekly to discuss the analytic process and review data at length while simultaneously developing a theoretical framing for the argument presented here. As themes began to emerge in our discussion and analysis, we twice brought selections from the video record before an interdisciplinary group of researchers to conduct interaction analysis sessions (Jordan & Henderson, 1995), which both refined and opened new avenues for our inquiry.

## Analysis

We present here an analysis of the lifespan of a single model: *Maggie Mars*. This model was the first video watched in the final discussion, and was both reenacted by new actors and built on to construct new theatrical models in real time. First we introduce the video as a model by describing its components and discussing the decisions made in its creation. We then narrate its lifespan in the course of the final discussion as it was viewed and reenacted, framing students' interpretive discourse as characteristic of scientific modeling (cf. Lehrer & Schauble, 2015).

### *Maggie Mars*

Maggie, Amanda, and Britney created *Maggie Mars* to explore Mars' perspective on the Earth-Sun relationship. They wrote it as a script before they performed and recorded it in private, knowing that it might be presented to the whole class for interpretation and questioning (see Figure 1).

Each model, including *Maggie Mars*, reflected a unique combination of modeling decisions that we categorize as literary, filmic, and computational. Literary decisions concern narrative aspects of the model, including story and point of view. Filmic decisions concern cinematic aspects of the model, including camera position and perspective. Computational decisions concern metric qualities of the model, including timing and actor motion. Literarily, the story is told from *Maggie Mars*' point of view as she recounts her own experience as *Amanda Earth*'s next-door neighbor. In this model, the filmic perspective is the same as the literary perspective: Maggie wore the camera in addition to being the story's narrator. She positioned the camera to maintain a consistent view of *Amanda Earth*, with *Britney Sun* usually at the left edge of the image. Computationally, "orbit" means *to traverse a circular path* and "rotate" means *to spin in place*—both of which were definitions used by the whole class.

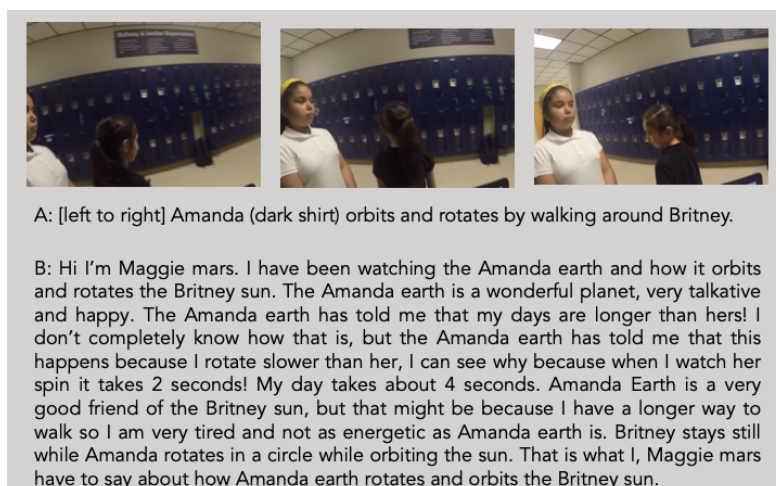


Figure 1A. Series of still frames from *Maggie Mars*. 1B. A copy of the script of *Maggie Mars*.

In both the script and video, *Amanda Earth* orbits *Ashley Sun* and rotates about her own axis every 2 seconds, producing a complex pattern of doubly circular walking. *Maggie Mars* follows in an orbit slightly outside of and behind *Amanda Earth's*, but does not rotate (in disagreement with the script, which is of consequence to our later analysis). *Britney Sun* holds her position at the center of both orbits. Here the use of “orbit” and “rotate” to denote different kinds of walking motion parallels the uses of functions in computational modeling. Considering the script alone, it would be possible to translate it into a computer-based model, which reinforces the validity of the script as an artifact of scientific modeling. What would be lost in the process, however, would be the perspectival understanding embedded in Maggie’s cinematic choices and the nuanced phenomenological understandings embedded in the model’s literary choices.

### Viewing the model

The final class began with a viewing of *Morgan Mars*. Ms. Rogan paused the video midway through to facilitate a brief discussion about the basics of the model, establishing a shared understanding of each actor’s role and the goal of the model. Then, Ms. Rogan instructed the students: “pretend you live on Amanda’s nose.” This was a bid to inhabit the model as a world, much like when Papert (1980) suggested that students “play turtle.” Ms. Rogan asked the students to clap when they’d “seen a full day,” then replayed the video. Students clapped in approximate unison each time Amanda completed a full rotation, suggesting that they used their embodied in-model perspective to infer when day and night would occur. This routine continued without teacher prompting, serving as the theatrical equivalent of a model-clock or tick-counter. Further discussion interrogated the literary and filmic perspective of *Maggie Mars*, from which students inferred that *Maggie Mars* was orbiting, but not rotating. Ms. Rogan built on this realization by asking what life would be like on *Maggie Mars*, garnering a chorus of claims about how either day or night would be everlasting depending on your location. In the language of planetary motion, *Maggie Mars* was tidally locked to the *Britney Sun* (like the moon is to Earth). The theatrical model not only supported students in realizing this fact, but also enabled them to imagine the experiential implications of tidal locking in a phenomenological way.

### Re-enacting the model

Ms. Rogan expressed her own confusion at students’ claims about everlasting day or night: “Could we demonstrate this for a second? Because you guys are talking but it’s hard for me to see it in my head.” After selecting actors and clearing a stage at the front of the room, the re-enactive demonstration began. Esteban played *Britney Sun*, Brian played *Maggie Mars*, and Kyle played *Amanda Earth*. The trio began their performance, portraying the motions of all three original actors with an impressive degree of accuracy given that they had never read the script. As the performance continued a researcher asked the class where daytime was on Brian, which also met a chorus of claims about which parts of Brian’s body directly faced Esteban. Macey pointed out that Brian was “actually moving,” by which she meant not that he was simply moving, but that he was moving differently relative to how Maggie had moved in the video. This insight reflected a remarkable understanding of the reenactment as a model of motion in comparison to the video as a model of motion, and suggests that Macey was thinking deeply about the computational and filmic qualities of both the video and reenactment. When the class faced the question of where daytime was on Kyle, Ms. Rogan “froze” the

performance to allow for closer inspection of Kyle's orientation without him continuing to rotate. Over the course of the reenactment, the performance came to be frozen, played in discrete steps, replayed, and slowed down to support finer-grained quantitative investigation by the students into the perspectival relations embedded in the model. This kind of flexible executability and repeatability is an affordance of computational modeling environments, as it supports both intuition-building and experimentation (Brady et al., 2015).

## Conclusion

We believe that the findings from this initial study show promise for the future iterations of this work and for the learning design community at large. Particularly given the constraints of this particular setting (i.e., 26-minute class periods), it is remarkable how richly these students were able to engage in both collaborative construction and interpretation of theatrical models of solar systems. These findings suggest that theatrical modeling enables students to explore both quantitative and qualitative aspects of solar systems in a bootstrapping kind of way. For example, we consider the intellectual work done by a student in imagining the stage from another student's perspective to be similar to the work done by a physicist when transposing frames of reference or considering relative motion. If composing and inhabiting models in which the physical world is blended with human experience is a quintessential scientific practice (cf. Ochs, Gonzales, & Jacoby, 1996), then we believe further research into the intersection of modeling and expression at the classroom level could offer significant insight to educators and other designers of learning environments. We have continued to explore and improve the theatrical modeling framework in subsequent implementations. Extended analyses of these data are pursuing an adaptation of the *liminal blends* framework (Enyedy, Danish, & DeLiema, 2015) to analyze theatrical modeling. Future work will explore a tighter coupling of theatrical modeling with agent-based computation, perhaps through the use of programmable robots.

## References

- Bollen, L., & van Joolingen, W. R. (2013). SimSketch: Multiagent Simulations Based on Learner-Created Sketches for Early Science Education. *IEEE Transactions on Learning Technologies*, 6(3), 208–216.
- Brady, C., Holbert, N., Soyly, F., Novak, M., & Wilensky, U. (2015). Sandboxes for model-based inquiry. *Journal of Science Education and Technology*, 24(2-3), 265-286.
- Brady, C., Weintrop, D., Anton, G., & Wilensky, U. (2016). Constructionist learning at the group level with programmable badges. In *Proc. Constructionism Conf* (pp. 61-68).
- Colella, V. (2000). Participatory simulations: Building collaborative understanding through immersive dynamic modeling. *The journal of the Learning Sciences*, 9(4), 471-500.
- Enyedy, N., Danish, J. A., & DeLiema, D. (2015). Constructing liminal blends in a collaborative augmented-reality learning environment. *International Journal of Computer-Supported Collaborative Learning*, 10(1), 7–34.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, 4(1), 39-103.
- Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. *Handbook of child psychology and developmental science*, 2(7), 671-714.
- Myers, N. (2012). Dance Your PhD: Embodied Animations, Body Experiments, and the Affective Entanglements of Life Science Research. *Body & Society*, 18(1), 151–189.
- Ochs, E., Gonzales, P., & Jacoby, S. (1996). "When I come down I'm in the domain state": grammar and graphic representation in the interpretive activity of physicists. *Studies in Interactional Sociolinguistics*, 13, 328-369.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc..
- Soyly, F., Holbert, N., Brady, C., & Wilensky, U. (2017). Embodied Perspective Taking in Learning about Complex Systems. *Journal of Interactive Learning Research*, 28(3), 269–303.
- Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories—an embodied modeling approach. *Cognition and instruction*, 24(2), 171-209.
- Wilensky, U., & Stroup, W. (1999, December). Learning through participatory simulations: Network-based design for systems learning in classrooms. In *Proceedings of the 1999 conference on Computer support for collaborative learning* (p. 80). International Society of the Learning Sciences.

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# Impact of Choice on Students' Use of an Experimentation Model for Investigating Ideas about Thermodynamics

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**Abstract:** This paper examines the impact of providing choice on students' use of an experimentation model to investigate their ideas using an online thermodynamics unit. Sixth-grade students working in pairs (N = 78) were randomly assigned to either a *choice* or *no-choice* condition for investigating the insulation effectiveness of different materials. The choice students were asked to select one of two equivalent scenarios to investigate with the experimentation model. In contrast, the no-choice students were randomly assigned a scenario to investigate. Our findings indicate that the choice students more often used the model to test their prior ideas than their no-choice peers. Furthermore, the choice students also ran more informative experimentation test patterns that yielded valid and useful data for understanding heat energy transfer with the model. The findings from this study provide promising insights into the potentially beneficial impact of incorporating choice into science learners' experiences in the classroom.

## Rationale and research objectives

This study investigates how providing choice during instruction impacts students' use of an interactive experimentation model in *Thermodynamics Challenge*, an online curriculum unit about heat energy transfer and thermal equilibrium. Providing different investigation choices can make the learning experience feel more personally relevant for students (Cordova & Lepper, 1996), which can in turn lead to more effortful self-regulated and metacognitive learning (Kamii, 1991; Pintrich, 1999). Although choice has been examined across a variety of educational contexts ranging from school choice (e.g., McLaughlin, 2005) to example choice (Reber, Hetland, Chen, Norman, & Kobbeltvedt, 2009), studies investigating the impact of choice in authentic classroom settings for a complex learning task such as scientific inquiry are rare (refer to: Flowerday & Schraw, 2000; Reber, Hetland, Chen, Norman, & Kobbeltvedt, 2009). We take the view that the sense of competency, relevancy and autonomy that providing choice can impart to students (Katz & Assor, 2007) may positively impact how they engage with learning. This study builds on prior research investigating the impact of choice on student learning outcomes within an authentic classroom context (King Chen, 2016), and we hope it provides additional insight into the potential value of providing choice during science inquiry instruction.

## Theoretical and methodological perspectives

This research work views learning from a constructivist perspective—that learners' pre-existing ideas can be effectively leveraged towards more normative and integrated understandings of challenging science ideas and concepts (Smith, diSessa, & Roschelle, 1993). The *Thermodynamics Challenge* curriculum unit was designed using the *scaffolded knowledge integration framework for instruction* (Linn, Davis, & Eylon, 2004), which specifies four iterative processes that can help students to integrate new ideas with their existing understandings as they engage in inquiry: elicit prior ideas, introduce normative scientific ideas, help establish criteria for evaluating ideas, and encourage the sorting and refinement of one's repertoire of ideas.

As a design-based research (DBR) study, this work aims to inform and advance the development of theories of learning as well as the design of innovative learning environments (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). The primary hallmarks of DBR are iterative cycles of implementation and evidence-supported refinement (e.g., Collins, Joseph, & Bielaczyc, 2004; Sandoval, 2014).

## Methods and study design

### *Thermodynamics Challenge* curriculum unit and experimentation model

*Thermodynamics Challenge* (or *Thermo Challenge*) was developed using the Web-based Inquiry Science Environment (WISE; Bell, Davis, & Hsi, 1995). The unit encourages students to apply their ideas about thermodynamics (specifically insulation, conduction, heat energy transfer and thermal equilibrium) towards the testing and evaluation of different materials for insulating a beverage using an experimentation model. We

designed the model to function as an interactive space for testing ideas, running experiments and making sense of acquired data. Students modify two parameter settings (cup material and starting liquid temperature) before running the model to observe the transfer of heat energy over time and the resulting heating or cooling temperature curve.

### Iterative refinement of the model and user interface

During our previous classroom implementations of the *Thermo Challenge* curriculum unit, we observed many students adopting a perfunctory approach towards using the model (e.g., completing a random subset of tests in a haphazard manner, or running quickly through all the test possibilities to “complete” the work) rather than taking a more self-directed and reflective approach towards conducting their experiments (i.e., making intentional decisions about which experimental tests to run and why these tests might be useful for improving their understanding).

Based on these observations, we redesigned the model interface to more explicitly promote students in engaging in reflective and self-directed experimentation with the model. Specifically, we made design changes to better support students with the following key scientific practices (NGSS Lead States, 2013): planning and carrying out an investigation, using the model to investigate ideas and explanations, and analyzing and interpreting data obtained from the model. The new design feature that supports students with these activities is the *experimentation matrix*, which allows students to easily view the full range of experimental trials for their planning, investigating and analyzing activities with the model (see Figure 1). (The matrix replaced the drop-down parameter menus previously available for operating and interacting with the model.) As can be seen in the figure, the column headers of the matrix indicate the six different materials available for testing (i.e., aluminum, wood, styrofoam, plastic, clay and glass) and the row headers of the matrix show the three starting liquid temperature options (i.e., hot, warm and cold). The resulting 3 x 6 matrix thus allows students to track the 18 possible experiments that they can run with the model. The experimentation matrix and supporting curriculum scaffolds aim to engage students in more directed and deliberate experimentation with the model: Students first use the matrix to discuss and record the key tests they want to run (*planning*; the matrix logs students’ preferred tests as “starred” experiments), they then use the matrix to select tests to run with the model (*experimentation and data collection*) and finally, students use the matrix to choose a subset of their collected data for scaffolded analysis and sense-making (*interpretation*).



**Figure 1.** Screenshot of the experimentation matrix and interactive model in *Thermo Challenge*. Students use the matrix to plan their key trials for investigation beforehand (recorded in the matrix as “starred” tests). Students then use the matrix to run the model (completed tests are indicated with green check marks).

## Choice study design and data collection

As stated previously, this study investigated the effect of providing choice on students' use of the *Thermo Challenge* model for investigating their ideas about thermodynamics. 156 sixth-grade students taught by one teacher at a public middle school participated in the study. Student pairs were randomly assigned within class periods to either the *choice* ( $N = 38$ ) or *no-choice* condition ( $N = 40$ ) and completed the unit over four hours of classroom time. Students in both conditions received exactly the same instructional content with only one difference: The choice students were offered the choice of two equivalent scenarios to investigate with the model (how best to insulate either a hot or cold beverage over time). In contrast, the no-choice students were randomly assigned to investigate either the hot or cold beverage scenario.

We captured the following sources of data: students' individual responses to the unit pre- and post-test, student pairs' written responses to embedded assessment prompts in the unit, their experimentation decisions with the model as logged by their use of the experimentation matrix, our classroom observation notes, and recorded video data of student pairs working together.

## Results and discussion

For the following analyses we examined the data logged by students' use of the experimentation matrix, specifically: Which experimental tests students *flagged beforehand* as important for their investigations, and which tests they *actually completed* and collected data for with the model. We present two primary findings.

*Fidelity of implementation of planned experimental tests.* We hypothesized that the choice students might demonstrate a higher fidelity of implementation (i.e., completing and collecting data for more of their planned tests). Our reasoning for this hypothesis was that the choice students might feel more engagement or ownership (and consequently, a greater sense of commitment) for carrying out their chosen investigation with the model compared to their no-choice peers (who were assigned to investigate either the hot or cold beverage scenario). Our analysis for fidelity of implementation found evidence to support this hypothesis. Students in the choice condition demonstrated a higher rate of following through and carrying out the experimental tests that they flagged during the experiment planning step compared to the no-choice students. This result was found to be statistically significant using the Chi-square test ( $p < 0.05$ ). In other words, the choice students more often used the model to test their prior ideas (the experimental tests they starred as the important ones for adding to their understanding of thermodynamics and their selected scenario during experimentation planning). We interpret this finding as an indication that giving students choice may provide them with the opportunity to engage in more self-directed learning; in this case, following through with the investigation of a scenario that students were able to choose for themselves. Since both choices are equivalent scenarios (the physics behind heat energy transfer for a hot or cold beverage are exactly the same), we posit that the effect of choice seen here is more likely to be an affective or motivational one. Furthermore, as offering choice allows the option to choose a more personally relevant situation to investigate, learners might have used the opportunity to examine and possibly build on their prior ideas about various materials using the model (e.g., "a steel water bottle keeps my water cold, so steel must be a good insulator").

*Frequency of informative experimentation patterns.* Another interesting finding from this study emerged when we analyzed the patterns of experimental tests students ran with the model. In our analysis, we looked specifically for completed sets of tests that demonstrated evidence of experimental proficiency or systematicity that would yield informative data for students to draw scientifically valid conclusions from their use of the model. (Some examples include: Running a set of tests that compared materials by controlling for starting liquid temperature, or running matched temperature tests for the same set of materials.) Again we found that the choice students demonstrated a higher rate of informative experimentation patterns than their no-choice peers. Interestingly, this finding was not found to be significant using the Chi-square test for the cold beverage students (comparing choice to no-choice) but was found to approach significance for the hot beverage students (choice versus no-choice;  $p = 0.07$ ). This finding raises a potentially interesting avenue for further analysis and investigation. For the entire population of choice pairs, 61% chose to investigate the cold beverage scenario, and only 39% chose the hot beverage scenario. These percentages suggest that students might have a preference for (or more familiarity with) thinking about the cold beverage scenario. Our previous observations and studies examining students' ideas about thermodynamics would seem to support this hypothesis. We have noticed that most students generate responses about heat energy transfer by referring to everyday experiences about keeping a beverage cold (refer to the steel water bottle example given above) rather than keeping a beverage hot. Another piece of evidence that lends weight to this idea from our analysis of the logged matrix data is that testing a cold liquid in an aluminum container was by far the experimental test students *most frequently selected whether during planning or data collection with the model*. Taken collectively, we hypothesize that these findings might provide evidence for the instructional value of utilizing choice as an instructional approach that



provides students with the important opportunity to engage in the learning of new ideas through activation of their prior knowledge and understandings. We acknowledge that this is at present a speculative conclusion that requires further investigation and evidence. (Additional analyses of the other data sources collected from the study are currently underway to find more evidence in support of this hypothesis.)

*Instructional value of student choice and the experimentation matrix for collaborative learning.* Another possible explanation for the promising findings we have found in favor of choice might be that requiring student pairs to choose an investigative topic promotes the need for collaborative discussion with a partner in order to negotiate ideas and preferences to reach a consensus about which investigative scenario to choose. In other words, choice promotes discussion and the need to collaborate during learning. Furthermore, the activities with the experimentation matrix are designed such that student pairs must negotiate decisions together (e.g., which experimental tests to start during planning; which tests to run with the model). Thus the matrix can help to make student thinking visible and available for discussion by providing an accessible, shared learning space for continual discussion, the negotiation of experimentation decisions, and sense-making.

## Conclusions and implications

We propose that the findings from this study, although preliminary, provide promising insight into the beneficial impact of incorporating choice into learners' experiences in the classroom. It is worth noting that we observed these positive impacts using a relatively simple embedding of choice in the curriculum, and that the study was implemented over only four hours total of instruction. We anticipate that other choice design studies employed over longer spans of instruction may yield even more positive and powerful benefits for learners. We hope that this work will help to serve as a starting point for more conversations with other researchers in the learning sciences community about how to design instructional innovations and technological tools that can support students' engagement with learning through choice and collaborative sense-making of complex scientific ideas.

## References

- Bell, P., Davis, E. A., & Hsi, S. (1995). The knowledge integration environment: Theory and design. In J. L. Schnase & E. L. Cunnius (Eds.), *Proceedings of the Computer Supported Collaborative Learning Conference, CSCL '95*, Bloomington, IN (pp. 14–21). Mahwah, NJ: Erlbaum.
- Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, 32(1), 9-13.
- Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences*, 13(1), 15-42.
- Cordova, D. I., & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology*, 88(4), 715.
- Flowerday, T., & Schraw, G. (2000). Teacher beliefs about instructional choice: A phenomenological study. *Journal of Educational Psychology*, 92(4), 634.
- Kamii, C. (1991). Toward autonomy: The importance of critical thinking and choice making. *School Psychology Review*.
- Katz, I., & Assor, A. (2007). When choice motivates and when it does not. *Educational Psychology Review*, 19(4), 429-442.
- King Chen, J. Y. (2016). Designing Technology-Enhanced Science Inquiry Instruction to Scaffold Student Choice Through Explanation and Reflection (Doctoral dissertation, UC Berkeley)
- Linn, M. C., Davis, E. A., & Eylon, B.-S. (2004). The scaffolded knowledge integration framework for instruction. *Internet environments for science education* (pp. 47-72).
- McLaughlin, T. (2005). School choice and public education in a liberal democratic society. *American Journal of Education*, 111, 442–463.
- NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: The National Academies Press.
- Pintrich, P. R. (1999). Chapter 2: The role of motivation in promoting and sustaining self-regulated learning. *International Journal of Educational Research*, 31, 459-470.
- Reber, R., Hetland, H., Chen, W., Norman, E., & Kobbeltvedt, T. (2009). Effects of example choice on interest, control, and learning. *Journal of the Learning Sciences*, 18(4), 509-548.
- Sandoval, W. A. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences*, 23(1), 18-36.
- Smith, J. P., diSessa, A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences*, 3(2), 115-163.

# What Can Be Learned About Computer-Supported Collaborative Learning From a Bibliographic Coupling Analysis?

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**Abstract:** Bibliographic coupling (BC) of 869 CSCL papers published between 2005 and 2014 showed a map of CSCL research organized around shared references. The CSCL map consists of ten BC research clusters with varying size and topics. A subset of CSCL were not well-connected, suggesting a degree of fragmentation in CSCL research. Bibliometric analysis also revealed hidden or implicit research practices.

## Introduction

With advances in technology, there has been much progress in the field of Computer-Supported Collaborative Learning (CSCL). In spite of its success in producing positive learning gains (Chen, Wang, Kirschner, & Tsai, 2018), there is awareness that CSCL is at an inflection point (Wise & Schwarz, 2017). A number of recent studies have examined CSCL research practices and showed that, while sharing the goal of supporting collaborative learning with technology, CSCL research is practiced and studied in a number of different ways and differing views exist as to the critical aspects of collaborative learning (Jeong, Hmelo-Silver, & Yu, 2014). Tang, Tsai, and Lin (2014) examined pairs of CSCL publications cited together and, by additionally applying exploratory factor analysis and social network analysis, identified six major research themes and 15 core publications. These field-wide reflections on CSCL research helped us understand the major research topics along with major theoretical and methodological frameworks.

The goal of this paper is to understand the current landscape of CSCL research between 2005 and 2014 using a bibliographic coupling analysis. Bibliographic coupling (BC), like co-citation analysis, use bibliometric information about publications (e.g., authors, references), but differs in that it uses shared citations between publications and identify clusters of research that share references. It can help us understand how CSCL research is grouped around major reference bases and what are the nature and characteristics of these references. The features of the clusters in terms of keywords, journal outlets, institutional backgrounds of the authors, for example, can also help us understand CSCL research practices around CSCL publications.

## Method

A CSCL corpus constructed in earlier examinations of CSCL research practices and outcomes was used (Jeong et al., 2014; Hmelo-Silver et al., under review). The corpus was constructed by journal-based searches as well as keyword-based searches on the Web of Sciences and ERIC databases. It contained a total of 869 papers published between 2005 and 2014. Metadata extraction includes information about the authors, title of the publications, keywords, publication source, institutions, country affiliated with authors, references, for example.

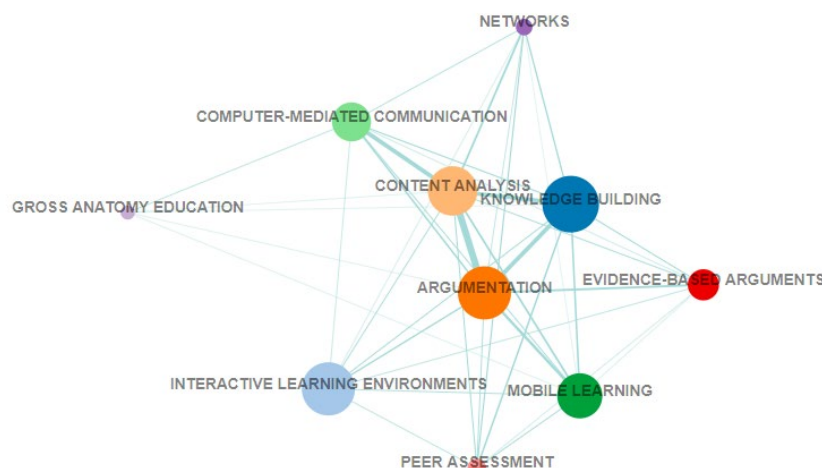
Bibliographic Coupling (BC) links were formed between publications when they share references (Kessler, 1963). A community detection algorithm based on modularity optimization (an implementation of the Louvain algorithm) was then applied to partition networks of linked papers into clusters. These clusters are represented in a map, in which a node represents a cluster with its size being proportional to the number of papers within the clusters. A frequency analysis was carried out to the papers within each cluster and provided results for (1) top 20 author keywords (2) top 10 publication sources, (6) top 10 countries, (7) top 10 references, (8) top 10 references sources, and (9) top 10 representative papers of the clusters. Representative papers here refer to papers that are most closely aligned with the papers within the cluster. In technical terms, they refer to the papers with the highest in-degree, where the in-degree of a paper is defined as the number of papers with the topic it is connected to by the shared references. Note that even when items such as author keywords or references appear in a given cluster with high frequency, the high frequency appearance may not be unique to that cluster, that is, the same keyword might appear frequently in other clusters too. A sigma value was used to identify whether the information is significant or significant, but note that it only indicates whether the item was more or less unique to the clusters and should not be likened to a statistical test.

## Results

## Bibliometric characteristics of the corpus and BC map

The most cited reference of the whole corpus was Vygotsky (1978) followed by Dillenbourg (1999) and Kirschner, Jochems, Dillenbourg, and Kansellaar (2002). Vygotsky was cited in 124 times (14%) in the corpus, twice as much as Dillenbourg (1999). The top three keywords used to describe the CSCL research were collaborative/cooperative learning, computer-mediated communication (CMC), and interactive environments. These keywords appear in many CSCL clusters, indicating the homogeneous nature of the corpus. In terms of publication sources, they were mostly published in *Computers and Education*, *Computers in Human Behavior*, and *Journal of Computer-Assisted Learning*. The *International Journal of CSCL (ijCSCL)* and *Journal of the Learning Sciences (JLS)* ranked fourth and fifth. The largest proportion of CSCL research (38%) were published in *Computers and Education*. It is by no means a CSCL exclusive journal, but publishes a large numbers of papers each (e.g., 12 issues per year, a contrast to 4 issues by ijCSCL). The CSCL research base is international with the United States (25%) followed by Taiwan (13%) and the UK (8%) forming the top three countries in which the authors were based.

The BC map of CSCL research is presented in Figure 1. The map consists of 10 clusters of varying size. Cluster labels were automatically selected from the most significant keywords used by the papers in the clusters. Note that not all papers in the corpus were included in the BC map. Out of the 869 papers in the corpus, a subset of the papers (n=122) did not share any references with other papers in the corpus and were not included in the cluster map. There were also a set of small clusters, consisting of two or three papers, that were unconnected to the rest of the clusters. Presence of such unconnected papers and clusters can be due to the inconsistencies in the data because of slight variations and inconsistencies in reference formatting (e.g., presence or absence of middle names, subtitles, etc.) that can make the same reference be treated differently by the BC algorithm.



**Figure 1.** BC Map of CSCL research clusters.

## Major CSCL research clusters

The major clusters refer to the five biggest clusters. They represent major areas of CSCL research in which many papers were published. They were: *knowledge building* (145), *argumentation* (127), *interactive learning environment* (127), *content analysis* (109), and *mobile learning* (90). Most of the research topics are concerned with issues related to developing CSCL environments but with different foci. While the *interactive learning environments* cluster is about generic interactive environment without strong association with specific technology or tools, the *knowledge building* is closely tied with Knowledge Forum as well as accompanying learning theories and pedagogy. The *argumentation* cluster reflects one of the major pedagogical foci in CSCL. The presence of a separate *mobile learning* cluster suggests a strong interest in these technologies by themselves. Although CSCL can occur both online and offline, much of the online collaboration is mediated by computers. The *content analysis* cluster reflects interests in method needed to analyze data often produced in computer-mediated discourses.

In addition to research topics or focus, these clusters also differ in the kinds of references they cited. A few references such as Vygotsky (1978) appear in multiple clusters, but highly cited references differ across clusters. This happened even when the clusters appear to study similar topics. For example, both the *knowledge building* and *interactive learning environments* clusters are interested in building collaborative environments. In the *knowledge building* cluster, theoretical papers about knowledge building communities and methodological papers about design experiments were one of the among the most cited references. On the other hand, in the

*interactive learning environments* cluster, publications on self-efficacy and statistical power analysis were highly cited (see Table 1). These differences in references show that the same issue of building a collaborative environment are designed and researched from quite different theoretical and methodological perspectives.

Clusters also differ in terms of the contexts in which the research was conducted, that is, the country in which authors are based in. As noted in the previous section, US-based researchers authored the majority of the papers throughout the corpus, but European-based researchers were more visible in the *argumentation* cluster producing 74% of the papers in this cluster. Researchers in Asia, especially from Taiwan, were prominent in the *interactive learning environment* and *mobile learning* clusters. Cultural emphasis on different styles of discourse and/or technology might have played a role, but more exploration is needed to better understand the causes of these differences.

**Table 1: Top three references (authors and titles) of the major CSCL clusters (number of publications)**

Clusters	Top Three References
Knowledge building (145)	<ol style="list-style-type: none"> <li>1. Vygotsky (1980). Mind in society: The development of higher psychological processes.</li> <li>2. Brown (1992). Design experiments.</li> <li>3. Scardamalia, &amp; Bereiter (1994). Computer support for knowledge-building communities.</li> </ol>
Argumentation (127)	<ol style="list-style-type: none"> <li>1. Webb (1989). Peer interaction and learning in small groups.</li> <li>2. Cohen (1994). Restructuring the classroom: Conditions for productive small groups.</li> <li>3. Clark &amp; Brennan (1991). Grounding in communication.</li> </ol>
Interactive learning environment (127)	<ol style="list-style-type: none"> <li>1. Bandura &amp; Wessels (1997). Self-efficacy</li> <li>2. Cohen (1988). Statistical power analysis for the behavioural sciences.</li> <li>3. Vygotsky (1980). Mind in society: The development of higher psychological processes.</li> </ol>
Content analysis (109)	<ol style="list-style-type: none"> <li>1. Hara et al. (2000). Content analysis of online discussion in an applied ed psy course.</li> <li>2. Rourke et al. (2001). Methodological issues in the content analysis of computer conference transcripts.</li> <li>3. Gunawardena et al. (1997). Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing.</li> </ol>
Mobile learning (90)	<ol style="list-style-type: none"> <li>1. Zurita, &amp; Nussbaum (2004). CSCL using wirelessly interconnected handheld computers.</li> <li>2. Dillenbourg (1999). Collaborative learning: Cognitive and computational approaches.</li> <li>3. Vygotsky (1980). Mind in society: The development of higher psychological processes.</li> </ol>

Note. Publications in the table only appear in the table (not in the reference section) due to space limitations.

### Minor CSCL research clusters

Minor clusters refer to the five smallest clusters, which were: *Computer-mediated communication* (n=66), *evidence-based argumentation* (n=41), *peer assessment* (n=13), *networks* (n=10), and *gross anatomy education* (n=7). *Computer-mediated communication* address various issues arise in computer-mediated communication situations (e.g., social presence, dialogue patterns). The *evidence-based argumentation* cluster research online discourse and computer-mediated learning, but with emphasis on structured pedagogical activities including argumentation, PBL, and/or inquiry. The rest of the minor clusters address feedback provided by peers (*peer assessment* cluster), networked learning and social network analysis (*networks* cluster), and education in a particular discipline (*gross anatomy education* cluster).

These clusters were again differentiated by the references they cited. This difference is noticeable when clusters with overlapping research topics were compared. As described earlier, *computer-based communication* (CMC) and *evidence-based argumentation* both share as emphasis in online discourse, but differed in their top references. In the *CMC* cluster, social and communication theories ranked high, whereas in the *evidence-based argumentation* cluster, references on pedagogies (e.g., PBL or web-based inquiry) were highly cited. We can also compare this cluster to the *argumentation* cluster, one of the major clusters, in which reviews and conceptual papers played a bigger role in grounding the research (see Table 1). These differences represent different traditions of argumentation research in CSCL and indicates how research examining the same topic such as argumentation can be built on quite different intellectual traditions.

Like major clusters, minor clusters varied in the country in which authors are based. While US based works were the majority, European researchers were again more visible in the *evidence-based argumentation* and *networks* cluster. Asian researchers were highly represented in the *peer assessment* cluster.

## Summary and conclusion

In this paper, we examined CSCL research based on the references they share and presented a BC map of CSCL research. The map showed that CSCL research is organized into ten clusters of research. They cover different topics, but the majority of the papers addresses topics related to knowledge building, interactive learning environments, and argumentation. There were also clusters that represent a small but distinct research topics such as peer assessment or gross anatomy education. BC analysis helped us to reveal these clusters and organizations that did not receive much attention. Both minor and major clusters are part of CSCL research. We need to be more mindful of integrating findings and lessons from all the clusters when we interpret and assess CSCL research.

Some of the clusters, although addressing similar topics, formed distinct clusters because they cited different references. Cited references show the intellectual backgrounds of the research. Many of them are related to the theoretical and methodological approaches adopted in the research. The diversity in theoretical backgrounds and methodology provide productive tensions from which new knowledge can emerge. At the same time, there is a danger that they may remain as separate body of knowledge bases. They do not need to be merged into one, but we need to make sure there are enough connections and awareness of each other within the field to ensure the coherence of CSCL as a research field.

The findings of the paper also showed that certain topics were published more in some journals over others and that certain topics were more researched by researchers from certain countries and regions, hinting that some of the clustering may not be purely intellectual. Researchers may value certain research questions, theoretical perspectives and/or research methods over others depending on their backgrounds and training. Journals are also likely to establish its identity by the editors, editorial boards, and reviewers. These factors may have been implicit in the past, but BC analysis revealed the influence of some of these factors. It will take time to explore these further and interpret properly, but it a new analytical tool that we can use to understand how the knowledge outcomes produced in research may interact with the process that produce the knowledge.

## References

- Chen, J., Wang, M., Kirschner, P. A., & Tsai, C. C. (2018). The role of collaboration, computer use, learning environments, and supporting strategies in CSCL: A meta-analysis. *Review of Educational Research*, 88(6), 799-843.
- Dillenbourg, P. (1999). *Collaborative learning: Cognitive and computational approaches. advances in learning and instruction series*. New York, NY: Elsevier Science.
- Hmelo-Silver, C. E., Jeong, H., McKeown, J., Hartley, K., Faulkner, R. T. & Andrade, A. (under review). Synergies among the pillars: A meta-synthesis of Computer-Supported Collaborative Learning in STEM domains.
- Kessler, M. M. (1963). Bibliographic coupling between scientific articles. *American Documentation*, 24, 123–131.
- Kirschner, P. A., Jochems, W., Dillenbourg, P., & Kanselaar, G. (2002). *Three worlds of CSCL: Can we support CSCL?* Heerlen: Open University of the Netherlands.
- Jeong, H., Hmelo-Silver, C. E., & Yu (2014). An examination of CSCL methodological practices and the influence of theoretical frameworks 2005–2009. *International Journal of Computer-Supported Collaborative Learning*, 9(3), 305-334.
- Tang, K. Y., Tsai, C. C., & Lin, T. C. (2014). Contemporary intellectual structure of CSCL research (2006–2013): A co-citation network analysis with an education focus. *International Journal of Computer-Supported Collaborative Learning*, 9(3), 335-36
- Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 423-467.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher mental process*. Cambridge, MA: Harvard University.

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# **Symposia**





# Group Formation in the Digital Age: Relevant Characteristics, Their Diagnosis, and Combination for Productive Collaboration

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**Abstract:** This symposium tackles a central topic in CSCL, group formation for productive collaborative learning with / in digital media. Traditional research on group formation has investigated mostly separate learner characteristics as preconditions of learning. Combinations of different learner characteristics and of learner characteristics with collaborative processes have been less in focus. Considering such combinations is necessary to represent the complexity of group interactions and learning. Despite the digitalization of learning, there has been only few attempts to investigate the diagnostic information that mining learner texts and learning processes can contribute to addressing this complexity for optimal group formation, and to assign groups automatically based on multiple parameters simultaneously. This symposium brings together a multi-disciplinary and international consortium of researchers who all focus on group formation for computer supported collaborative learning. They complement each other in investigating different combinations of learner characteristics, learning processes and automatic techniques for optimal group formation.

**Keywords:** group formation, learning processes, automatic diagnostic, optimal grouping

## Introduction

### Symposium focus and major issues addressed

Group formation for productive collaboration has been a central topic in the research agenda of CSCL for a long time. Early research shows that how a group of learners is formed principally influences collaborative learning, and most results favor heterogeneous groups (e.g., Webb, 1982). However, learners tend to self-form homogenous groups, which might not always foster learning (Bell, 2007). Learning success also strongly depends on group learning processes, which develop throughout collaboration (e.g. Weinberger & Fischer, 2006). The digitalization of society and the outspread of social media has emphasized the complexity of group interaction and learning. Productive interactions are becoming extremely important in the age of shallow processing of information and self-presentation, and need to be induced and sustained to warrant quality discussions (e.g., Greenhow, Robelia, & Hughes, 2009; Tsovaltzi, Puhl, Judele, & Weinberger, 2014). The research focus is, hence shifting towards identifying learner characteristics and processes that account for the complexity of interactions and can support transactive processes that emphasize communication with each other and can increase quality discussions

(Weinberger & Fischer, 2006; Fu, van Aalst, & Chan, 2016). Varying multiple learner characteristics for group formation simultaneously, and on the fly “spying” the development of learning processes may help represent the complexity of collaborative learning better. New technologies provide ways to form groups beyond one-dimensional distinctions: homogenous vs. heterogeneous. Still, research that investigates diagnostic and optimization techniques for online group formation (e.g. Konert, Bellhäuser, Röpke, Gallwas, & Zucik, 2016), or tests that against self-organized groups (Siqin, van Aalst, & Chu, 2015) is sparse. Systematic research on learning processes for group formation is also rare, and little research relates learning processes to group formation criteria (Fransen, Weinberger, & Kirschner, 2013).

This symposium looks at matching multiple learner characteristics through technological means and investigates process characteristics to tap on the complexity of group interactions for group formation. It raises the following questions: How do multiple learner characteristics need to be combined to leverage collaborative learning? What learning processes are most relevant, and how should we combine characteristics and processes: homogeneously vs. heterogeneously? Are there sequencing effects of homogenous and heterogeneous collaboration? How is the balance between productivity and learning opportunities of groups affected by the complexity of factors influencing group processes? What automatic techniques do we need to handle such combinations and to mine for relevant information to optimize learning processes for small and larger groups, or over longer periods of time?

### Significance of the contributions

Each individual contribution addresses several of the above general questions and formulates concrete research questions to test them empirically. They each contribute significantly to systematically addressing group formation to account for complex group interactions with scientific rigor.

Bellhäuser and colleagues look at forming groups automatically to optimize heterogeneity distribution. *How do homogenous and heterogeneous combinations of multiple learner characteristics distributed by a complex group-formation algorithm affect learning?* Measures of personality traits show main effects of heterogeneity on performance when extraversion and conscientiousness were manipulated in parallel.

Gijlers and colleagues examine learning processes in a jigsaw variant. *How does sequencing of homogenous vs. heterogeneous grouping affect learning processes and outcomes?* They show that sequencing can cause procedural losses, but quality during homogenous collaboration relates to conceptually oriented contributions in later heterogeneous collaboration, which, in turn, influences learning outcomes.

Erkens and colleagues use text mining to form knowledge-heterogeneous groups and to support group awareness: *How can automatically diagnosed knowledge influence processes and outcomes of heterogeneous groups?* They report promising results on automated grouping and recommend which method should be used for the additional visualization of co-learners' heterogeneity.

Lara Schmitt and colleagues study collocated collaborative embodied learning with tablets and additional cognitive support. *To what extent does heterogeneity of bodily processes influence cognitive processes and learning outcomes?* They point to differential effects of bodily and cognitive process heterogeneity that exemplify the need investigate such processes heterogeneity and their interaction.

Sankaranarayanan and colleagues combine automated methods to support transactive processes in collaborative work settings. They investigate conditions of balancing productivity while allowing possibilities for learning to take place within a group. *Can technological supporting scrutiny of processes and transactivity cater for a good balance of productively working together and learning from each other?* They are finding positive results that transfer between different contexts.

### Collective contribution towards the issues raised

Together the contributions disentangle a central topic in the learning sciences, group formation for collaborative learning. They tackle the question from technological and psychological perspectives. They use a broad range of learning contexts and methods. All studies use innovative grouping variables and designs. They utilize either automatic group formation, or technology-based communication, or both. They indicate best candidates of information that group-formation algorithms can draw upon to deliver optimal grouping, i.e. types of learner characteristics and productive learning processes, and of potent heterogeneous vs. homogenous combinations. The contributions, hence, present a wide spectrum of research while sharing a cutting edge focus to foster quality discussion in complex collaborative interactions through on the fly evaluation of processes and group formation.

The discussion will attempt a synthesis of the presented research, while maintaining a critical eye to pinpoint weaknesses and gaps that still need to be addressed before a comprehensive account on the topic can be claimed. This will be a source of inspiration for further research, but also for collaboration possibilities among and beyond the contributors. The discussant, Jan Van Aalst, is a leading researcher in the learning sciences

enjoying a broad overview of the developments in the field through his editorial work. He is currently publishing research, cited here, in group formation. He is, therefore, aptly suited to provide insightful, productive critiques, lead the discussion and help us advance our common approach. Other researchers can profit and orient their own future research around the proposed further possibilities. Presentations will be 12 min. long, including an introduction to the topic. A 20 min. discussion will follow, which will also be opened up for the audience.

## **Birds of a feather learn well together? An experimental study on the effect of homogeneous and heterogeneous learning group composition on satisfaction and performance**

Henrik Bellhäuser, Adrienne Müller, Johannes Konert, and René Röpke

Collaborative learning is an effective learning strategy, well-established in research, and frequently implemented in academic learning settings. However, one aspect of collaborative learning that has received only little attention from both researchers and practitioners is the question of composition of learning groups: Which participants should form a group together so that all of them profit the most from the group? Group composition is particularly important because when students are free to form groups by themselves they tend to form homogeneous groups (Hinds, Carley, Krackhardt, & Wholey, 2000). This phenomenon, often called homophily, can lead to undesirable outcomes because heterogeneous groups tend to perform better than homogeneous groups (Bell, 2007).

In our approach, we focus on two personality traits as grouping criteria that have been investigated the most in literature on group composition effects: Extraversion and conscientiousness. For extraversion, researchers have postulated that heterogeneous distribution within each learning group should be beneficial (Kramer, Bhawe, & Johnson, 2014). It is argued that extraverted persons often engage in leadership behavior and that conflicts may arise when too many group members exert leadership. For conscientiousness, one hypothesis is that homogeneous distributions should lead to better outcomes (Prewett, Walvoord, Stilson, Rossi, & Brannick, 2009). The presumed mechanism is that group members with the same level of conscientiousness can easily agree on a common goal for the group work (e.g. high achievement goals for highly conscientious groups).

One important point of critique towards these hypotheses is that they were derived solely based on correlational studies. Experimental approaches, that would allow for causal effects, are still missing in the literature. Experimental variation of group formation requires complex algorithms. In our interdisciplinary approach, we therefore developed a software that is capable of randomly splitting the population into several subpopulations in which different predefined criteria can be applied for group formation. Data is collected via questionnaires to diagnose extraversion and conscientiousness for each person. The algorithm then optimizes the formation of groups respecting homogeneity for conscientiousness and heterogeneity for extraversion.

### **Method and results**

In the present study, N=430 students in an online mathematics preparation course were randomly assigned to one of nine conditions in a completely balanced 3x3 design, with extraversion and conscientiousness each distributed homogeneously, heterogeneously, or ignored for group formation (in the latter condition, the algorithm did not apply restrictions for this criterion, hence groups in this condition could be either homogeneous, heterogeneous or in between). This design allows for the analysis of the two main effects of heterogeneity of extraversion and conscientiousness, and of the interaction effect between the two variables. To increase test power, we intentionally included conditions that were hypothesized to be maleficial. As results of the voluntary mathematics preparation course did not have implications for the subsequent university courses, this experimental design was considered acceptable from an ethical point of view. Students enrolled voluntarily in the preparation course to recapitulate mathematics school knowledge before the actual university lectures began. The preparation course was carried out completely online and included a large collection of instructions and self-tests to work with individually. Additionally, participants were asked to complete three weekly group assignments with complex modelling tasks that allowed for different approaches towards the solution. The groups of four members each were free in their choice of communication channel; the majority chose online communication (forum posts, video chat) due to distance between places of residence. As outcome measure, participants rated their satisfaction with the quality of group collaboration on a 6-point Likert scale and retrospectively estimated their time investment for the group assignments. Furthermore, quantity of assignments handed in (0 to 3) and respective quality (rated by tutors on a 10-point Likert scale) was collected as measures of performance.

For the 3x3 ANOVA, we found no significant main effects for any of the dependent variables, but instead several significant interaction effects that were difficult to interpret. For a deeper insight into the data, we therefore split up the design in three separate parts: Part 1 included the two conditions where conscientiousness was ignored,

thereby using extraversion as the sole grouping criterion (homogeneous vs. heterogeneous). Inversely, part 2 included those two conditions where extraversion was ignored and conscientiousness was used as the sole grouping criterion (homogeneous vs. heterogeneous). Lastly, part 3 included those four conditions where both criterions were manipulated simultaneously (each of them either homogeneously or heterogeneously).

For part 1, consistent with our hypothesis, we found positive effects for heterogeneous extraversion on performance, but no effects on time investment and satisfaction. For part 2, also consistent with our hypothesis, positive effects for homogeneous conscientiousness were shown on performance and satisfaction, with no effect on time investment. However, when both variables were manipulated simultaneously in part 3, results partly contradicted our hypotheses: We found positive main effects for heterogeneous extraversion and for heterogeneous conscientiousness on performance, satisfaction, and time investment. Thus, whether conscientiousness should be distributed homogeneously or rather heterogeneously seemed to be dependent on whether extraversion is manipulated simultaneously or not. These findings will be critically evaluated in the light of a replication study that was conducted recently. Preliminary analyses from the second study seem to support parts of the results of the first study. Implications for future research and application in teaching settings will be discussed.

## **Knowledge exchange of students using the differentiated Jigsaw approach**

Hannie Gijlers, Elise Eshuis, and Tessa Eysink

Active participation is an important factor related to successful collaborative learning. Students with different ability levels might not benefit equally from group work (Tomlinson et al., 2003). We can compose homogeneous and heterogeneous ability groups, each with their own advantages and drawbacks. Homogeneous ability groups make it possible to adjust the material, and level of scaffolding to the needs of the students (Lou et al., 1996). Research indicates that homogeneous grouping is effective when combined with tailored instruction and scaffolding (Kulik & Kulik, 1991). Within homogeneous groups, students are more likely to build on their partner's contribution because students have access to comparable knowledge and skills, and discussions are based on equality. Without appropriate support, below average students in homogeneous groups might have insufficient knowledge and skills to complete the task. In heterogeneous groups, below average students might benefit from high ability peers because they might receive help and feedback (Saleh, Lazonder, & de Jong, 2005). The tutee, tutor relation is more likely to occur between below average and above average peers, average peers might be left out of these tutoring conversations (Lou et al., 2006). The jigsaw is a collaborative learning technique that is often used to promote participation in collaborative learning tasks. By requesting students to study different parts of the material that are required to complete the final group task interdependence between group members is created. Each learner can make a unique contribution. In the STIP approach (Dutch Acronym: Samenwerken tijdens Taak-, Inhoud- en Procesdifferentiatie), working in homogeneous and heterogeneous ability groups is combined in a so called differentiated jigsaw (Eysink, Hulsbeek, & Gijlers, 2017). In this approach, students first construct knowledge in homogeneous groups, with materials and instruction tailored to the students' ability level. Subsequently, students exchange their knowledge in heterogeneous groups in order to complete a group assignment. Different subtopics are available for the homogeneous phase to ensure that students can provide a unique contribution to the heterogeneous group.

In the present study we focus on the effect of the STIP-approach on the learning processes and knowledge gains of students with different ability levels. Resulting in three research questions:

- 1) What is the effect of the STIP approach on the knowledge gains of students?
- 2) Are there differences in knowledge exchange processes between heterogeneous groups and are they related to individual knowledge gains of the students?
- 3) Are students' learning outcomes of the homogenous phase related to their learning process and learning gains of the heterogeneous phase?

## **Method and results**

A comparison was made between the STIP condition ( $N = 95$ ) and a control condition ( $N = 149$ ) (grade 4, 9-10 years old). Heterogeneous groups consisted of one below average student, three average students and one above average student. Students participated in 6 STIP modules, each consisting of 2 lessons) about STEAM related topics like the weather. Students in the STIP condition worked in homogeneous groups during the first lesson and heterogeneous groups during the second lesson. Heterogeneous groups consisted of one below average student, three average students and one above average student. In the present study we focus on the sixth and final module

(about the weather). Teachers in the control condition taught the same content but used their regular teaching approach (business as usual).

Student products from the homogeneous and heterogeneous groups were scored as indicators of performance in these groups. Furthermore, an individual knowledge pre- and posttest was administered. Group work was recorded with digital cameras, students' contributions to the overall discussion and more specifically their exchanged knowledge was coded to provide information about the amount and nature of students' contributions to the group work.

With respect to the learning outcomes it was found that students in the control condition reached higher learning gains compared to students in the STIP condition ( $F(1, 242) = 22.84, p < .001$ ). Although the total time of the lessons was shorter in the control condition, the time students actively engaged with learning material was higher in this condition. Video analysis revealed that in the STIP condition a lot of time was needed to organize seating arrangements, collect materials students created in the homogeneous phase etc. Zooming in on the results of the STIP condition, we found a positive relation between the amount of contributions made by individual students and their individual learning gains ( $r = .649, p < .001$ ). Moreover, the quality of the outcomes of the homogeneous group was positively related to the number of conceptual oriented contributions in the heterogeneous groups ( $r = .588, p < .001$ ). The quality of the results of the heterogeneous collaboration was positively related to students' individual learning gains on the knowledge tests ( $r = .222, p < .047$ ). The first results of the video analyses and products of the heterogeneous groups shows that students engage in a high amount of coordinative activities. A first exploration of the data suggests that in the knowledge exchange phase no significant differences were found in the amount knowledge exchange related utterances made by students from varying competence levels ( $F(2, 25) = 2.50, p = .102$ ). At the moment, coding of the process data is fine-tuned and further analysis is performed to gain insight in the participation levels of students with different ability levels.

## **Impact of text-mining based group formation and group awareness on learning in small groups**

Melanie Erkens, Sven Manske, H. Ulrich Hoppe, and Daniel Bodemer

Small group learning is a powerful educational approach, if collaborating students are a good match and know enough about each other's knowledge to use the group beneficially. One measure to ensure that the characteristics of participants are distributed across groups in a favorable way is to form groups of students with heterogeneous knowledge (cf. Dillenbourg & Jermann, 2007). In particular, learners with complementary knowledge are expected to learn by compensating for gaps in individual knowledge through explaining missing concepts to each other (Ploetzner, Dillenbourg, Preier, & Traum, 1999). However, it is difficult for learners to find out about knowledge levels and knowledge differences on their own. Cognitive group awareness tools provide learners with such information by collecting, transforming, and visualizing socio-cognitive variables and feeding them back to the group, frequently allowing the learners for comparison (cf. Bodemer, Janssen, & Schnaubert, 2018). Thereby, these tools support learners discovering gaps and expertise in knowledge, which can improve knowledge exchange and knowledge acquisition. It thus seems reasonable from a learner's and teacher's view to combine knowledge-complementary group formation with group awareness support. However, if teachers want to support their students with both measures in class, this is a burden for them as they have to collect information on the students' knowledge, enabling them to form appropriate learning groups and to provide feedback to students about their knowledge. A facilitation of both could lie in automated technologies such as text-mining methods that allow the efficient formation of groups of learners with a magnitude of text dissimilarities and to support group awareness by visualizing degrees to which learners wrote on specific topics (Erkens, Bodemer, & Hoppe, 2016; Manske & Hoppe, 2017). We investigated the suitability of text-mining methods in two studies. The first study examined the research questions: Do text mining-based group formation and group awareness visualizations have an effect on knowledge acquisition? In the second study, we were interested in optimizing the feedback and investigated the research question: Which text-mining method provides the most accurate group awareness visualizations?

### **Method and results**

Regarding the first research question, we assumed that the effect of text mining-based support on knowledge acquisition becomes larger the greater the heterogeneity of a dyad is. This hypothesis was tested in a collaborative classroom scenario with 54 dyads discussing the topic of climate change that were either formed of students with high knowledge heterogeneity and provided with awareness information (supported group) or of students with random knowledge heterogeneity and without awareness information provided (unsupported group). A moderation model with group membership (supported / unsupported) as independent variable, text dissimilarity as moderator and knowledge acquisition as dependent variable explained 21 % of the variance of knowledge

acquisition caused by the discussion ( $R^2 = .21$ ,  $F(3, 50) = 4.53$ ,  $p = .007$ ). However, since there was no significant effect of the interaction term, we included only the main effect terms into the analysis. This model explained 20 % of the variance of knowledge acquisition caused by the collaboration ( $R^2 = .20$ ,  $F(2, 51) = 6.40$ ,  $p = .003$ ) with both group membership ( $\beta = .327$ ,  $t(53) = 2.61$ ,  $p = .012$ ) and dissimilarity ( $\beta = .279$ ,  $t(53) = 2.21$ ,  $p = .031$ ) significantly predicting knowledge acquisition. Regarding the second research question, we used texts created by 22 students in a similar collaboration to compare the quality of automatic semantic extraction approaches compared to a correct (manual) classification. To assess the quality of the text analysis approaches, we used recall ('true positive rate'), precision ('true positive accuracy') and the F-measure (a weighted harmonic mean of precision and recall) on the sets of extracted concepts of each method (automatic extraction) compared to the set of relevant concepts from a manual coding. The text analysis approaches used are network text analysis ('NTA'), ontology-enriched NTA and DBpedia Spotlight. The ontology-enriched NTA uses an ontology created by domain experts in order to increase the accuracy of the NTA. The ontology encodes the domain knowledge structured as synonym-term-category triplets in the domain of the learning context. DBpedia Spotlight is a semantic extraction method, which spots keywords in a text using an ontology based on Wikipedia. The results indicate that the ontology-enriched NTA performed best in precision (84.4%), recall (44.2%), and F-measure (56.6%).

Overall, text mining-based support seems suitable to collect, transform, and visualize cognitive information from educational data for supporting teachers in their challenging task to form knowledge-heterogeneous groups and to visualize co-learners' cognitive information for better group awareness. Regarding knowledge acquisition, the results show that text-mining generated knowledge heterogeneity is positively related to learning, either with or without additionally supported group awareness. In addition, the results illustrate that group awareness support can increase knowledge acquisition. Regarding the visualization of information, it was shown that collecting cognitive information by using ontology-enriched NTA provided the most accurate values.

## Effects of process heterogeneity in collaborative embodied learning with tablets

Lara Schmitt, Dimitra Tsovaltzi, and Armin Weinberger

Learner characteristics may affect learning processes and outcomes in collaborative settings. Learner prior characteristics, like prior knowledge and attitude to collaborative learning (Harrison, Price, Gavin, & Florey, 2002; Webb, 1982), have been tested extensively. Heterogeneous combination of these characteristics influence cognitive processes, but results are inconsistent. They seem to heavily depend on the development of cognitive processes during collaboration (Cheng, Lam, & Chan, 2008), but also in interaction with bodily processes (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). However, little is known about heterogeneous combinations of embodied processes, i.e. mixed cognitive and mixed bodily processes. Process heterogeneity may impact the further development of learning processes in co-located collaborative settings where bodily expression is innate. We investigate process heterogeneity to inform automatic group formation in embodied learning.

Besides shallow cognitive processing, bodily expression of emotion and gesturing are crucial in describing spatial elements of a situation accurately, which is described as deep processing. Notwithstanding learner prior characteristics, task conditions like technological affordances, verbalization prompts and group processes, may lead to deep processing (Niedenthal et al, 2005). When the task representation is explained to a partner to reach a common embodied action, deep embodied processing and learning are promoted. Explaining may be especially necessary when partners are heterogeneous with regard to their bodily expression and cognitive processing and cannot assume a common ground. Previous studies on proportional thinking with tablets, tested the effects of embodied processes using the 'Proportion' app (Rick, Kopp, Schmitt, Weinberger, 2015). Users directly manipulated two bars to bodily experience their proportional relation. A pedagogical agent, a wise owl, provided *verbalization prompts* to elicit explanations about physical actions in the app, and foster abstraction from embodied experiences. The studies highlighted a high potential of heterogeneous embodied processes for learning (Rick et al, 2015), and showed learning gains from embodied learning. Verbalization prompts increased cognitive processes (quality of discussions), and bodily expression of emotion (Schmitt & Weinberger, 2018).

Here, we test the effects of heterogeneous bodily processes on the quality of cognitive processes, as well as the effects of heterogeneous bodily processes and of heterogeneous cognitive processes on performance.

## Method and results

A sample of  $n=80$  participants (around 10 years old) learned collaboratively for 40 minutes with 'Proportion'. They physically manipulated proportional quantities and received verbalization prompts requesting them to explain, summarize, and generalize their actions to prompt deep embodied processing of the task representation. Heterogeneity was observed in group processes. Pre- and a post- math tests as well as surveys were applied

individually. We analyzed embodied processes (bodily expression of emotions), and cognitive processes (epistemic quality, transactivity, off-task behavior). Coding schemes with sufficient inter-rater reliability were used to measure emotions and off-task behavior, focusing on gestures and gaze, as well as epistemic quality and transactivity, focusing on content of discussions and on co-constructing explanations. Regarding performance variables, we analyzed knowledge outcome and knowledge convergence (math tests), and efficiency (number of solved problems). Variables were aggregated at dyad level. Process heterogeneity and knowledge convergence were determined with the Coefficient of Variation (CoV, Weinberger, Stegmann, & Fischer, 2007). We split the sample into two sub-groups: homogeneous (lower ~50% of CoV), vs. heterogeneous (upper ~50% of CoV).

MANOVAs showed a large overall significant effect of **heterogeneity of bodily processes on quality of cognitive processes**:  $F(3,26)=4.732, p=.009, Pillai's Trace=.353, \eta_p^2=.353$ . A large negative effect on transactivity just missed significance:  $F(1,28)=3.796, p=.061, \eta_p^2=.119$ . Consistent with theoretical claims about the interaction of bodily and cognitive processes, heterogeneity of bodily processes influences cognitive processes, but rather groups with homogeneous bodily processes were more cognitively transactive by trend. Possibly, homogeneity in bodily expression frees space up for shared cognitive processing. There was also an overall significant effect of **heterogeneity of bodily processes on performance**:  $F(3,31)=3.858, p=.019, Pillai's Trace=.272, \eta_p^2=.272$ . As expected, there was a large significant effect on efficiency,  $F(1,33)=9.179, p=.005, \eta_p^2=.218$ , but an effect on knowledge outcomes could not be found. Heterogeneous groups with regard to bodily processes tended to solve more problems in the embodied learning app. This deep embodied learning did not transfer to cognitive knowledge outcomes in the posttest, which aligns with situated cognition. Regarding **heterogeneity of cognitive processes**, we found a large significant effect of **heterogeneity of epistemic quality on performance**:  $F(3,30)=3.096, p=.042, Pillai's Trace=.236, \eta_p^2=.236$ . A medium negative effect on knowledge outcomes just missed significance,  $F(1,32)=4.025, p=.053, \eta_p^2=.112$ , and there was a large negative effect on knowledge convergence,  $F(1,32)=8.120, p=.008, \eta_p^2=.202$ . There were no effects of transactivity or task focus on performance. Unexpectedly, homogeneous groups with regard to epistemic quality tended to learn more, which increases the possibility for more similar knowledge scores within groups. The results surprisingly showed some negative effects of embodied heterogeneous processes, bodily and cognitive. Investigating heterogeneity of embodied processes may help to avoid false assumptions on group formation for collocated collaboration.

## CSCS Gets to Work: Towards Collaborative Learning with Working Professionals

Sreecharan Sankaranarayanan, Cameron Dashti, Chris Bogart, Xu Wang, Majd Sakr, Michael Hilton, and Carolyn Rosé

Automation is blamed for the projected loss of 5 million jobs by 2020 as argued by the World Economic Forum. As educational technologists however, we adopt a more optimistic view of its place in the workplace, even as automation in terms of group formation and support for collaboration gets cast in a dystopian light (Rummel et al., 2016). The ultimate aim of our work is to inject learning opportunities in work settings with particular focus on technical fields like software development. We start by investigating how technology can support the correct balance between productivity and learning in project-based learning contexts. Group formation figures into this with the idea that the extent to which working groups provide an environment that is conducive to learning is related to the plethora of personal and contextual factors discussed within the contributions to this symposium. If technology is effective in placing individuals into project groups that bring out the best in them, that assignment can lead to advantages, both in terms of learning and productivity. Our own work on team assignment has been developed and tested in lab studies and real instructional contexts (Wen et al., 2016). In our past work, observed exchange of transactive conversational contributions in one context when used as an indicator of collaboration potential in order to form teams in a second context resulted in significant improvements to group products and processes over randomly assigned teams (Wen et al, 2016). In this contribution, we focus on a new paradigm for collaborative learning which we call Online Mob Programming (OMP) in which group work is conducted online where the collaboration can be instrumented to support team assignment, role taking, and work structuring.

Learning in the context of group work is a concern both in industry and in the more familiar confines of formal learning in project courses. While collaborative project based learning provides opportunities to foster needed teamwork skills, it also exposes other difficulties such as management overhead and conflict, among others. These challenges are exacerbated online and at scale, two contexts that have become more prominent in computer science education. In industry, the conflict is even more keenly felt, and the pressures of productivity frequently undercut parallel efforts to provide training opportunities for employees. The challenge in our work is

to create a context in which learning and productivity can be jointly optimized within group work and the emerging trend from industry we build on is Mob Programming (Zuill, 2016).

## Method and results

We have begun formal investigation of the OMP paradigm in the context of a 6-week free online Cloud Computing course offered to working professionals in the summer of 2018. We thus first ensure that the industry-inspired paradigm can be cast in a pedagogical setting to simultaneously prioritize productivity and learning. The instrumentation enables instructors to check on group processes and progress, but also allows for automated forms of support for group learning such as Conversational Agents (Wang et al., 2017). OMP involves students assuming and rotating through distinct roles responsible for brainstorming potential ideas, deciding on a path forward and implementing the selected path thus providing the benefit of a structured collaboration that manages group processes for relatively large groups of 4-6 students. Within this paradigm, automated group assignment could be used to place students in teams that bring out the best in them based on the prediction of collaboration potential from observed exchange of transactive contributions in a class discussion forum (Sankaranarayanan et al., 2018).

In an instructional context, we cast OMP as a form of collaborative learning where 4-6 participants assume different roles to collectively contribute a solution to a programming challenge. In this way, cognition is distributed, and group members with differing abilities are able to contribute in different roles while benefiting from the support of the group.

Results from the study show evidence of success with students following the structure of OMP and the mob setup scaling to groups having 3 to 6 participants. Further, subjective feedback from students indicate that they are teaching and learning from their peers and shifting from focusing solely on productivity to a combination of productivity and learning. The success of the paradigm in this context has prompted us to further investigate OMP in the undergraduate computer science context where it will be offered as a part of a semester-long project-based Cloud Computing course. We are now conducting an experimental study where we compare the OMP paradigm with automated transactivity based team assignment with OMP and randomly assigned teams and an individual condition as a control. At the symposium we will present an experience report that summarizes our key takeaways allowing instructors and other researchers to use these pedagogically valuable insights as well as join us in further investigating and adopting the paradigm for their classrooms.

## Selected references

- Bell, S. T. (2007). Deep-level composition variables as predictors of team performance: a meta-analysis. *The Journal of Applied Psychology*, 92(3), 595–615. <http://doi.org/10.1037/0021-9010.92.3.595>
- Fransen, J., Weinberger, A., & Kirschner, P. A. (2013). Team Effectiveness and Team Development in CSCL. *Educational Psychologist*, 48(1), 9-24.
- Fu, E. L. F., van Aalst, J., & Chan, C. K. K. (2016). Toward a classification of discourse patterns in asynchronous online discussions. *International Journal of Computer-Supported Collaborative Learning*, 11(4), 441–478. <http://doi.org/10.1007/s11412-016-9245-3>
- Greenhow, C., Robelia, B., & Hughes, J. E. (2009). Learning, Teaching, and Scholarship in a Digital Age: Web 2.0 and Classroom Research: What Path Should We Take Now? *Educational Researcher*, 38(4), 246–259. <http://doi.org/10.3102/0013189X09336671>
- Konert, J., Bellhäuser, H., Röpke, R., Gallwas, E., & Zucik, A. (2016). MoodlePeers: Factors relevant in learning group formation for improved learning outcomes, satisfaction and commitment in E-learning scenarios using GroupAL. In K. Verbert, M. Sharples, & T. Klobucar (Eds.), *Adaptive and Adaptable Learning: Proc. of the 11th European Conf. on Techn. Enhanced Learning (EC-TEL 2016)* (pp. 390–396). Lyon, France: Springer LNCS, Berlin. [http://doi.org/10.1007/978-3-319-45153-4\\_32](http://doi.org/10.1007/978-3-319-45153-4_32)
- Siqin, T., van Aalst, J., & Chu, S. K. W. (2015). Fixed group and opportunistic collaboration in a CSCL environment. *International Journal of Computer-Supported Collaborative Learning*, 10(2), 161–181. <http://doi.org/10.1007/s11412-014-9206-7>
- Tsovaltzi, D., Puhl, T., Judele, R., & Weinberger, A. (2014). Group awareness support and argumentation scripts for individual preparation of arguments in Facebook. *Computers & Education*, 76, 108-118.
- Webb, N. M. (1982). Group composition, group interaction and achievement in cooperative small groups. *Journal of Educational Psychology*, 74, 475-484.
- Weinberger, A., & Fischer, F. (2006). A framework to analyse argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education*, 46, 71-95.



# Ghost in the Machine: A Symposium on Collaboration Between Human and Computerized Agents in Educational Contexts

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**Abstract:** The importance of collaboration is growing in an era where knowledge-based tasks are increasingly accomplished by teams of people with complementary roles and expertise, as opposed to individuals doing isolated work. Moreover, the nature of collaboration is shifting to a more sophisticated skillset that includes accomplishing tasks through mediated interactions with peers halfway across the world or even computer-generated agents. The 4 papers presented in this symposium focus on this new opportunity of introducing computer-generated agents in collaboration as well as the challenges entailed. The presentations will cover a broad range of topics ranging from the assessment of collaborative problem-solving skills to the use of computer-generated agents in intelligent tutoring systems. In addition, they will illustrate the validity and practicability of various state-of-the-art approaches to introduce non-human collaborators into human collaboration.

## Overall focus of the symposium

Collaboration between humans and computerized agents, a scenario seemingly taken right out of science fiction just a few decades ago, has become part of our everyday life. Whether learning to play chess using online tutoring systems, playing PC games with non-player characters, or using intelligent personal assistants for work, most people interact and collaborate with computerized agents more frequently than they may be aware of. Research on 21<sup>st</sup> century collaboration therefore needs to investigate the possibilities and challenges that come with human-agent collaboration. The aim of this symposium will therefore be to present research projects that focus on the collaboration between humans and computerized agents as well as discuss the implementation, benefits, challenges and potential pitfalls entailed.

Historically, there have been two approaches to human-agent interaction (Terveen, 1994). The first approach assumes that the way to get computers to collaborate with humans is to endow them with human-like abilities, to enable them to act like humans. The second approach assumes that the way to get computers to collaborate with humans is to exploit their unique abilities, to complement humans, beginning from the premise that computers and humans have fundamentally asymmetric abilities. These two approaches are not completely distinct of course as will be obvious from our symposium. Both of them require adequate models of human ability and the computational modeling underlying artificial intelligence. The study of human-agent interaction is therefore inherently interdisciplinary and necessitates to be approached from various perspectives at once. The proposed symposium recognizes this requirement in combining research in psychology, educational sciences, and computer science.

## Specific contributions of the presentations

In total, the symposium will include 4 presentations covering several broad areas within the field of human-agent collaboration: Automated tutoring, language processing, computer supported learning, and the use of computerized-agents in the assessment of collaborative problem-solving skills. Obviously, these areas are neither representative in and by themselves, nor are they comprehensively and fully covered within this limited selection of papers. They do however represent a good overview of the current state-of-the-art on a long journey to our understanding of collaboration in the 21<sup>st</sup> century. We will begin by discussing whether human-agent collaboration can actually be compared to human-human collaboration in assessments of collaborative problem-solving in educational contexts such as PISA 2015 (OECD, 2017). This is followed by two presentations that employ conversational agents to assess and improve collaborative skills and learning. One study discusses how

automated text analysis is used to predict participants' success in collaboratively solving problems together with computerized-agents. The other study demonstrates how conversational pedagogical agents can potentially be used in large collaborative learning activities to improve the quality of peer dialog. Finally, we present a learning environment using human-agent collaboration to teach collaborative diagnostic competencies to medical students. All four presentations will be discussed by Art Graesser, an internationally renowned expert in computerized assessment, intelligent tutoring and human-computer interaction.

## **The assessment of collaborative problem solving in PISA 2015: Can computer agents replace humans?**

Matthias Stadler and Samuel Greiff

Due the increasing significance of CPS, educational and political initiatives, including PISA 2015 and ATC21S, are assessing CPS to ensure that students demonstrate proficiency in CPS skills at the end of compulsory education. However, even though the construct of CPS is receiving increasing educational attention, there is a general debate on the ideal methodology for the assessment of CPS due to a lack of empirical evidence in academic research (von Davier & Halpin, 2013). To assess the collaboration aspect of CPS, virtual CPS tasks require participants to collaborate with either computer-simulated agents (the human-to-agent technology: H-A) or real humans (human-to-human technology: H-H). Both approaches have advantages and disadvantages in the assessment of CPS. H-A approaches, as applied in PISA 2015, can offer standardized assessment conditions, which are especially crucial for student comparisons on the individual level. However, such conditions are often criticized for being limited in the extent to which they can allow natural collaboration to unfold because they limit conversational interactions between team partners (Graesser, Kuo, & Liao, 2017). H-H approaches, such as applied in ATC21S, assess CPS during collaborations between humans and therefore provide better representations of natural collaboration. However, they lack controllability, which was crucial for the PISA 2015 CPS assessment, which aimed to compare students' CPS skills across countries. Also, H-H logfiles with natural speech information are complex to analyze and would take long to be implemented in large-scale assessments.

### **The present study**

We conducted this study to investigate whether the original PISA 2015 CPS tasks were able to reflect the extent to which students' collaborations with computer agents represented the way students would interact with human partners. Our long-term goal was to determine whether agents can replace humans as collaboration partners in CPS assessments. This study does not fully achieve this long-term goal but does take an initial step in addressing the issue. In particular, some of the original PISA 2015 CPS tasks were reformatted and redesigned into a constrained H-H format by replacing one of the agents with a classmate in each task to allow real human interaction to take place. One of the computer agents was replaced by a classmate, a peer of equal status to the student. It is important to note that the computer agents replaced by classmates were not in the role of the experts, but rather, the role within the group was defined by the students' CPS skills performing the computer-agent. The predefined chat communication was adopted and extended in the new H-H tasks. More specifically, the original PISA 2015 H-A approach was fully adopted, and only the type of collaboration partners was changed (computer-agents or computer-agents and a real classmate). Students in the role of the collaboration partners also received predefined messages to choose from. Students of equal status to the main test taker were in the role of the collaboration partners and replaced one of the simulated agents in each task. These students acted as George within the group, and also received predefined messages to select from and to reply in the group chat. Among the predefined messages is George's original message "I kind of like the idea of the market. It would be cool to go there" that the agent George sent to the chat in the H-A format (Fig. 1). Based on the CPS proficiency levels as published in the PISA 2015 CPS report, George's original message was rated as medium collaboration proficiency. In addition, the two further messages "I like all ideas" (low collaboration proficiency) and "Let's think, whether the market or the car factory is the better idea" (high collaboration proficiency) were also offered to the students replacing George, so that they also had three messages to select from. In a first step, this study investigated the factorial validity of both approaches in assessing CPS using several consecutive confirmatory factor analyses. The reformatting allowed stipulating the following research questions for this study.

Research Question 1: Are there differences in factorial validity when assessing students' CPS performance using computer agents versus classmates?

Research Question 2: Are there differences in CPS performance accuracy and behavioral actions when assessing students' CPS performance using computer agents versus classmates?

## Results and discussion

For RQ1, the one-dimensional model identified CPS as a general factor in both types of formats (H-A versus H-H). Second, the two-dimensional model identified CPS as two separate H-A and H-H formats. Finally, two different bifactor models allowed for a general CPS factor plus a specific method factor for the H-A and H-H tasks. Overall, the models supported the general CPS factor in both types of formats and did not support the separation into two factors or the necessity of an additional method factor. Therefore, this study offers support for the use of computer agents as collaboration partners as implemented in the standardized H-A approach and discussed in the body of literature on the use of computer agents in CPS assessments (e.g., Rosen, 2015). However, it still needs to be considered that the H-H condition in this study was constraint and did not allow free response collaboration when drawing this implication. For RQ2, we investigated the differences in students' correctness scores and number of actions made by students assessed using only computer agents with that of students assessed using a classmate by applying multivariate analyses of variance (MANOVAs). First, we compared CPS performance accuracy and correctness scores of students assessed using only computer agents with that of students assessed using one real classmate in addition to the agents. The results did not suggest any performance accuracy differences. These findings in which we identified no significant difference in CPS performance between type of format have been found before in other academic studies (e.g., Rosen & Tager, 2013). Regarding the number of behavioral actions during the assessment, we compared the number of behavioral actions (i.e., clicking, dragging and dropping, or moving elements of the tasks) implemented by students assessed using only computer agents with those of students assessed using a classmate in addition to the agents. The results showed that students collaborating with classmates interacted slightly more frequently during the tasks than students collaborating with only the computer agents did.

## Language and group performance on science inquiry in simulated synchronous collaboration

Haiying Li, Jiangang Hao, and Art Graesser

Collaborative problem solving (CPS) involves a high level of social and cognitive skills, which is critically important for career and life success (OECD, 2017). Even though CPS is in high demand in workplace and life, collaboration is not explicitly taught or assessed in schools. Instead, it is acquired through group work in core academic subjects, such as science or extracurricular activities. Recently, researchers have developed computer-assisted, simulated environments to provide platforms for students to augment CPS skills for supporting science learning (Hao et al., 2017; Lin et al., 2013). Computer simulations with online text chats serve as group cognitive tools to facilitate mutual understanding of the problem and quest for solution through group discussion (Gijlers et al., 2009). Researchers found that simulated environments effectively enhanced learning performance during the CPS (Hao et al., 2015), boosted high-level cognitive skills (Lin et al., 2014), and augmented active engagement (Chang et al., 2017). Previous studies on group discourse analyses concentrated on the utterances in sequential order based on thread analyses that were related to specific sub-tasks during problem solving, such as simulation run (Chang et al., 2017). To date, no studies have examined whether language used by groups is correlated with group performance, which is the focus of the present study. The study on language use in CPS is fundamentally important and significant because language is an essential means of communication among members of a group in CPS to share and negotiate ideas, regulate and coordinate behaviors, and sustain the interpersonal exchanges to solve a shared problem (Liu et al., 2016). In this study, we aimed to answer two research questions: (1) Does language used by groups predict group performance in a simulated CPS task? and (2) What language used by groups can augment group performance in the CPS task?

## Method

956 Participants were recruited through Amazon Mechanical Turk, a crowdsourcing data collection platform to evaluate online learning environments (Li & Graesser, 2017). These participants were randomly paired into 478 dyadic groups. Two participants in each group synchronously collaborated to interact through text chats with two virtual agents to complete a set of science inquiry practices on volcanoes which includes data collection and data interpretation. In this study, we only analyzed the team interactions between dyads. Interactions were used to measure CPS competency, including sharing ideas, negotiating ideas, regulating problem-solving activities, and maintaining communication (Liu et al., 2016). Language used during group interaction was measured by 18 language features at the multiple textual levels (see Table 1), including descriptive (e.g., the number of turns and words in group interactions, syllables in a word, words in a sentence), word information (e.g., pronouns, word frequency, age of acquisition), syntactic complexity (e.g., the number of modifiers per noun phrase, sentence

syntactic similarity), referential cohesion (e.g., noun overlap), and situation model that represent deep cohesion and clear causality to fill the information gap during communication (e.g., causal verb, intentional verb, expanded temporal connectives). We used these features to measure language because these features enabled us to predict the quality of students' scientific explanations in the form of constructed responses during science inquiry within an intelligent tutoring system (Li et al., 2018). All these features were extracted through Coh-Metrix, an automated text analysis tool (Li et al., 2018). Performance of each group on inquiry competency was evaluated by the total scores of responses to seven multiple choice items and four constructed responses. Multiple choice responses were randomly chosen from one team member, whereas four constructed responses were submitted by one randomly chosen team member.

## Results, discussion, and conclusions

Results indicated significant correlations between group performance and all language features except the number of words during interaction, with correlations ranging from small to medium (see Table 1). Results of a multiple linear regression with stepwise 10-fold cross-validation showed a significant regression model, with 9 language features explaining 21.91% of the total variance in group performance on science inquiry practices. Table 1 displays significant predictors as well as the constant and coefficients. Specifically, more turns between group members and longer sentences in each turn positively predicted group inquiry performance, whereas the number of words in group interaction negatively predicted group performance. These findings imply that more high quality of communication elicits explicit and detailed information, which ultimately facilitates group performance. The minimal use of pronouns but more use of first and third plural pronouns in high quality of group inquiry practices implies that the use of more formal language to deliver information but the use of "we" or "us" to emphasize their embeddedness into social relationships did enhance group performance. The more use of rare words that people never or rarely encounter and of spoken words that are acquired in later than earlier ages denotes that the use of more formal or academic words is related to high quality group performance. Scores of group performance increased with the less use of intentional verbs, which signal actions that are enacted by team members, motivated by plans in pursuit of solutions for the problems. It is surprising that language features such as referential cohesion and situation model were not significant predictors. The possible explanation is that team members shared contexts, so no much information gaps exist during their interaction.

These findings confirmed the use of more formal, academic language in inquiry correlated with higher performance on inquiry practices, such as longer utterances, more turns, more use of third person plural nouns, more less frequently-used words, and words acquired at later ages (Li et al., 2018). However, findings also demonstrated the unique characteristics of group interaction in CPS, such as the more use of first personal plural pronouns to signify team identity during collaboration as well as the less use of action verbs or plan words to decrease the demand or request from group members so as to demonstrate collaboration. Based on findings such as these, teachers or virtual agents will be able to identify and address the specific language used inappropriately in CPS that may cause social or cognitive issues during collaboration. In the future, real-time, automated scaffolds could be designed and provided to students to enhance their CPS competence.

Table 1: The correlations between group performance and language features

Textual Levels	Language Features	Mean	SD	Pearson <i>r</i>	Coefficients
Descriptive	Number of turns	79.68	34.93	-0.09*	0.011
	Number of words	391.72	24.46	-0.02	-0.003
	Number of words per sentence	4.55	1.18	0.35**	0.638
	Number of syllabus per word	1.25	0.05	0.25**	-----
Word Information	Pronoun	129.12	25.79	-0.13**	-0.010
	1 <sup>st</sup> person singular pronoun	64.13	19.11	-0.11*	-----
	1 <sup>st</sup> person plural pronoun	16.39	9.47	0.10*	0.025
	2 <sup>nd</sup> person pronoun	15.64	9.50	-0.11*	-----
	3 <sup>rd</sup> person singular pronoun	4.02	4.78	0.01	-----
	3 <sup>rd</sup> person plural pronoun	5.55	4.55	0.05	0.031
	CELEX word frequency for content words	2.52	0.11	-0.13**	-1.827
	Age of acquisition for content words	330.88	23.66	0.15**	0.006
Syntactic Complexity	Number of modifiers per noun phrase, mean	0.47	0.11	0.21**	-----
	Sentence syntax similarity, adjacent sentences	0.16	0.05	-0.12**	-----
Referential Cohesion	Noun overlap, all sentences	0.02	0.01	0.14**	-----
Situation Model	Causal verb	63.99	14.24	-0.12*	-----
	Intentional verb	40.52	13.08	-0.17**	-0.019

Textual Levels	Language Features	Mean	SD	Pearson <i>r</i>	Coefficients
	Expanded temporal connectives	13.25	6.74	0.10*	-----

Note. \*  $p < .05$ . \*\*  $p < .01$ . The constant was 12.339 in regression model. --- refers to insignificant predictors.

## Conversational agents for collaborative learning activities in the lab and “in the wild”

Pantelis Papadopoulos

Peer dialogue, written or verbal, as the externalization and sharing of one’s thoughts and understandings with peers, is a key element in collaborative learning in order to reach a common understanding. Despite the unequivocally crucial role of peer dialogue, empirical evidence suggested that not all dialogue-based activities ensure effective collaborative behavior among students (Vogel et al., 2016). Therefore, additional questions emerge regarding the nature of an effective peer dialogue. Towards this direction, the Academically Productive Talk (also known as APT or Accountable Talk) framework is based on the analysis of what could be deemed as effective classroom discussion for the purpose of promoting academic learning and reasoned student participation (Michaels et al., 2008; Resnick et al., 2010). According to APT (Resnick et al., 2010), students’ discussion should be accountable to the learning community (students should build upon their peers’ understandings), accurate knowledge (use explicit evidence and refer to shared knowledge to validate contributions), and rigorous thinking (connect logically their claims). APT suggests a set of different types of strategic interventions (talk moves, e.g., “Do you agree or disagree with what your partner said about ...? Why?”) a teacher could use in the classroom to trigger valuable discourse (adding-on, elaborate on agreement/disagreement, re-voicing, pressing for accuracy, building on prior knowledge, pressing for reasoning, expanding on reasoning). One crucial characteristic of APT (and one that perhaps invites the use of conversational agents into the learning design) is that it focuses on students’ reasoning over correctness, allowing also the teacher to hand over the control of the discussion to the students. This presentation will discuss the use, potential, and practicability of conversational pedagogical agents (i.e., software tools that can use text/voice to interact with the user through natural language) in collaborative learning activities in the context of the MentorChat tool and the colMOOC project.

### Studies with MentorChat

By utilizing the APT framework, conversational agents can model effective teacher-student interactions and scaffold both one-to-one and group discussions (e.g., Dyke et al., 2013; Stahl, 2015). This is also the case with the MentorChat tool (e.g., Tegos et al., 2016, 2017) that can employ both directed (available to one student) or undirected (available to both students) interventions in pair, chat-based, discussions. Technically, MentorChat is based on three elements: the domain model of the subject matter, the intervention model, and the peer interaction. The teacher (domain expert) is responsible for configuring the first two, first by creating a concept map with concepts and relationships, and second by deciding on the discussion patterns that will trigger agent interventions. During peer discussion, the system monitor students’ utterances in the chat room and builds respective domain models that represent the knowledge of students and pairs. These models are continuously compared to the domain model created by the teacher and agent interventions occur when a defined pattern is recognized (e.g., the agent recognizes that the discussion revolves around a concept and asks the students to extend their discussion to a linked concept). Additional factors, such as the time lapsed after agent’s last intervention, the pace of the peer discussion, etc. are also taken into consideration by the system before the agent intervenes. Despite the usual limitations of similar agents in dealing with natural language in a group discussion, the simple prompts used can still trigger student thinking and explicit reasoning. Even though MentorChat focused on interventions regarding prior knowledge, the same tool could have been used for other types as well. Corroborating previous studies, the empirical evidence recorded in the MentorChat study series showed significant domain knowledge gains for the students (both as individual and as pairs) that received agent’s interventions. In addition, interventions significantly affected explicit reasoning, which in turn served as a mediator, allowing students under the directed condition to outperform students in the undirected one.

### Agents in MOOCs and the colMOOC Project

Based on the outputs of MentorChat, colMOOC is a recently started Erasmus+ project that aims at integrating conversational agents and learning analytics in the context of MOOCs (Demetriadis et al., 2018). While the MentorChat activities were conducted as controlled experiments, starting in Fall 2019 colMOOC will explore the potential of conversational agents in real-life settings focusing both on the learning gains MOOC participants can reap and on how their engagement is affected (aiming at reducing the dropout rate). Similar efforts have already demonstrated a positive impact on behalf of the conversational agents (Rosé et al., 2015). To validate the

effectiveness and practicability of the colMOOC approach, the agent is going to be used in three subjects: Programming for Non-Programmers, Computational Thinking, and Educational Technologies in the Classroom. The MOOCs are going to be offered in four languages in total (English, Spanish, German, and Greek), while SPOC versions of the MOOCs are going to be tested in a formal education context, allowing the comparison of the agent's potential in different situations.

## Practicability of agents

Regarding the validity and practicability of using conversational agents in the classroom and “in the wild” (i.e., MOOCs), empirical evidence has already revealed both a great potential for additional learning gains and a series of factors that can hinder any positive impact mentioned earlier. Despite the simple interface and the straightforward task of configuring a domain model, the fact remains that the effectiveness of an agent depends largely on how capable the teacher is in defining the domain model and the types of interventions needed (acting both as a domain expert and as a learning designer). Higher reusability and interoperability between agents could allow teachers to use pre-configured agents in the same or similar topics. Another issue for the teacher, especially in the case of MOOCs, is to ensure student availability. This is a practical task that can nevertheless affect the outcome. In most cases, grouping students in synchronous activities in MOOCs occurs in an ad hoc basis, with little room for effective matching of learners' characteristics. The expected differences in MOOC participants' prior knowledge, skills, and motivation may not be easily addressed by an agent.

## Learning to diagnose collaboratively: Validating a simulation for medical students

Anika Radkowitz, Ralf Schmidmaier, Martin Fischer, and Frank Fischer

Physicians with different professional backgrounds often collaboratively solve a patients' problem. In those situations, physicians are expected to be able to diagnose individually by gathering and integrating case-specific information with the goal to reduce uncertainty to make a medical decision (Wildgans et al., 2018). But physicians additionally need collaborative problem-solving competences for sharing the relevant information, negotiation, as well as regulation skills for the interaction (Liu et al., 2016). Combining both, we define collaborative diagnostic competence as the competence to accurately and efficiently diagnose a patient's problem by sharing relevant information, negotiating evidence and regulating the interaction based on clinical knowledge about symptoms and diseases and meta-knowledge about the collaboration partner's discipline (e.g., Hesse, Care, Buder, Sassenberg, Griffin, 2015). Our objective is, to investigate and facilitate collaborative diagnostic competences of advanced medical students by simulating a physician with whom learners can interact to solve a patients' problem. By simulating a physician, we expect that medical students can repeatedly engage in beneficial activities that help to reconfigure internal collaboration scripts (Fischer, Kollar, Stegmann, Wecker; 2013). In order to ensure the validity of the simulation, we develop a validity argument based on Kane (2006). We see the following aspects as evidence for a satisfactory validity: if practitioners from the field rated the simulated collaboration as authentic (Shavelson, 2012); if medical students and medical practitioners with high prior knowledge showed better test performance (i.e., better and more efficient collaboration) and lower intrinsic cognitive load compared to medical students with low prior knowledge (Sweller, 1994).

## Research questions of the validation study

1. To what extent do medical practitioners perceive the simulated collaborative process as authentic?
2. To what extent do medical students and practitioners with different levels of prior knowledge differ with respect to (a) their diagnostic performance (i.e., diagnostic efficiency, diagnostic accuracy, and information sharing skills) within the simulation and (b) the reported intrinsic cognitive load?

## Method

In a quasi-experimental validation study, 45 medical students (5<sup>th</sup>-7<sup>th</sup> semester, low prior knowledge), 27 medical students (10<sup>th</sup> semester and higher, intermediate prior knowledge), and 26 internal specialists (more than 3 years of experience, high prior knowledge) participated. All participants worked on five case scenarios in which they first individually inspected patient information from a health record, then collaborated with a simulated radiologist by requesting a radiologic examination that was to be justified by sharing patient information and differential diagnoses, and finally solved the patient case individually by suggesting a diagnosis. All participants completed an interim-test and a post-test to assess intrinsic cognitive load (1 item, 5-point Likert scale, Opferman, 2008), as well as the perceived authenticity with respect to the collaborative process (3 items, 5-point Likert-Scale,

Schubert, Friedmann, Regenbrecht, 2001). To assess the performance, we used the diagnostic accuracy (solution of the patient case and its backing with symptoms and findings), the diagnostic efficiency (diagnostic accuracy weighted by the time needed to solve a single patient case), and the information sharing skills (the inverted proportion of requests rejected by the simulated radiologist due to insufficient justification). We then calculated the mean of authenticity for both measurement times and contrasted it to a threshold (3.0) using a one-sample t-test. A mean authenticity above 3.0 indicates that practitioners on average perceive the simulation as rather authentic or authentic. Additionally, we examined the skewness of the authenticity ratings. Highly negatively skewed distributions indicate higher authenticity ratings. Further, we conducted ANOVAs with the independent variable prior knowledge and the dependent variables diagnostic accuracy, diagnostic efficiency, information sharing skill, as well as intrinsic cognitive load.

## Results

Concerning research question 1, participants with high prior knowledge rated the perceived authenticity of the simulated collaborative process as  $M = 3.57$  ( $SD = 0.91$ ) which is significantly above the threshold ( $t(24) = 3.14$ ,  $p < .01$ ). Further, the distribution of the authenticity ratings is highly negatively skewed (skewness = -1.45,  $SE = 0.64$ ). These results indicate that practitioners with high prior knowledge perceive the simulation as authentic. Additionally, results show that the groups differ significantly with respect to the efficiency of the diagnostic process ( $F(2,93) = 15.33$ ,  $p < .001$ ,  $\eta^2 = 0.25$ ), to the information sharing skills ( $F(2,92) = 6.22$ ,  $p < .003$ ,  $\eta^2 = 0.12$ ), and to intrinsic cognitive load ( $F(2,95) = 26.12$ ,  $p < .001$ ,  $\eta^2 = 0.36$ ) with advanced students and practitioners being more efficient, showing better information sharing skills and lower intrinsic cognitive load compared to students with low prior knowledge. No differences between groups were found with respect to diagnostic accuracy ( $F(2,94) = 3.05$ ,  $p = .052$ ,  $\eta^2 = 0.06$ ). However, we found solution rates (i.e., the final diagnosis) up to .94 for three of the five patient cases indicating ceiling effects.

## Discussion

The objective of the validation study was to assess whether the developed simulation is a valid instrument to assess and facilitate collaborative diagnostic competences. We collected validity evidence (Kane, 2006), which, to a large extent, supports the validity argument: Participants with higher levels of prior knowledge are better able to justify their requests and thus convince the simulated radiologist to conduct a test by sharing more relevant information; they collaborate more efficiently, and experience less intrinsic cognitive load. However, we found ceiling effects for the case solutions making it difficult to interpret the results with respect to diagnostic accuracy. Our findings thus allow concluding that the interaction with the simulated physician is sufficiently authentic. The simulation entails valid cases and content that potentially help less knowledgeable students to advance their individual diagnostic competences and their collaborative competences by interacting with a simulated physician (Fischer et al., 2013). In further studies, we want to focus more on how to facilitate and scaffold the interdisciplinary collaboration and further take into account negotiation skills and meta-knowledge as important aspects of the interdisciplinary collaboration (Hesse et al., 2015).

## References

- Chang, C.J., Chang, M.H., Liu, C.C., Chiu, B.C., Fan Chiang, S.H., Wen, C.T., ... & Chai, C.S. (2017). An analysis of collaborative problem-solving activities mediated by individual-based and collaborative computer simulations. *Journal of Computer Assisted Learning*, 33(6), 649–662.
- Dyke, G., Adamson, D., Howley, I., & Rosé, C. P. (2013). Enhancing scientific reasoning and discussion with conversational agents. *Learning Technologies, IEEE Transactions on*, 6(3), 240-247.
- Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist*, 48(1), 56–66.
- Gijlers, H., Saab, N., van Joolingen, W.R., De Jong, T., & Van Hout-Wolters, B.H.A.M. (2009). Interaction between tool and talk: How instruction and tools support consensus building in collaborative inquiry-learning environments. *Journal of Computer Assisted Learning*, 25, 252–267.
- Graesser, A., Kuo, B.-C., & Liao, C.-H. (2017). Complex problem solving in assessments of collaborative problem solving. *Journal of Intelligence*, 5(10), 1–14.
- Hao, J., Liu, L., von Davier, A., & Kyllonen, P. (2015). Assessing collaborative problem solving with simulation based tasks. In O. Lindwall, P. Häkkinen, T. Koschmann, P. Tchounikine, & S. Ludvingsen (Eds.), *Exploring the material conditions of learning: The computer supported collaborative learning (CSCL) Conference 2015* (Vol. 2, pp. 544–547). Gothenburg, Sweden: International Society of the Learning Sciences, Inc.
- Hao, J., Liu, L., von Davier, A.A., & Kyllonen, P.C. (2017). Initial steps towards a standardized assessment for

- collaborative problem solving (CPS): Practical challenges and strategies. In A. A. von Davier, M. Zhu, & P. C. Kyllonen (Eds.), *Innovative Assessment of Collaboration* (pp. 135–156). New York: Springer.
- Hesse, F., Care, E., Buder, J., Sassenberg, K., Griffin, P. (2015). A framework for teachable collaborative problem solving skills. In P. Griffin & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 37–56). Dordrecht: Springer.
- Kane, M. T. (2006). Validation. In R. L. Brennan (Ed.), *Educational Measurement* (pp. 17 – 64). Westport: Praeger.
- Li, H., & Graesser, A.C. (2017). Impact of pedagogical agents' conversational formality on learning and engagement. In E. André, R. Baker, X. Hu, M. Rodrigo, & B. du Boulay (Eds.), *Artificial Intelligence in Education. AIED 2017. Lecture Notes in Computer Science* (Vol. 10331, pp. 188–200). China: Springer.
- Li, H., Gobert, J., Dickler, R., & Morad, N. (2018). Students' academic language use when constructing scientific explanations in an intelligent tutoring system. In C. P. Rosé, R. Martínez-Maldonado, H. U. Hoppe, R. Luckin, M. Mavrikis, K. Porayska-Pomsta, B. McLaren, & B. du Boulay (Eds.), *Artificial Intelligence in Education (AIED): 19th International Conference, AIED 2018* (Vol. 1, pp. 267–281). Cham, Switzerland: Springer.
- Lin, T.J., Duh, H.B.L., Li, N., Wang, H.Y., & Tsai, C.C. (2013). An investigation of learners' collaborative knowledge construction performances and behavior patterns in an augmented reality simulation system. *Computers & Education*, 68, 314–321.
- Michaels, S., O'Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in Philosophy and Education*, 27, 283-297.
- OECD (2017). *PISA 2015 results (Volumn V): Collaborative problem solving*. Paris: PISA, OECD Publishing.
- Opfermann, M. (2008). There's more to it than instructional design: The role of individual learner characteristics for hypermedia learning. Berlin: Logos.
- Resnick, L. B., Michaels, S., & O'Connor, C. (2010). How (well structured) talk builds the mind. In R. Sternberg & D. Preiss (Eds.) *From Genes to Context: New Discoveries about Learning from Educational Research and Their Applications* (pp. 163-194). New York: Springer.
- Rosé, C. P., Ferschke, O., Tomar, G., Yang, D., Howley, I., Aleven, V., ... Baker, R. (2015). Challenges and Opportunities of Dual-Layer MOOCs: Reflections from an edX Deployment Study. In *Proceedings of the 11th International Conference on Computer Supported Collaborative Learning*, 848–851.
- Rosen, Y. (2015). Computer-based assessment of collaborative problem solving: Exploring the feasibility of H-A approach. *International Journal of Artificial Intelligence in Education*, 25(3), 380–406.
- Rosen, Y., & Tager, M. (2013). *Computer-based assessment of collaborative problem- solving skills: Human-to-agent versus human-to-human approach*. Boston, MA: Pearson Education.
- Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The Experience of Presence: Factor Analytic Insights. *Presence: Teleoperators & Virtual Environments*, 10, 266-281.
- Shavelson, R. J. (2012). Assessing business-planning competence using the Collegiate Learning Assessment as a prototype. *Empirical Research in Vocational Education and Training*, 4(1), 77-90.
- Stahl, G. (2015). Computer-supported academically productive discourse. *Socializing intelligence through academic talk and dialogue*, 213-224. Retrieved on May 1, 2016 from <http://gerrystahl.net/pub/lrdc2015.pdf>
- Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, 4, 295-312.
- Tegos, S., & Demetriadis, S. (2017). Conversational Agents Improve Peer Learning through Building on Prior Knowledge. *Educational Technology & Society*, 20 (1), 99–111.
- Tegos, S., Demetriadis, S., Papadopoulos, P. M., Weinberger, A. (2016). Conversational Agents for Academically Productive Talk: A Comparison of Directed and Undirected Agent Interventions. *International Journal of Computer-Supported Collaborative Learning*, 11(4), 417-440.
- Terveen, L. G. (1995). Overview of human-computer collaboration. *Knowledge Based Systems*, 8(2), 67-81.
- Vogel, F., Wecker, C., Kollar, I., & Fischer, F. (2016). Socio-Cognitive Scaffolding with Computer-Supported Collaboration Scripts: a Meta-Analysis. *Educational Psychology Review*, 1-35.
- von Davier, A. A., & Halpin, P. F. (2013). Collaborative problem solving and the assessment of cognitive skills: Psychometric considerations. *ETS Research Report Series*, 2013(2) i-36.
- Wildgans, A., Fink, M. C., Pickal, A. J., Weber, C. ..., DFG research group COSIMA. (2018). Erfassung des Diagnoseprozesses und der Diagnosequalität im Rahmen von simulationsbasierten Lernumgebungen [Assessing the diagnostic process and the diagnostic quality in the context of simulation-based learning environments]. Presentation held at GEBF 2018, Switzerland: Basel.



# A Wide Lens on Learning in a Networked Society: What Can We Learn by Synthesizing Multiple Research Perspectives?

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**Abstract:** Learning in a networked society is presented in this symposium with the basic assumption that “schooling” and “society” cannot be considered as separate entities and should bring together the theoretical and practical tools of scientists in both the social and educational sciences. Despite the powerful potential for cross-fostering of ideas between these fields, one key question arising inquires whether educational scientists—who focus on the interventionist, design-based study of learning—and social scientists, who concentrate on analytic study of spontaneous social interaction and knowledge construction, can engage in a productive collaboration. This symposium seeks to address this question by adopting an interdisciplinary lens, through which these perspectives have been integrated, or at least juxtaposed, to develop new insights regarding what it means to learn in an information-based networked society. Six interdisciplinary research projects that represent lessons learned from synergistic projects among researchers from these fields are presented in this symposium.

## The overall focus of this symposium

We often associate computer-supported collaborative learning with specially designed tools for small group collaboration in formal learning settings. Yet, today’s networked society, presents a broader and more diverse landscape of collaborative learning. In these diverse settings, the scale, scope and nature of learning is also expanded. In the past, people may have been in contact with members of various professional communities only as an audience, now, online interactions offer opportunities for collaboration with these professionals. Communities that may have been insular can be in greater contact with other communities and may change through this encounter. Are these sites of collaborative learning? How might we investigate whether and how learning occurs in such settings, and can this knowledge inform the design and study of CSCL in formal settings?

These changes in the landscape of computer-supported collaborative learning call for new theoretical lenses and methodological tools. The learning sciences have much to offer regarding the manner in which representations and participant structures can advance specific learning goals effectively. Yet, this understanding is mostly useful for explaining how learning occurs through hierarchical teacher-student interactions within existing school structures. Social scientists, on the other hand, offer a deep understanding of the ways in which

people use and adopt technologies in a variety of everyday contexts. Unlike much of the research in the learning sciences, they tend to observe without intervention as they examine various virtual communities that interact using social networking platforms (e.g., Facebook, Twitter) or Web 2.0 platforms (e.g., Wikis, Blogs).

We can gain inspiration on how to design learning environments and on how to interpret learner interactions in these settings from social scientists' research on how learning occurs incidentally within spontaneous online communities. At the same time, learning sciences research offers new directions for studying the learning that might occur in non-formal communities and as people adopt new technologies. In particular, it provides theoretical frameworks and methodological approaches for fine-grained analysis of the development of specific knowledge structures.

In this symposium, we present a set of six studies that were conducted as part the Learning in a NetworKed Society (LINKS) Center, all of which were studied with an interdisciplinary lens, through which these perspectives have been integrated, or at least juxtaposed, to develop new insights regarding what it means to learn in an information-based networked society. The set of studies we present here are part of the LINKS book, currently in press in Springer's CSCL book series, who have granted permission to reuse parts of the chapters in this symposium. Christopher Hoadley, who is the editor of the series will serve as discussant in the symposium.

The symposium will be carried out as a structured poster session, starting with a rationale presented by the organizers (10 minutes), and brief introductions from each of the poster presenters (total of 15 minutes). This will be followed by concurrent poster interactions (30 minutes), remarks from the discussant (20 minutes), and finally, a discussion with the audience, facilitated by chair (15 minutes).

## Theoretical background

Historically, there seems to have been a disconnect between in-school and out-of-school practices and experiences. This is evident both in terms of discourse patterns (Cazden & Beck, 2003), and in terms of knowledge goals, task characteristics and the motives for pursuing these tasks (e.g., Berland et al., 2015; Chinn & Malhotra, 2002). More recently, and more visible in the public's perception of formal schooling is the disconnect in the centrality and form of the use of technological tools (Selwyn, 2006). In some cases this disconnect can result in an underestimation of learners' capacity, and consequently in their inability to benefit from in-school activities for personal development and social mobility (Moje, 2000). In other cases, learners regard schooling with disdain, and are reluctant to embrace the curriculum deeply (Kolikant, 2009). Consequently, there is an increasing call for creating more permeability between in-school and out-of-school activities.

Similarly, processes of development and change at the individual, group and community level, as studied by anthropologists, sociologists, communication scholars, and other social scientists, other than a few notable exceptions (e.g., the work of Jean Lave (e.g., 1996)), have remained mostly outside the purview of learning scientists, and have not necessarily been considered as contributing to pedagogical theory. Yet, understanding the mechanisms that underlie some of these processes can help us understand classroom processes in new ways, or suggest novel approaches to designing and orchestrating in-school learning. For example, understanding how individual micromotives give rise to macrobehaviors (Schelling, 1978) can provide new insights on how the classroom as a whole might project different knowledge and attitudes toward learning than what might be found with individual students. Network analyses of online knowledge sharing, such as in Wikipedia or YouTube (Kumar et al., 2010) can provide insights on the ways in which useful knowledge and skills might be acquired in a bottom-up interest-based process, rather than a top-down curriculum.

Therefore, there is great promise in bringing together the theoretical lenses and methodological tools of social scientists and learning scientists to better understand how norms, dispositions, choices, skills and knowledge develop through technology-infused knowledge sharing and co-construction. This not only serves the long-term research goals of the CSCL community (Ludvigsen, Cress, Law, Rosé, & Stahl, 2016; Wise & Schwarz, 2017), but also serves to break down historical boundaries, and reconceive "schooling" and "society" as complementary spaces on a continuum. The papers in this symposium demonstrate the insights that can arise from juxtaposing and integrating these perspectives. The overall approach taken together by the papers in this symposium is a focus on an ongoing process of knowledge production through joint activity that can be distributed over time, space and context. It further examines new media rather than "educational" or "generic" tools per se.

Study 1 and 2 within this symposium examine the role of new media in putting the public in closer contact with science in informal and formal settings. In study 1, the indirect communication between the public and scientists and science reporters is examined from a critical perspective noting the ways in which new media enhances opportunities for knowledge growth, and the ways in which it might foster false notions of competence. Study 2—focused on science learners—integrates several bodies of literature to suggest designs for formal learning that could in the long run help mitigate the double edged sword alluded to in study 1.

Three studies, as a whole, suggest ways in which we might blur distinctions between formal and informal

collaboration, and how we might study collaboration as it occurs in more open and unstructured settings. Study 3 illustrates how grassroots ICT practices can challenge, subvert, and reshape existing norms and practices in insular communities, such as Ultra-Orthodox (Haredi) Jews in Israel. Study 4 explores how our growing understanding of such processes of technology-infused knowledge building in the wild can be used to create more open and dynamic learning spaces. Specifically, the ways in which a novel physical space can mediate knowledge production that occurs through movement between formal and informal contexts. Study 5 responds to the need for new ways of understanding complex interaction patterns and trajectories of ideas between points of interaction that collaboration in the wild and in future learning spaces demand. They present their approach of appending analytics to social learning to derive quantifiable measures of interactional patterns and use of learning resources that explain the resulting learning process.

Finally, study 6 adopts the combined perspective of educational and social science research to examine the broader implications of the types of research explored by the papers in this session. Drawing on Dewey's *Education and Democracy* (1916), this study considers how democratic values may be reflected in these new media configurations. Analyzing a case example, they exemplify how such new media might increase permeability between formal and informal spaces, allowing for designed and spontaneous learning.

## **Study 1. New media—A double-edged sword in public engagement with science**

Ayelet Baram-Tsabari and Amit Schejter

Here we explore the special attributes of new media, compared with their “traditional” predecessors, in the context of public engagement with science online and specifically with informed decision making regarding science-related issues. Modern life requires adult individuals with little formal educational background in the sciences to make science and technology-based decisions, such as vaccinating one's children, consuming genetically modified food or buying a house near a nuclear power plant. The chief or sole information source for many such decisions is the internet, that became the public's primary reference database concerning science and technology (National Science Board, 2016; Israeli Ministry of Science, 2017). New media thus increasingly shape public engagement with science (Brossard, 2013; Brossard and Scheufele, 2013; Peters et al., 2014).

The new media landscape is characterized by an abundance of content and channels through which information travels, as well as by interactivity, mobility and multimodality (Schejter and Tirosh, 2016). New media have the potential to enrich information and make its transference more effective. We tackle both the benefits and the challenges of making informed decisions based on access to these media.

We attempt to combine two theoretical frameworks. The first concerns rules for deliberation, the need to ensure they are egalitarian and the goal of guaranteeing inclusion of that those who have been excluded from them—the least advantaged members of society based on Jürgen Habermas's model for deliberation and John Rawls and Amartya Sen's theories of justice. All should have an opportunity to express themselves, their needs and their desires, when such deliberation concerns science-related decisions. The second component concerns types of knowledge acquired in social interaction and the skills that are required to interpret them. We then sought to determine whether new media supports diverse audiences who do not possess the necessary expertise in each scientific field requiring everyday decisions, considering the unique characteristics of the relevant media. We found that new media constitute a double-edged sword and that each of their novel features can either boost or decrease knowledge levels as defined by Bloom (Anderson et al., 2001; Bloom et al., 1956).

We discuss the benefits and challenges of using new media for public engagement with science in the context of one's actual ability to use available online resources rather than simply having access to them. These skills concern both higher and lower thinking skills, as demonstrated in the context of four features of new media.

## **Study 2. Citizen science: Opportunities for learning in the networked society**

Ornit Sagy, Yaela Golumbic, et al.

Seeking to promote science communication, civic engagement and informal education, citizen science is a genre of research that connects scientists and non-scientists around projects involving science. This meeting point creates opportunities for potential benefits to both sides. Scientists may advance their research, obtain prestigious funding and publish scientific papers (Golumbic, Baram-Tsabari, & Fishbain, 2017). Non-scientists (citizens) stand to gain enjoyment, community building, new skills and knowledge and hands-on understanding of scientific processes (e.g., Brossard, Lewenstein, & Bonney, 2005), important information about their local environment, and in some cases the means to influence policymakers. Although these outcomes are optimistic and inspiring, much work is still needed to understand how learning occurs within such collaborations, especially when citizen science is getting more focused on education and being put to schools (Hod, Sagy, Kali, & TCSS, 2018; NRC,

2018).

To shed light on learning processes of citizen science participants, we conceptualize citizen science and its myriad stakeholders as an ecology. Relationships between parties within the citizen science ecology refer to interactions among scientists, project participants, educational institutions, policymakers, etc. We complement the ecology metaphor with the term mutualism to express our desire for interactions in which all parties benefit from their involvement (Bronstein, 1994). With these two metaphors in mind, we propose a Mutualistic Ecology of Citizen Science (MECS) as an analytic framework that can potentially contribute to both conceptualization of learning in citizen science projects, as well as their design. To operationalize this framework, we use four lenses that span several disciplines to look at potential benefits to different participants: The *Learning Communities* lens provides a means for examining cultural and interactional processes involved in citizen science, with an eye on those interactions that promote learning and growth. The *Science Communication* lens reveals the power of citizen science as a vehicle to enhance the general public's understanding and engagement with science. The *Statistical Education and Data Science* lens aid the development of data literacy, that may be required and enhanced for citizen science participants. The *Science Education* lens is mostly relevant to formal education, as it is concerned with the promotion of scientific literacy.

Understanding the different ways citizen science projects benefit diverse participants is a vital step towards designing effective MECS that contribute to all who are involved in them. At the new Taking Citizen Science to School Research Center (Hod et al., 2018), we recently proposed an example for a MECS model based on the four lenses described above. The new model, Students as Citizen Science Ambassadors (Atias et al., 2017), integrates a citizen science program in a K-12 school as part of its formal science curriculum. Scientists worked closely with educational researchers and teachers to co-design curricular resources and student activities. These were designed to advance science and data literacies and engage students in communicating information to their close community by planning and executing project-related activities. This model is expected to intensify the mutualistic nature of citizen science; the students develop data and science literacies, as well as science communication skills, while being empowered to promote change in their own community. The community gains access to relevant scientific information and an option to contribute to scientific research. The scientists benefit from the students' acting as agents promoting public participation in their research, producing increased capacity for data collection and analysis, along with a well-informed, attentive audience.

### **Study 3. ICTs in religious communities: Communal and domestic integration of new media**

Nakhi Mishol-Shauli, Malka Shacham, and Oren Golan

Since the 1990s, the integration of information and communication technologies (ICTs) into everyday life, including work, education, leisure and overall personal management, has become a hallmark of modern societies. Considering this development, British scholars (Horst, 2012; Silverstone & Haddon, 1996), established the domestication approach of technologies, contending that technological integration processes within modern families and communities are not technology-deterministic, but are largely affected by cultural and social factors. While these scholars explored modern-western populations' legitimation of new media, further nuanced investigation of ICT integration among communities that manifest strong ideological, cultural or religious objections to modern practice is required. Despite overall resistance, an apparent boost in internet and new media use by members of such communities has been recorded and described by researchers representing various disciplines (Busch, 2010; Horowitz, 2001). This study discusses the patterns and implications of ICTs domestication and use in Israel's ultra-Orthodox (Haredi) community.

While ICT use has been rejected from Haredi formal educational settings, it has been largely integrated into informal home and workplace settings. Considering the apprehension expressed by religious communities—especially enclaved and marginalized groups—regarding ICTs, as well as the opportunities they embody for these sectors, we question how do socializing agents in Haredi society negotiate ICT use within informal educational spheres. Haredi education has often been observed through its formal settings (Perry-Hazan, 2013). By contrast, we contend that an exploration of the domestication processes effected by families and online journalists can shed light on the impact of ambient or semi-structured learning environments on religious and bounded communities.

We focus on two key fields of engagement with ICTs: (1) An emergent mass communication venue, namely that of online journalism within the Haredi community, perceived as a type of informal education for adults that specializes in culture, norms and identity (McQuail, 2010) and (2) everyday engagements with personal computers by family members, including children, within the Haredi household. While household socialization of children is a widespread educational practice, we believe that the religious underpinnings attributed to modern and/or technological artifacts have not been accorded sufficient attention in contemporary research.

As engagement with ICTs increases, parents and educators often raise concerns over chaotic consumption of technologies in modern societies, lamenting the abundance and ubiquity of new media technologies to which youngsters are exposed from an early age and noting that such developments may disrupt their socialization and erode their value system (Clark, 2013; Selwyn, 2006). Although much of this discourse may be attributed to overall moral panic regarding technology (Cohen, 2011), we suggest that Western dominated scholarship in this field could benefit from the study of responses to new media among traditional groups, thereby acquiring an innovative viewpoint for reflection on new media integration in both modern and traditional societies.

While offering meaningful gains and opportunities towards bridging economic and digital divides, ICTs raise concern by such communities for potential rupture of cultural boundaries. Focusing on Israeli ultra-Orthodox Jewry, we inquire how grassroots socializing agents negotiate ICT usage within informal educational spheres for adults and children. Analyzing interviews and children's drawings, findings show that while ICTs are proscribed from formal ultra-Orthodox education and mass media, the home constitutes the epicenter of computer education for children, and web-journalism becomes a valued information outlet for adults. We detail how these agencies grapple with silencing efforts and challenge communal authority, posing an avenue for long-range identity and worldview changes.

#### **Study 4. Future learning spaces: Exploring LINKS research perspectives**

Yotam Hod, Keren Aridor et al.

The networked society has brought about dramatic changes to the way in which people learn. Among these changes, learning spaces have become a topic of immense interest. One does not need to look far to find this in public media, popular educational discourse, and large-scale school reforms (Hod, 2017). The 2016 Horizons report, one of the most comprehensive international reports on educational innovation, views the redesign of learning spaces as a main driver of educational change in the years to come (Adams Becker, et al., 2016). Yet, the billions of dollars allocated in recent years to implement large and expensive renovations to learning spaces at all levels of education, in both formal and informal settings, have by no means brought the desired outcomes. This is a challenge that calls for rigorous scholarship to further explore, understand, and guide this phenomenon (Ellis & Goodyear, 2016). To advance this goal, this chapter refines the relatively new notion of 'Future Learning Spaces' (FLSs: Sutherland & Fischer, 2014) via the unique prism of learning in the networked society.

Drawing on what is known about learning spaces from the past several decades of research, we analyze several LINKS-related examples to reveal and share new insights about this generative and timely concept. Specifically, we analyzed FLSs in learning communities (Connections, KCI-SC), in informal settings (Maketec Makerspace), and in medical centers using simulations (MSC: Medical Simulation Centers). As can be seen across these examples, FLSs allow many types of sophisticated pedagogies to be implemented, whether by supporting free-flowing activities (e.g., Connections and Maketec) or in more orchestrated and scripted designs (e.g., KCI-SC and MSC). Similarly, the learning process can be supported by different technologies such as in online spaces to gather community data with digital tools that facilitate the development of reasoning skills, physical devices that encourage creation, or video equipment used for self-reflection of learned skills. These can range from low-to high-tech solutions. Together with content areas that span statistical learning in elementary and middle schools, medical education during undergraduate and residency programs, and interdisciplinary topics in public spaces, there is a large range of span of diverse FLS designs, all of which share several core characteristics.

The diversity of FLS pedagogies and technologies provides exciting opportunities to apply 'innovation mindsets' towards the design of learning environments in a continually expanding endeavor. FLSs are a cornucopia of innovation – a testbed where a wide range of pedagogies and technologies can be combined and remixed, with few restrictions. FLSs thus provide a way forward for the design of educational environments. It is not coincidental that the Horizon report (2016) couples "rethinking how schools work" with "redesigning learning spaces". FLSs are at the forefront of an exciting period of development for learning in the networked society.

#### **Study 5. A theoretically informed methodology for analytics of collaborative learning**

Carmel Kent, Amit Rehavi and Sheizf Rafaeli

Extracting analytics based on digital traces and footprints from social platforms provides socio-computational opportunities and challenges alike. Beyond the ethical and privacy considerations (Pardo & Siemens, 2014), dilemmas surrounding any policy dependent on predefined performance indicators will accompany endeavors relating to learning assessment (Ellis, 2013), especially when based purely on online interactions. Despite these challenges, we perceive digital traces as a promising tool with which to access the rich world of online learning communities (Ferguson et al., 2014). We aim to join others who appended "analytics" to "social learning" and to

suggest that quantifiable interactional patterns, based on well-accepted social learning theories, should be considered as tools for the assessment of collaborative online learning.

Social learning analytics focus on how communities of learners co-create knowledge. MOOCs (Massive Open Online Courses) and other online learning endeavors are based on online conversations and enable rich logging data collection and data mining, based on learners' collaborative behavioral patterns (Sinha, 2014; Wu, Yao, Duan, Fan & Qu, 2016). At the same time, the absence of face-to-face interactions in online learning invites further analysis and research of online interactions. Specifically, our contribution to this symposium is to suggest a network analysis methodology for the assessment of the performance and design of learning communities.

As distant and blended learning play an increasingly central role, policies are required concerning the evaluation and assessment of individual and collective online learning. To jump-start this debate, we propose a set of quantifiable and scalable learning indicators, based on social network analysis, that we believe can complement traditional assessment tools. To develop such metrics, we suggest perceiving online discussions in learning communities as networks, in which both human agents and content posts are the nodes, while interactions among nodes are represented as edges. The collaborative learning process is thus regarded as the construction and growth of a network containing various types of interactions among learners and content items (AlDahdouh, Osório, & Caires, 2015). We demonstrate our proposition using a case study of a single higher education learning community that used online discussion in a blended mode during an entire academic semester, and show two assessment indicators for individual learning, and two for collective learning, both in the context of social learning.

Our results in the individual learner context suggest that in the course of online learning, creating connections with surrounding resources and co-learners, as well as being creative when doing so (proposing original tags for relations instead of choosing from a readymade dropdown list) are correlated with improved grades. Also, we show that learners involved in connecting detached information resources have special topological parameters and a high potential to contribute to community learning.

Our results in the collective context show that as learning evolves, the distances between the learners and discussed subjects become closer, contributing to the communal sharing of ideas and knowledge. We also show that the number of cliques (closed groups) grows concomitantly with the size of the network, buttressing the assumption that the presence of cliques supports the process of creating knowledge. Furthermore, we found evidence that the proportion of large cliques decreases as the network evolves, pointing to the emergence of additional opportunities to interact.

One possible future implication is the use of such aggregate indicators in providing measures at the course level, as well as in providing feedback to learners.

## **Study 6. Democracy, communication, and education in the 21st century**

Adi Kidron, Noam Tirosh, Yael Kali and Amit Schejter

A century has gone by since John Dewey published *Democracy and Education*, positing that education “consists primarily in transmission through communication” (Dewey, 1916/2012, p. 13). The dramatic technological advancements that characterize our current networked society have shifted the ways that people communicate, educate and interact with each other. This work integrates notions from research on communication (social sciences) and socio-constructivist education in order to explore the new educational opportunities the networked society offers to enhance democratic processes for the benefit of society and its members. We focus on a specific case study – the LINKS courses – which aimed at supporting the development of students' interdisciplinary understanding of the LINKS theme. We designed an interdisciplinary curriculum and used a learning community (LC) approach that emphasizes collaborative knowledge advancement and the synthesis of diverse individual contributions as a means of personal learning as well as the learning of the whole community (Bielaczyc, Kapur and Collins, 2013). Building on the affordances of contemporary media – mobility, abundance, multimediality and interactivity (Schejter & Tirosh, 2016) – we designed technological features to embody our pedagogical rationale as a set of two parallel courses (for undergraduate and graduate students, respectively) offered four times between the years 2013 and 2017, at the University of Haifa.

To analyze the LINKS case study, we synthesised varied theoretical notions of democracy into four tenets: active participation, free movement of voices, equal and just expression, and ability to influence. Our perspective on socio-constructivist pedagogies is exemplified by four meta-level design-principles (Kali and Linn, 2008) that support meaning-making through knowledge integration: help students learn from each other, make contents accessible, make thinking visible, and promote autonomous lifelong learning.

Building on the tenets of democracy and the four design principles, our analysis shows how the different technology-enhanced features embodied discrete aspects of the democratic idea. It also shows how thoughtful and careful design, which took potential challenges and threats into consideration, led to the formation of a positive

learning environment in which these democratic ideas were fulfilled to promote students' learning and interdisciplinary understanding. For example, to ensure the voicing of those who are mostly silenced ('equal and just expression' tenet), students received encouraging feedback from the course moderators ('make contents accessible' design principle). Another important aspect of free expression in the courses was the safe environment, constructed through learning community norm prompts presented to the students on different occasions and via various channels. Interactions between the graduate and undergraduate parallel courses allowed knowledge to be "shared among the many, rather than being exclusively the preserve of the few" (Jay, 1984). Knowledge authority was not reserved for teachers alone since no one expert had all the disciplinary answers. Collaborative knowledge-building activities encouraged students to participate in a public discussion thereby strengthening the 'ability to influence' tenet. Technology guaranteed the 'free movement of voices' and enabled inclusion of all students in the community to participate equally without the need to struggle for the right of expression.

To summarize, we argue that since interdisciplinary understanding allows for more than one sole truth, it has the potential to promote democratic notions. Furthermore, a learning community approach is democratic by nature, as it builds on active expression of individual interests to promote shared ones. Finally, in face of varied possible threats (as described in Study 1), contemporary media's added value to democratic processes is not obvious and only careful design of the way these media are used, especially in the context of educational interventions, can lead to positive change and a better future in terms of democracy and education.

## References

- Adams Becker, S., Freeman, A., Giesinger Hall, C., Cummins, M., and Yuhnke, B. (2016). *NMC/CoSN Horizon Report: 2016 K-12 Edition*. Austin, Texas: The New Media Consortium.
- AlDahdouh, A. A., Osório, A. J., & Caires, S. (2015). Understanding knowledge network, learning and connectivism. *International Journal of Instructional Technology and Distance Learning*, 12(10), 3-21.
- Anderson LW, Krathwohl DR and Bloom BS. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Allyn & Bacon.
- Atias, O., Sagy, O., Kali, Y., Angel, D., & Edelist, D., (2017). Jellyfish and people—a citizen-science collaboration with mutual benefits to citizens and scientists. Poster presented at the *American Educational Research Association Conference*, San Antonio, Texas, April.
- Berland, L. K., Schwarz, C. V., Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2016). Epistemologies in practice: Making scientific practices meaningful for students. *Journal of Research in Science Teaching*, 53(7), 1082-1112.
- Bielaczyc, K., Kapur, M., & Collins, A. (2013). Cultivating a community of learners in K-12 classrooms. In C. E. Hmelo-Silver, C. A. Chinn, C. K. Chan & A. O'Donnell (EDS.), *International Handbook of Collaborative Learning*, (pp. 233-249). New York: Routledge.
- Bloom BS, Engelhart MD, Furst EJ, et al. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals*, New York: David McKay.
- Bronstein, J. L. (1994). Our current understanding of mutualism. *The Quarterly Review of Biology*, 69(1), 31-51.
- Brossard D. (2013) New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences* 110, 14096-14101.
- Brossard, D., & Scheufele, D. A. (2013). Science, new media, and the public. *Science*, 339(6115), 40-41.
- Busch L. (2010). To "come to a correct understanding of Buddhism": A case study on spiritualising technology, religious authority, and the boundaries of orthodoxy and identity in a Buddhist web forum. *New Media & Society*, 13(1): 58-74.
- Cazden, C. B., & Beck, S. W. (2003). Classroom discourse. In A. C. Graesser, M. A. Gernsbacher, & S. R. Goldman (Eds.), *Handbook of discourse processes* (pp. 165-197). Mahwah, NJ: Lawrence Erlbaum.
- Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, 86(2), 175-218.
- Clark, L. S. (2013). *The parent app: Understanding families in the digital age*. Oxford: Oxford University Press.
- Cohen, S. (2011). *Folk Devils and Moral Panics*. London and New York: Routledge.
- Dewey, J. (1916/2012). *Democracy and education*. Hollywood, FL: Simon and Brown.
- Gordon, N. (2001). Dahl's procedural democracy: A Foucauldian critique. *Democratization*, 8(4), 23-40.
- Ellis, C. (2013). Broadening the scope and increasing the usefulness of learning analytics: The case for assessment analytics. *British Journal of Educational Technology*, 44(4), 662-664.
- Ellis, R. A., & Goodyear, P. (2016). Models of learning space: integrating research on space, place and learning in higher education. *Review of Education*, 4(2), 149-191.
- Ferguson, R., Macfadyen, L. P., Clow, D., Tynan, B., Alexander, S., & Dawson, S. (2014). Setting learning analytics in context: Overcoming the barriers to large-scale adoption. *Journal of Learning Analytics*,

- 1(3), 120-144.
- Golumbic, Y. N., Baram-Tsabari, A., & Fishbain, B. (2017). Why and how should we facilitate scientific information to the public [in Hebrew]. *Ecology and the Environment*, 8(3), 5-6.
- Hod, Y. (2017). Future learning spaces in schools: Concepts and designs from the learning sciences. *Journal of Formative Design in Learning*, 1(2), 99-109.
- Hod, Y., Sagy, O., Kali, Y. & Taking Citizen Science to School. (2018). The opportunities of networks of research-practice partnerships and why CSCL should not give up on large-scale educational change. *International Journal of Computer Supported Collaborative Learning*. 13(4), 457-466.
- Horowitz, N. (2001). The Haredim and the internet. *Kivunum Hadashim*, 3, 7-30. [Hebrew]
- Horst, H. A. (2012). New media technologies in everyday life. In Horst, H. A., & Miller, D. (eds.). *Digital anthropology* (pp. 61-79). London and New York: Berg.
- Israeli Ministry of Science. (2017) *Public Perceptions and Attitudes in Israel: Science, Technology and Space*. Tel Aviv: GeoCatography for the Israeli Ministry of Science, Technology and Space.
- Jay, M. (1984). *Marxism and totality: The adventures of a concept from Lukács to Habermas*. Berkeley and Los Angeles: University of California Press.
- Kali, Y., & Linn, M. C. (2008). Technology-enhanced support strategies for inquiry learning. In J. M. Spector, M. D. Merrill, J. J. G. V. Merriënboer, & M. P. Driscoll (eds.), *Handbook of research on educational communications and technology* (3rd ed., pp. 445-461). Mahwah, NJ: Lawrence Erlbaum Associates.
- Kolikant, Y. (2009). Students' perceptions of the appropriateness and usefulness of the internet for schoolwork and the value of school. *Journal of Educational Computing Research*, 41(4), 407-429.
- Kumar, A., Tewari, A., Shroff, G., Chittamuru, D., Kam, M., & Canny, J. (2010). An exploratory study of unsupervised mobile learning in rural india. Paper presented at the *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.
- Lave, J. (1996). Teaching, as learning, in practice. *Mind, Culture, & Activity*, 3, 149-164.
- Ludvigsen, S., Cress, U., Law, N., Rosé, C. P., & Stahl, G. (2016). Future-looking conversations in cscl. *International Journal of Computer-Supported Collaborative Learning*, 11(3), 255-262.
- McQuail, D. (2010). *McQuail's mass communication theory*. London: Sage.
- Moje, E. B. (2000). "To be part of the story" the literacy practices of gangsta adolescents. *Teachers College Record*, 102(3), 651-690.
- National Science Board. (2016). *Science and Engineering Indicators*.
- Pardo, A., & Siemens, G. (2014). Ethical and privacy principles for learning analytics. *British Journal of Educational Technology*, 45(3), 438-450.
- Perry-Hazan, L. (2013). *Ultra-orthodox education in Israel: Law, culture and politics*. Jerusalem: Nevo and Magnes.
- Peters HP, Dunwoody S, Allgaier J, et al. (2014) Public communication of science 2.0. *EMBO reports*.
- Schejter AM and Tirosh N. (2016) Media Policy and Theories of Justice. *A Justice-Based Approach for New Media Policy*. Springer, 51-59.
- Schelling, T. C. (1978). *Micromotives and macrobehavior*. London, UK: W. W. Norton & Company.
- Selwyn, N. (2006). Exploring the 'digital disconnect' between net-savvy students and their schools. *Learning, Media and Technology*, 31(1), 5-17.
- Selwyn, N. (2016). *Is technology good for education?* Hoboken, NJ: John Wiley & Sons.
- Silverstone, R., & Haddon, L. (1996). Design and the domestication of information and communication technologies: Technical change and everyday life. In: Mansell, R., & Silverstone, R. (eds.). *Communication by design: The politics of information and communication technologies* (pp. 44-74). Oxford: Oxford University Press.
- Sinha, T. (2014). *Supporting MOOC instruction with social network analysis*. Arxiv Preprint. Ithaca, NY: Cornell University Library.
- Sutherland, R., & Fischer, F. (2014) Future learning spaces: design, collaboration, knowledge, assessment, teachers, technology and the radical past. *Technology, Pedagogy and Education*, 23(1), 1-5.
- Wise, A. F., & Schwarz, B. B. (2017). Visions of cscl: Eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 423-467.
- Wu, T., Yao, Y., Duan, Y., Fan, X., & Qu, H. (2016). NetworkSeer: Visual Analysis for Social Network in MOOCs. In 2016 *IEEE Pacific Visualization Symposium*, 194-198, Taipei

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# Computerized Text Analysis: Assessment and Research Potentials for Promoting Learning

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**Abstract:** Rapid advancements in computing have enabled automatic analyses of written texts created in educational settings. The purpose of this symposium is to survey several applications of computerized text analyses used in the research and development of productive learning environments. Four featured research projects have developed or been working on (1) equitable automated scoring models for scientific argumentation for English Language Learners, (2) a real-time, adjustable formative assessment system to promote student revision of uncertainty-infused scientific arguments, (3) a web-based annotation tool to support student revision of scientific essays, and (4) a new research methodology that analyzes teacher-produced text in online professional development courses. These projects will provide unique insights towards assessment and research opportunities associated with a variety of computerized text analysis approaches.

## Purpose, structure, and significance

Written texts play an important role in the process of learning as they are used for learners to read inscribed knowledge as well as to express their ideas and understanding. Many discipline-specific practices are carried out by means of texts, e.g., explanation, argumentation, and communication. Written texts are used for the purpose of assessing learners or for the purpose of generating theories of learning. For the last few decades, the analysis of written texts relied on a relatively stable, circumscribed, post hoc set of qualitative data analysis methods, e.g., Miles and Huberman (1994). But we are now entering a new era, one in which our toolkits have been expanded by a quite different set of computational techniques, rooted largely in methods drawn from machine learning. For researchers in the CSCL community, computational text analysis can play a number of roles, which fall into two main categories. First, forms of computational text analysis can be embedded within computer-based learning environments that we design. In this context, computational text analysis can allow these environments to better guide learners, as well as to provide better feedback, both to learners and their teachers. Second, computational text analysis can be employed more directly as a tool for researchers, as a means of analyzing data in support of research goals. In the context of CSCL research, the text for this latter category can come from multiple sources. It might be generated by learners as they interact with a computer-based learning environment, or it might be developed in alternative ways, such as when learners are interviewed at the end of a computer-based intervention and the interviews are transcribed.

The purpose of this symposium is to shed light on these two different ways to use computerized text analyses in the current work of four research projects as shown in Table 1. The first and fourth presentations address the research aspect of computerized text analyses while the second and third presentations address practical applications to support student learning in the classroom. The first two presentations address texts written by middle school students while the third presentation addresses those written by high school students. Texts in the fourth presentation were created by K-2 school teachers who were taking online professional development courses. Computerized text analyses were conducted by different software packages including *c-rater ML*<sup>TM</sup> developed by Educational Testing Service and *Tactic Text*. The first presentation concerns an important issue of whether automated scoring models provide equal opportunities for students with different language backgrounds. The second presentation shows a seamlessly integrated formative assessment system that can help students' revision of written arguments in real time. The third presentation tests a formative assessment system in two task conditions to optimize design features. The fourth presentation uses computerized text analysis to find emergent

patterns without the researcher’s implicit bias.

The session moderator, Dr. Hee-Sun Lee, will briefly describe the purpose and organization of the symposium, followed by the introduction of the speakers (~5 minutes). All presenters will introduce their computerized text analysis methods and applications in their learning contexts (a total of ~60 minutes, ~15 minutes per presentation). Dr. Danielle McNamara at Arizona State University will lead a discussion focusing on the challenges and complexities involved in research and development efforts for collaborative learning settings (~10 minutes). Then, the audience will have opportunities to interact with presenters as well as the discussant for synthesis of ideas presented in the symposium (~15 minutes). The topic of this symposium is critical for setting the next research agenda in designing and testing productive language-intensive learning environments where computerized text analyses can add unique instructional values.

**Table 1: Summary of computational text analysis method, learning context, and research focus for each presentation**

Presentation	Computational Text Analysis	Research/Learning Context	Research Focus
1	Automated scoring model development	Assessment of middle school students’ scientific argumentation	Examination of potential linguistic bias in the automated scoring models as compared to human scoring
2	Automated content scoring using c-rater ML; machine learning-based natural language processing	Scientific argumentation tasks embedded in an online Earth science curriculum module	Formative assessment function: student performance diagnosis using automated scoring and real-time, targeted feedback provided to students
3	c-rater ML to provide content guidance and Annotator to provide revision strategy guidance	Short essays embedded in web-based unit on plate tectonics	Design of automated guidance to strengthen student agency and ability to make constructive revisions to short essays
4	Topic modeling, simple counts of word usage	Online professional development environment for K-2 math and science	Demonstration of a computational environment designed to support the work of qualitative data analysis

## **Presentation 1: Using automated scoring to assess argumentation while minimizing linguistic bias**

Zoë Buck Bracey, Christopher Wilson, Jonathan Osborne, and Kevin C. Haudek

The automated scoring project in this study is carried out by an interdisciplinary team of science educators, cognitive scientists, and computational linguists. The goal of the project is to develop automated scoring models and corresponding multidimensional science assessment items aligned with the scientific argumentation practice identified in the Next Generation Science Standards (NGSS Lead States, 2013) for grades 6-8. The project builds upon the learning progression-based scientific argumentation assessment work by Osborne et al. (2016). This project’s automated scoring model development addresses two concerns: (1) whether we can develop automated text scoring models for students’ explanation and argumentation responses that are comparable to expert human scoring and (2) whether or not the degree to which the computer-based algorithmic text scoring is more or less biased against English Language Learners (ELLs) than human scoring of the same data (relative linguistic bias). As machine scoring of open-ended responses is expected to permeate into the classrooms internationally, combined with the current trend of classrooms having more and more culturally diverse students as they bring new languages into the classroom makeup, it is imperative to ask these questions in order to monitor the potential impact of the use of automated text scoring on the assessment of students from non-dominant cultural and linguistic backgrounds who are often underserved by educational reforms.

Written assessments have the capacity to expand the ways in which participants can express their competences (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001), but only when our interpretation “listen[s] past English fluency” to evaluate students’ science ideas (Moschkovich, 2007). In other words, teachers and other educators scoring assessments can learn to consciously counteract their biases associated with the linguistic patterns of students who are learning English. Computers may not have that ability. However, computer-based models have been shown to take on the biases of the humans who scored the data that were in turn used to train them. This suggests that there may be steps we can take to reduce the bias associated with the computerized text scoring models. This study addresses the research question: Can we develop automated computer scoring models of students’ explanations that are unbiased to variations in English fluency?

We are currently collecting data in school districts across Northern California. After a short lesson on argumentation in science, students answer a set of argumentation-related science items on an online platform (i.e., Qualtrics) designed by the project's interdisciplinary team. The assessment is written in English. ELL students within our sample are asked to produce textual responses in English. ELL status from our sample will be determined by the state's English language proficiency scores. The sample size of this study is approximately 1,000 students, of whom about 15% are ELLs. The data are scored by three human scorers with expertise in the science content and the scientific argumentation practice. Human-scored responses are used to develop automated text scoring models. In addition, these human-scored responses are analyzed using Facets software to determine relative bias between the biased human scorers, the less-biased human scorers, and the two computer models based on level of English proficiency. The Facets software extends the objective measurement principles of Rasch modeling (Rasch, 1966) using generalizability theory to apply to more complex areas such as judged performances (Solano-Flores, 2006). This analysis is used to determine the relative bias of the human versus the computers, as well as the relative bias of the human scorers on the overlapped data sets, and to train the machine learning algorithm on selected sets of less and more biased scorers.

This research contributes to the field by establishing not only the feasibility of creating high-quality automated scoring-based assessments for scientific argumentation, but also examining the degree to which the automated scoring models for such assessments are more or less biased against responses written by students who are learning a new language than human scoring. Researchers, both within science education and in the education community at large who are considering automated scoring technologies, need to have productive conversations about how to diagnose, monitor, and counteract bias. This study provides evidence to inform the nature and the direction of those conversations. Science teachers and curriculum designers should be aware of the potential risks associated with bringing automated text scoring into the classroom as formative or summative assessment methods. For researchers, it is important to critically examine the ways in which the risks and potentials can manifest while automated text scoring tools are in place so that these automated text scoring technologies can be leveraged to provide opportunities for multilingual students to express competence while learning science.

## **Presentation 2: Formative assessment of scientific argumentation practice enabled by automated scoring**

Ou Lydia Liu, Hee-Sun Lee, and Amy Pallant

This presentation addresses supporting secondary school students' revision of scientific arguments when students' claims and explanations about scientific phenomena are based on imperfect data. Students need adequate support so that they formulate strong written scientific arguments, particularly when uncertainty arises due to theoretical, methodological, measurement-related, analytical, and interpretative limitations associated with investigations. We developed HASbot, a formative feedback system that (1) diagnoses students' written arguments through automated-scoring technologies, (2) provides instant feedback on student performance, and (3) offers a teacher dashboard for teachers to monitor class-level performance in real time.

HASbot is integrated in an online curriculum module that explores freshwater availability and sustainability. There are eight scientific argumentation tasks in this water module. In writing scientific arguments, students submit open-ended responses that explain how their data support claims and how limitations of their data affect the uncertainty of their explanations. Students are expected to develop scientific reasoning that explains their claims based on evidence (McNeill, Lizotte, Krajcik, & Marx, 2006), and articulate critical thinking that examines limitations of the investigations (Allchin, 2012; Lee et al., 2014). Figure 1 shows a set of four prompts that elicited a student's scientific argumentation responses. In this study, HASbot evaluated these responses in real time using c-rater-ML<sup>TM</sup>, a natural language processing scoring engine that uses machine learning methods to extract and weight textual features relevant for scoring developed by Educational Testing Service. Table 2 lists Human-Human and Human-Machine agreements measured in Quadratic Weighted Kappa values for all automated scoring models associated with the eight tasks. HASbot returns scores with feedback to guide student revisions. See Figure 1 for how formative feedback was provided to a student after submission (note the colored bar and text below the bar in the figure).

Data were collected from 343 middle and high school students taught by nine teachers across seven states in the United States. Students took the uncertainty-infused scientific argumentation test developed by Lee et al. (2014) before and after the water module. Students' initial formulation and revision of eight scientific argumentation tasks in the module were logged. We analyzed these data to investigate how students' utilization of HASbot feedback impacted their ability to formulate scientific arguments related to freshwater systems. We also collected video data that captured how students worked together with HASbot. We analyzed videos of 14

groups of students working on the first scientific argumentation task to identify affordances and limitations of the current design of HASbot.

Paired t-tests indicate that students made statistically significant gains from pre-test to post-test, effect size = 1.52 SD,  $p < 0.001$ . Our linear regression analysis of student posttest scientific argumentation score indicates that students' interaction with the HASbot system significantly contributed to the post-test score after controlling for gender, English language learner status, and prior computer experience. HASbot helped students (1) determine what information to include and how to revise argument responses, (2) motivated to revise with feedback from a friendly, non-judgmental robot, (3) frame how to talk about uncertainty as part of argumentation, and (4) engage more deeply with the content and the data. HASbot constrained students because (1) false positive machine scores hindered students' revision efforts, (2) some students had difficulty interpreting the feedback statements, and (3) repetitive feedback statements irritated some students when their revisions did not yield improved scores. We discuss implications for supporting scientific argumentation involving uncertainty and developing a feedback system based on automated text scoring.



Figure 1. HASbot feedback example.

Table 2: Quadratic Weighted Kappa (QWK) values for human-human and human-machine agreements

Task	Students (n)	Explanation		Uncertainty Attribution	
		Human-Human	Human-Machine	Human-Human	Human-Machine
1. Trap	935	0.90	0.78	0.90	0.86
2. Bedrock	522	0.94	0.92	0.94	0.89
3. Pumice	890	0.96	0.85	0.93	0.91
4. Aquifer	717	0.95	0.90	0.95	0.88
5. Vernal	709	0.94	0.84	0.92	0.85
6. Impact	704	0.86	0.70	0.93	0.86
7. Runoff	638	0.94	0.83	0.87	0.85
8. Supply	457	0.93	0.85	0.96	0.87
Average		0.93	0.84	0.93	0.87

### Presentation 3: Critique essay by peer or self to learn to revise in science

Libby Gerard and Marcia C. Linn

In prior research, we used c-rater ML™ to develop automated scoring models for students' short essays on a 0-5 knowledge integration rubric that assesses the connections among normative ideas about science (Liu, Rios, et al., 2016). To work with autoscores, knowledge integration (KI) guidance was developed to help students move up one score level in the KI rubric. Even though this autoscore-based, adaptive KI guidance was more effective in improving students' knowledge integration abilities than other types of guidance typically used in middle school

classrooms (Gerard, Ryoo, et al., 2015), many students still struggled to use the KI guidance to revise their essays. Some students tacked ideas on to the end of responses rather than thoroughly integrating the new information, leading to superficial edits while others did not revise their essays at all (Gerard, Linn, Madhok 2016). These findings were not unexpected as research shows that students tend to add disconnected ideas, fix mechanical errors, or make superfluous edits rather than modifying connections among all ideas (Fitzgerald, 1987). When confronted with contrasting evidence, students tend to ignore the evidence and restate their own perspective (Mercier & Sperber, 2011), consistent with confirmation bias (Clark & Chase, 1972).

To promote integrated revision, we developed the Annotator. The Annotator provides students with an interactive model of the revision process (see Figure 2). Students place pre-written or self-constructed labels on sections of an essay to suggest areas for change or improvement. Selecting the relevant labels and placing them in the essay encourages distinguishing of key ideas and the integration of new and prior knowledge, rather than novice practices of tacking on disconnected information. In the initial Annotator design, students critiqued a fictional peer's essay containing common ideas that required revision (Gerard et al., 2016). We added the Annotator guidance to the adaptive KI guidance to strengthen the quality of student essay revisions.

This study compared peer- and self-annotations to determine optimal design features. We compared the initial Annotator design involving peer annotation to a modified version involving self-annotation that was intended to strengthen student agency in revision. We hypothesized that instantiating the student's own essay in the Annotator would encourage students to view their essay as a scientific product and attend more carefully to each expressed idea and the connections among them. Flower and Hayes (1980) showed that when students succeeded in analyzing the structure and argument of their essay they were capable of making valuable revisions to their reasoning. When students moved to the next step, they were randomly assigned to one of two conditions: (a) annotate their essay or (b) annotate Sara's (see Figure 2). In the "annotate own" version, the student's essay was imported into the Annotator. In the "annotate Sara's" version, an essay by a fictitious peer was pre-loaded in the Annotator. In both conditions, students used labels to address gaps or inaccuracies in the essay; reviewed their essay to revise; and then had one opportunity to receive adaptive KI guidance and revise again.

The study was conducted in two schools with four teachers and their 513 students who used the WISE "*Plate Tectonics: Why are there more earthquakes, volcanoes and mountains on the West Coast?*" One school served primarily white, middle-class students (School A, N = 332 students, 37% non-White, 11% free/reduced price lunch); the other school served primarily non-White, low-income students (School B, N = 181 students, 94% non-White, 89% free/reduced price lunch). Data included students' logged initial and revised embedded and pre/post-test essays, student annotations, interviews, and classroom observations. Essays were scored using the five-point knowledge integration rubrics (Liu, Lee, et al., 2008); annotations from one teacher in each school were scored using a 0-3 rubric assessing engagement and accuracy.

The Annotator plus adaptive KI guidance supported students in both conditions to successfully critique and revise their essays during inquiry. Although there were substantial school differences, the rate of revision was the same between the two conditions (School A: 88% revised; School B: 89%). Students significantly improved their essays in both conditions during revision (School A:  $t(164) = 7.57, p < 0.001$ ; School B:  $t(89) = 3.50, p < 0.001$ ). In School A, there was a marginal effect for condition when controlling for initial essay scores in favor of annotating a fictional peer's response,  $F(2, 162) = 12.08, p = 0.086$ .

Students in both conditions, on a novel item calling for students to write and revise an essay on the formation of Mt. Hood, made significant pre- to post-test gains showing that students gained integrated understanding of plate tectonics (School A:  $t(304) = 8.67, p < 0.001$ ; School B:  $t(116) = 5.90, p < 0.001$ ). Another post-test item measured students' ability to use guidance to revise essays by giving students one round of guidance and the opportunity to revise their initial response. Students made significant improvements (School A:  $t(315) = 11.04, p < 0.001$ ; School B:  $t(142) = 3.15, p < 0.001$ ). There was no significant effect of the condition on pre/post gains or post-test revisions.

Annotating a peer's essay supported deeper engagement in critiquing than annotating one's own essay. Students were more likely to identify weaknesses accurately when annotating a peer's essay. The difference between conditions was significant in School A,  $F(1,88) = 8.18, p < 0.01$ , but not in School B,  $F(1, 99) = 1.87, p = 0.175$ . In School B, this may be because a large percentage of students in both conditions did not place labels. In both schools, a greater percentage of students created their own labels when annotating a peer's essay (20% of students), compared to when annotating their own (12%). When annotating a peer's essay students created new labels that called for incorporation of mechanistic evidence such as, "*why does the blob rise to the top*" or "*what does heat have to do with it?*" When annotating their own essays, student-constructed labels often paraphrased an idea already expressed in their initial essay or corrected spelling.

In sum, the Annotator plus adaptive KI guidance engaged students in critique and revision of their science essays. Annotating a peer's essay showed advantages in the depth of analysis of an essay, possibly by reducing

the effect of confirmation bias. The different school outcomes suggest that automated guidance for annotation may benefit some students by helping them to create and place labels. These results suggest the value of further study of peer collaboration and confirmation bias.

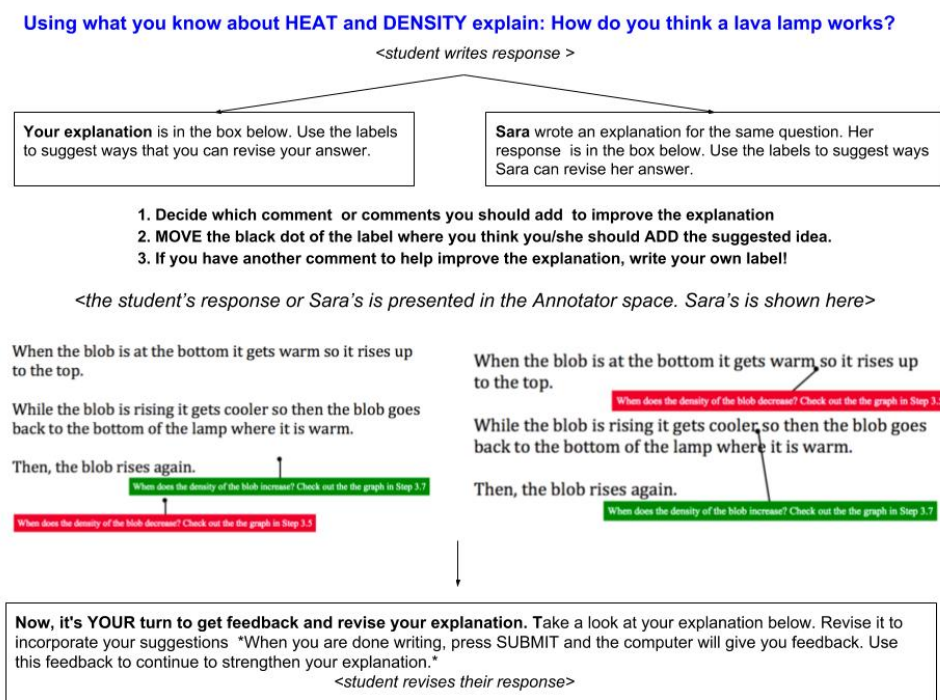


Figure 2. Comparison between “Annotate own” and “Annotate Sarah’s” versions.

## Presentation 4: Tactic Text - A new platform for computational text analysis

Bruce Sherin

The work reported on here is primarily concerned with the application of computational text analysis to research data. The potential benefits here are great. But the work is still very much in its early days, and I believe we still do not have a full picture of how the tools of computational text analysis should be woven into our research workflows. The purpose of this presentation is to introduce a new platform for computational text analysis, Tactic Text, designed for social scientists engaged in the study of learning. It is worth introducing Tactic Text in this venue not solely because it exists and is a new tool for researchers, but also because it embodies a proposed model for how we can incorporate text analysis into our research workflows. Tactic Text has been mentioned in earlier conference presentations and talks. However, to date, no presentation or research paper has laid out the design of the technology, and the argument for that design, in any detail.

The central tenet of the philosophy behind Tactic Text is this: Computational text analysis should not be seen as a replacement for, or even separate from, forms of qualitative text analysis. Rather, it should be integrated with traditional forms of qualitative text analysis in a manner that amplifies both. The two forms of analysis should be interactive. This core philosophy has a number of implications for the design of Tactic Text, and for the community of users. If the two forms of analysis are to be integrated, then there must be a population of researchers capable in both sorts of work. Furthermore, the tool must support an interactive style of analysis. In contrast, existing tools for computational text analysis tend to hide the data once it is loaded into the system.

Tactic is a fully web-based environment built to embody this philosophy. In some respects, it is akin to existing GUI-based tools for computational analysis, including Weka (Hall et al., 2009), RapidMiner (Mierswa, Wurst, Klinkenberg, Scholz, & Euler, 2006), and LightSide (Mayfield & Rosé, 2013). However, it is unlike these other tools in a number of respects, including the manner in which it is tuned for an interactive style of work. A more complete description of Tactic will be given in the talk, along with a contrast to other platforms. Figure 3 provides an example of a Tactic Text workspace, with an analysis in process. The data are visible on the left, filling a large table. All data in Tactic are accomplished with tiles, which can be added to the environment from menus. The workspace in Figure 3 has two tiles at the right. Tiles have access to the data, and can communicate

with each other.

Each user's library begins with a default set of tiles, and more are available from a shared repository. However, a core belief underlying the design of Tactic is that the vast majority of research projects require at least some programming by users. Thus, the ability to program tiles is fully integrated into Tactic. All programming in Tactic is done in the Python language, and Tactic provides an integrated editor, where tiles can be directly programmed (refer to Figure 4). Tiles have access both to a Tactic-specific API, as well as a wide range of libraries that are useful for computational text analysis. Although Tactic requires users to engage in Python programming, it does take steps to make this programming more accessible. For example, because Tactic is entirely web based, there is nothing for end users to install. Furthermore, all computational work is performed on the server, so Tactic can be used on any machine with a web browser.

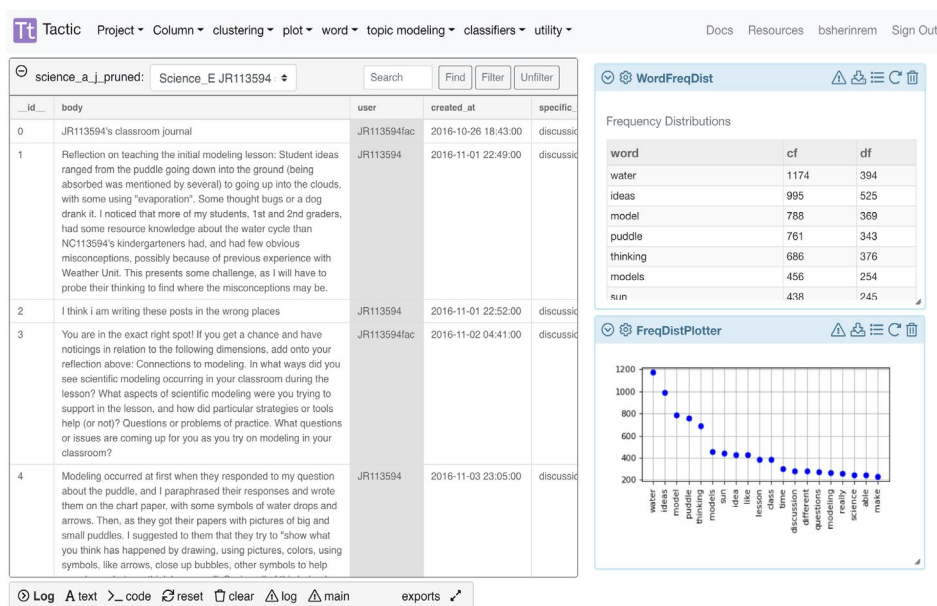


Figure 3. A sample Tactic workspace.

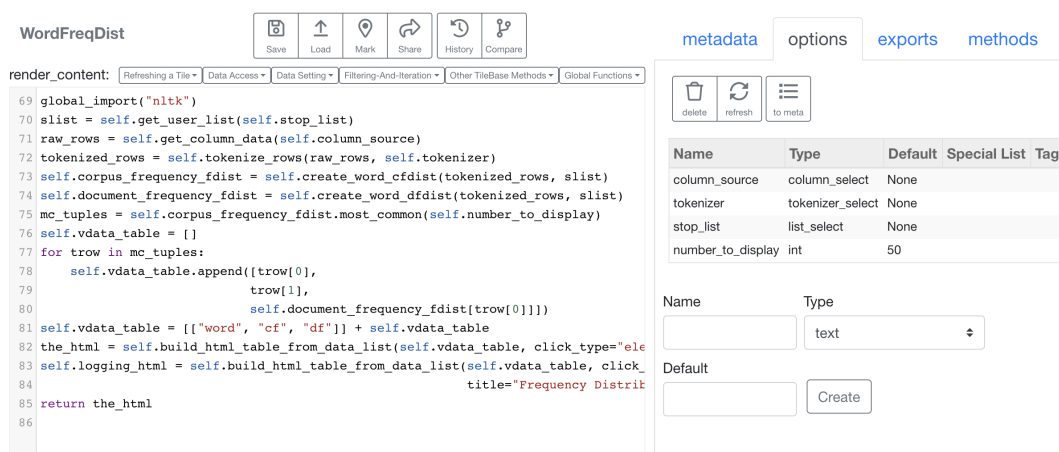


Figure 4. The tile creator in Tactic.

In the talk, I will illustrate the use of Tactic with data from the Learning Labs project (Lomax & Kazemi, 2016; Richards, Thompson, & Shim, 2016). As part of the Learning Labs project, two online courses were developed for in-service K-2 teachers, designed to guide teachers in introducing modeling-based activities into their mathematics and science lessons. The courses each span multiple weeks, and include a wide range of online activities. Many of these activities required them to enter text. Each participating teacher had to upload, watch, and comment on videos, and they could respond to the comments of other teachers, as well as answer questions presented to them as part of the course. In the presentation, I will illustrate how Tactic can be used to capture the



changing way in which teachers understood the nature of modeling as the courses unfolded.

## References

- Allchin, D. (2012). Teaching the nature of science through scientific errors. *Science Education*, 96(5), 904-926.
- Clark, H. H., & Chase, W. G. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology*, 3(3), 472-517.
- Fitzgerald, J. (1987). Research on revision in writing. *Review of Educational Research*, 57(4), 481-506.
- Flower, L. S., & Hayes, J. R. (1980). The dynamics of composing: Making plans and juggling constraints. In L. W. Gregg & E. R. Steinberg (Eds.), *Cognitive processes in writing* (pp. 31-50). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Gerard, L. F., Linn, M. C., & Madhok, J. J. (2016). Examining the impacts of annotation and automated guidance on essay revision and science learning. In C-K. Looi, J. Polman, U. Cress, & P. Reimann (Eds.), *International Conference of the Learning Sciences* (Vol. 1, pp. 394-401). Singapore: International Society of the Learning Sciences.
- Gerard, L. F., Ryoo, K., McElhaney, K., Liu, L., Rafferty, A. N., & Linn, M. C. (2015). Automated guidance for student inquiry. *Journal of Educational Psychology*, 108(1), 60-81.
- Hall, M., Frank, E., Holmes, G., Pfahringer, B., Reutemann, P., & Witten, I. H. (2009). The WEKA data mining software: An update. *ACM SIGKDD Explorations Newsletter*, 11(1), 10-18.
- Lee, H.-S., Liu, O. L., Pallant, A., Roohr, K. C., Pryputniewicz, S., & Buck, Z. E. (2014). Assessment of uncertainty-infused scientific argumentation. *Journal of Research in Science Teaching*, 51(5), 581-605.
- Liu, O. L., Lee, H. -S., Hofstetter, C., & Linn, M. C. (2008). Assessing knowledge integration in science: Construct, measures and evidence. *Educational Assessment*, 13(1), 33-55.
- Liu, O. L., Rios, J. A., Heilman, M., Gerard, L. F., & Linn, M. C. (2016). Validation of automated scoring of science assessments. *Journal of Research in Science Teaching*, 53(2), 215-233.
- Lomax, K., Fox, A., & Kazemi, E. (2016). Modeling with mathematics: An online course for K-2 teachers. University of Washington.
- Mayfield, E., & Rosé, C. P. (2013). LightSIDE: Open source machine learning for text. M. D. Shermis & J. Burstein (Eds.) *Handbook of automated essay evaluation: Current applications and new directions* (pp. 124-135). New York, NY: Routledge.
- McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *Jrl of the Learning Sciences*, 15, 153-191.
- Mercier, H., & Sperber, D. (2011). Why do humans reason? Arguments for an argumentative theory. *Behavioral and Brain Sciences*, 34, 57-111.
- Mierswa, I., Wurst, M., Klinkenberg, R., Scholz, M., & Euler, T. (2006). Rapid prototyping for complex data mining tasks. In *Proceedings of the 12th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (pp. 935-940). ACM.
- Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis*. Thousand Oaks, CA: Sage Publications.
- Moschkovich, J. N. (2007). Beyond words to mathematical content: Assessing English learners in the mathematics classroom. In A. H. Schoenfeld (Ed.), *Assessing mathematical proficiency* (pp. 345-352). New York, NY: Cambridge University Press.
- Osborne, J. F., Henderson, J. B., MacPherson, A., Szu, E., Wild, A., & Yao, S. Y. (2016). The development and validation of a learning progression for argumentation in science. *Journal of Research in Science Teaching*, 53(6), 821-846.
- Rasch, G. (1966). *Probabilistic models for some intelligence and attainment tests*. Chicago, IL: University of Chicago Press.
- Richards, J. Thompson, J., & Shim, S.-Y. (2016). *Scientific modeling with young students: A blended course for K-2 teachers*. University of Washington.
- Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, 38(5), 529-552.

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# Technology-Mediated Teacher-Researcher Collaborations: Professional Learning Through Co-Design

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**Abstract:** Collaborative co-design between teachers and researchers can provide the kinds of learning opportunities for teachers that lead to teacher agency, and flexible, adaptive, principled pedagogy. This symposium features four projects in which teachers and researchers engaged in technology-mediated collaboration to design inquiry-based learning environments to engage students in authentic disciplinary practices in a variety of content areas, including literary reading, literacy in mathematics, science, and engineering design. The size and scope of the collaborations vary, ranging from one-to-one to larger groups, as does the time span of the collaborations, providing opportunities to examine temporal affordances of technology supports. All four papers discuss collaborative co-design as sites of professional learning for teachers. We argue that these are excellent cases of CSCL and that they afford new insights into roles for technology in supporting and facilitating teacher and researcher learning.

## Overview

This symposium features four projects involving teachers and researchers collaborating in co-design of inquiry-based learning environments. Across the projects, technology mediated the collaborations in two primary ways (Hmelo-Silver, et al., 2016): (1) As a *context* for reflection on implementation of the designs via video capture of classroom instruction, and (2) as a *conduit* for connecting participants and facilitating communication during various phases of the process. As context, video of classroom instruction or of the design process itself can serve as a boundary object (Akkerman & Bakker, 2011) that focuses discussion and inquiry by teachers and researchers. In this way, boundary objects mediate sharing perspectives, joint construction of knowledge in use, and potentially the emergence of negotiated perspectives on various aspects of teaching and learning processes (Hmelo-Silver, et al., 2016). As conduit, video conferencing and other forms of communication technology (e.g., web-based forums, chat rooms) enable collaboration, reflection, and analysis across time and space.

The collaborative co-design efforts described in the four presentations aimed to engage student learners (ages 8 – 17 years) in authentic disciplinary practices in a variety of content areas, including literary reading, literacy in mathematics, science, and engineering design. As such, the four contributions reflect what might be called a second generation of (computer) technology-supported collaborative learning research in the following sense. Co-design involves working with teachers throughout all phases of the iterative design cycle (design, implementation, reflection, and redesign). This can be contrasted with design-based research wherein researchers created designs for teachers to implement. (See for discussion Penuel, Fishman, Cheng, & Sabelli, 2011.) Collaborative co-design throughout all phases of the design cycle reflects perspectives grounded in practice as well as in learning theory and research. Rather than teachers being positioned as the “end users,” they are agents in co-designing what they will implement. This second generation of CSCL creates new opportunities to study learning as it occurs in the course of iterative design cycles (e.g., Ko, et al., 2016).

In this symposium, three of the papers (Gomoll & Hmelo-Silver; Hall, Ko, Goldman, & Fortune; Kyza & Agesilaou) focus on different ways in which technology creates artifacts that provide contexts for reflecting on implementations and redesign. Two discuss how technology enables communication across time and space among co-designers (Gomez, et al; Kyza & Agesilaou). The size and scope of the collaborations vary, ranging from one-to-one to larger groups. The papers differ with respect to the time span of the collaborations, providing opportunities to examine temporal affordances of technology supports. All four papers discuss collaborative co-

design as sites of professional learning for teachers. Details of each presentation are provided below. The discussant for the symposium is Iris Tabak, Ben Gurion University. Dr. Tabak, former co-editor of the *Journal of the Learning Sciences*, is an extremely accomplished learning scientist who has created and researched science inquiry learning environments and teachers' professional learning throughout her career.

## **Rationale and background for the symposium**

Collaborative co-design between teachers and researchers throughout the design-implement-reflect-redesign cycle has emerged as an alternative to earlier design-based research (DBR) paradigms. Prototypical early DBR (Brown, 1992) involved researchers designing, teachers implementing, and researchers reflecting and then redesigning. Researchers sought teachers' input as part of the reflection and redesign process, but teachers did not have agency in redesign beyond providing input based on their experiences with what they had been given to enact. One lesson from early DBR is the highly embedded nature of classroom practice. For example, even the same teacher's implementations of the "same" lesson over three different classes of students are not identical in part because the students are different from class to class. This context-specificity creates the need for design modifications and adaptations in response to local circumstances *during* implementation. Hence, though the resultant implementations bear a family resemblance to one another (Wittgenstein, 2009), they are not identical. For teachers to adapt and modify, they need to understand the principles underlying the designs and how to flexibly implement them in ways that are consistent with the underlying principles (e.g., Brown & Campione, 1996). In other words, teachers need adaptive expertise to be able to respond to changing sets of demands (Hatano & Inagaki, 1986; Bransford, Derry, Berliner, & Hammerness, 2005). This is especially so when they are teaching for deep learning (National Research Council (NRC), 2012; Wang, Derry, & Ge, 2017).

The adaptive expertise perspective on the teaching process calls for shifts in the teaching practices of the vast majority of teachers. They need to change what they do, how they do it, as well as their understanding of why they do it (Bereiter, 2014). Just as transmission models of student learning fall short of the goal of deep learning (NRC, 2012), transmission models of professional development are inadequate in supporting teachers in developing flexible knowledge and adaptive expertise (Darling-Hammond & McLaughlin, 1995; Guskey & Huberman, 1995; Joyce & Showers, 2002). Rather, teachers need professional learning opportunities that build a principled knowledge base and sustainable, responsive pedagogical knowledge. This form of professional learning empowers teachers as agents of change by engaging them as co-creators of curriculum that directly addresses their problems of practice in their own contexts in response to their own students.

Collaborative co-design between teachers and researchers is one way in which learning scientists attempt to provide the kind of learning opportunities for teachers that lead to teacher agency, and flexible, adaptive, principled pedagogy (e.g., Kyza & Georgiou, 2014; Kyza & Nicolaidou, 2016). There are several variants of collaborative co-design. Some of these models draw from principles of improvement science and negotiate common goals for improvement efforts as well as sources of evidence that allow close monitoring of anticipated and unanticipated outcomes of implementation (Bryk, Gomez, Grunow, & LeMahieu, 2015). Others expand the DBR process to embrace practitioners in Design-Based Implementation Research (DBIR). DBIR confronts the realities of implementation from the very initial phases of design (Penuel, et al., 2011). In a similar vein, Research-Practice Partnerships (RPPs) reflect long-term commitments to collaborative co-design to address problems of practice (Coburn & Penuel, 2016). All three models tend to situate teacher learning in problems of practice that teachers see as relevant to their own circumstances and hold much promise for productive adaptation to new settings and problems of practice. (See for elaboration Gomez, Kyza, & Mancevice, 2018.) The collaborative co-design projects discussed in this symposium are instances of one of these three forms of professional learning experiences. We argue that these are excellent cases of CSCL and that they afford new insights into teacher learning and, although not discussed here, researcher learning as well.

## **Organization of the symposium**

A short introduction to the symposium is followed by four presentations plus a discussant. The presentation order of the papers moves from work in technology-mediated, one-on-one collaborative co-design (Gomoll & Hmelo-Silver) to professional learning in several one-on-one cases and in teacher-researcher multi-discipline communities (Hall, Ko, Goldman, & Fortune). The third paper examines professional learning in hybrid co-design environments (Kyza & Agesilaou). The fourth paper marshals technology to enable rapid and agile learning from practice among researchers and community college instructors of developmental mathematics (Gomez, Gomez, Pressman, & Rodela). Tabak offers a discussion and takes questions from the audience.

## **Co-designing Problem-Based Learning (PBL) experiences using video as a boundary object**

This presentation explores how a co-design experience that leveraged video analysis supported the design of a problem-based robotics curriculum. This curriculum was grounded in user-centered design and asked students to address local problems using innovative technologies. Within the research-practice partnership (RPP) described here, collaborative video analysis of past and current implementations of our robotics curriculum served as a boundary object (Akkerman & Bakker, 2011) for design partners. Video analysis collaboratively done by the first author and the teacher allowed us to communicate around the curriculum design and how it was enacted via in-class facilitation. To support development of user-centered design practices and the coordination of functional design teams in the classroom, we used video reflection to interrogate what collaborative student work can and should look like as well as how to support it in real time.

The specific focus of this presentation is an ongoing partnership with one teacher and our co-design experience orchestrating CSCL experiences for students. In our earlier work with the robotics curriculum, this teacher was inspired by high levels of student engagement. The school and community were concerned about student safety, a concern exacerbated by the increasing frequency of shootings in US schools. Students acted on this concern and opted to design robots that served an emotional need in the school—helping students to feel safe during school shooting drills. We converged on a focus for the robotics curriculum: how robots might enhance school safety.

In this presentation we focus on the co-design process between teacher and first author as we designed and implemented a robotics unit for students (ages 13 – 14) taking an elective science course in a rural community. Students engaged in the work of co-design as they designed and built safety-focused robots for their local community. Thus, in this case study, co-design is positioned as a means of learning for teacher and researcher as well as the process engaged in by the students. Through co-design, students are better supported in their efforts to collaborate effectively and to learn with and through user-centered design and computing. The co-design process between the teacher and researcher, specifically joint video analysis played an important role in supporting the effort to create, deepen, and sustain a locally meaningful engineering design experience for students. Prior research has highlighted that for teachers to develop robust practices, they need to develop rich professional vision (PV)—the ability to see nuanced issues of teaching and learning in their environment (Borko, 2004; van Merriënboer, Kirschner, & Kester, 2003; Rehak et al., 2016). Carefully organized viewing of classroom video can make PV visible and inspire action. For example, video analysis of prior and current implementations helped the teacher and researcher to refine their understanding of what productive collaboration looks like within engineering design as well as how to best support collaborative group work.

In the teacher-researcher collaborative design of this robotics unit, school stakeholders were contacted who could identify safety issues in the school that could potentially be addressed by a robot (e.g., students who have disabilities need additional assistance evacuating during emergencies; providing a live video feed to the police station during active shooter scenarios). These stakeholders agreed to play the role of design clients within the robotics unit. The unit was designed to promote authentic engagement with local issues—asking student groups to select clients they would like to design and build robot prototypes for.

We explore how the teacher refined her PV as a designer and facilitator—focusing on the ways that she oriented to and facilitated collaboration in student design groups. We illuminate the role collaborative video analysis played in co-design and implementation using discourse analysis methodology (Potter & Wetherell, 1987). In attending to discursive patterns related to PV in the work of co-design and facilitation, we study how the use of video as a reflective tool can support the development of PV and the design of CSCL experiences.

Preliminary results highlight discursive patterns including the teacher's attention to establishing and maintaining group norms (e.g., ensuring that all voices are heard), emphasizing the iterative nature of design (e.g., modeling how to talk about work as “in progress” and “a prototype”), and helping students build on each other's design ideas (e.g., modeling how to summarize and respond to a peer's comment). Teacher-researcher reflection on video of the teacher's classroom during the implementation allowed the teacher to view group work that she had not experienced in real time—informing interventions made during future class periods. Furthermore, the instructor was inspired to integrate video analysis into students' design work. The instructor used her own experience of co-design to inform the design work that her students engaged with in real time. Throughout this RPP, both teacher and researcher used video to communicate and collaborate as well as to design rich CSCL experiences for students.

## **Teacher-researcher collaborative reflection supported by classroom video**

Allison H. Hall, Mon-Lin Monica Ko, Susan R. Goldman, and Angela Fortune

Facilitating productive disciplinary discourse (PDD) in classroom discussions is a complex and multi-faceted task: teachers need to make *in-the-moment* decisions as they elicit and problematize students' ideas (Hammer, Goldberg, & Fargason, 2012; van Es et al., 2017). Teachers need to consider these ideas in light of the learning goals and respond in ways that lead to the development of disciplinary knowledge and skills. Moreover, teachers' in-the-moment responsiveness is shaped by the constraints of their teaching contexts and informed by their knowledge of their students, the curriculum, the discipline, and its epistemic commitments. There is a dearth of research on how teachers learn the requisite skills and knowledge to engage in this work and the kinds of learning experiences that may promote these pedagogical shifts.

This paper discusses ongoing work in the context of a larger project whose overarching aim is to promote PDD in literary reading, mathematics, and science. We are pursuing three goals in collaboration with middle and high school teachers: 1) to understand how teachers learn to facilitate productive disciplinary discourse (PDD), 2) to characterize what aspects of facilitating PDD are specific to the disciplines of math, science, or literature, and 3) to co-design models of professional development to support teachers in developing knowledge and skills to facilitate PDD. This paper focuses on the first two goals in literary reading and science.

To address the first goal, we are drawing on a library of classroom videos recorded during a prior multi-year, design-based research project. During that work, teachers and researchers collaborated in disciplinary design teams to design curricular modules to promote disciplinary reasoning about multiple texts. Teachers implemented these modules in iterative cycles across several years. For the current project, we recruited two literature and two science teachers for whom we had multiple years of classroom video from the prior project. These teachers are collaborating with researchers on the current project to try to understand how they learned to facilitate PDD. During one-on-one teacher-researcher meetings, the pair engages in collaborative reflection on the teacher's classroom videos to identify shifts in teacher practices over successive iterations of the co-designed modules. As well, they explore what may have induced noticed changes (e.g., discussions in design teams, other professional learning opportunities from the prior project, responses and reactions from students during the implementations). Thus, the classroom videos serve both as tools to identify what changed in teacher practice over time and as "video triggers" (Hmelo-Silver et al., 2016) to prompt teachers to reflect on events or experiences they think contributed to changes in practice. Videos are sampled from beginnings and ends of implementation cycles and from events or moments identified by teachers as potentially significant or critical to their own or their students' learning. To address the second goal of the project, these videos are also being used as "context-rich cases" (Hmelo-Silver et al., 2016) for cross-disciplinary conversations. In cross-disciplinary groups, teachers and researchers view and discuss video segments in service of identifying and describing characteristics of PDD within and across disciplines—what's common; what's unique. We documented the one-on-one as well as the larger group meetings via audio and/or video recordings and analytic memos. The data from each context were analyzed using open-coding and constant comparative methods (Corbin & Strauss, 1990) to determine themes across teacher-research teams and across disciplines.

Analyses of these two contexts revealed common themes in what practices changed, in experiences that influenced changes, and in what teachers identify as being disciplinarily specific to facilitating PDD in classrooms. One common theme that emerged in the video co-analysis with individual teachers was around the amount and type of teacher talk and how it shifted over successive iterations of the co-designed modules. Teachers indicated surprise at how much they talked in their early implementations and noticed themselves doing much of the intellectual work during discussions. In later enactments, sometimes of the same modules, teachers re-positioned students by removing activities where content was 'given' to students and opening up space for ideas to be contested and resolved among students (as opposed to students looking to the teacher to validate the "correct" response). This pedagogical shift created room for students to ask questions, propose alternative claims, and engage in debate about disciplinary questions and problems. The teachers cited the implementation and reflection on the co-designed modules that occurred during the design team meetings of the prior project as a powerful influence on making these pedagogical shifts. They also reported that using the modules in their classrooms enabled teachers to see that students were indeed capable of engaging in sophisticated intellectual work. Reflecting on opportunities to learn during the prior project, the teachers reported that engaging in conversations with researchers before and after the enactments helped them in the recursive process of soliciting and responding to students' ideas. They said that the conversations fostered a deeper understanding of the epistemology of their discipline. Analyses of the larger group meetings brought to light both similarities in guiding discussions (e.g., types of questioning, participation structures, setting expectations) and differences (e.g., what counts as evidence and justification within each discipline).

Our findings point to the benefits of using video as a trigger for supporting teacher learning and reflecting on teacher's growth over time. Using videos to reinstate the teachers own prior contexts provided a natural point of comparison to their existing instructional practice, illuminating their trajectory of learning

across time. Viewing and discussing clips outside of their own disciplines pushed teachers to articulate their taken-for-granted and tacit knowledge of their own disciplinary practices and how that influences their facilitation of classroom discussions.

## **Co-designing at a distance: An investigation of teacher-researcher interactions in video-based and face-to-face meetings**

Eleni A. Kyza and Andria Agesilaou

Teacher-researcher collaborations, and, in particular, the co-design of innovative learning environments can lead to professional learning and serve as contexts for teacher professional development (Kyza & Nicolaidou, 2016; Kyza & Georgiou, 2014). Nonetheless, teachers are often hesitant to commit to extended professional development programs due to challenging schedules and multiple demands on their personal and professional lives (Loucks-Horsley, Stiles, Mundry, & Love, 2009). In previous work (Kyza & Georgiou, 2014) we introduced a hybrid model of teacher professional development (TPD) in which face-to-face meetings were interspersed with video-mediated meetings and electronic communication technologies (i.e., email, instant messaging) to support collaboration and co-design. In this case, technology serves as a conduit for learning and communication (Hmelo-Silver, et al., 2016). Reports of video mediation of computer-supported collaborative work are not common (Brubaker, Venolia, & Tang, 2012). The goal of this study was to investigate the nature of interactions during technology-mediated teacher-researcher co-design sessions in relation to teachers' professional learning. The collaborative co-design was focused on generating inquiry learning environments around controversial socio-scientific issues that were to be enacted in the teachers' classrooms.

As part of a broader project, four in-service science teacher co-design teams (a total of 27 teachers), each led by a university researcher, developed inquiry learning environments that integrated Responsible Research and Innovation (RRI) ideas. RRI seeks to involve stakeholders in the processes of research and innovation so that the final outcome meets the needs and expectations of society (Owen et al., 2012) and advocates a more dynamic and inclusive relationship between scientific advancements and societal involvement. In this context, teachers participated in a year-long professional development (PD) program which placed them in the roles of learners, designers, instructors and reflective practitioners. Teachers along with researchers worked in co-design teams in biology, chemistry, and elementary school science to develop and implement with their students an RRI unit, based on the pedagogical framework known as Socio-Scientific Inquiry Based Learning (SSIBL) (Levinson et al., 2017). SSIBL, an approach to engage students in inquiring about contemporary socio-scientific controversies, operationalizes how RRI can be integrated in science teaching. Specifically, SSIBL requires students to make decisions about how to actively address particular socio-scientific issues in their school, communities, or broader societal context (critical citizenship). The co-design teams developed learning activities using the SSIBL framework to engage students in inquiring about the relation between the quantified self movement (also known as lifelogging), that advocates the use of technology to study one's data from daily activities, and privacy issues related to sharing personal data in a networked society. The co-design teams adopted a hybrid mode of collaboration. Some collaboration was conducted online in technology-mediated meetings, while other meetings took place face-to-face. Teachers enacted the learning materials with their students and then used these experiences to revise the curriculum they had co-designed. Thus, the co-design cycle consisted of the initial design, which was concluded in five months, the enactment phase, which took place during a period of two months, and the reflection and redesign phase which happened during three meetings in the months that followed the enactment.

In this paper, we draw from four face-to-face (f2f) and six online meetings from one of the elementary school teachers' co-design teams. This team consisted of seven elementary school teachers and a university researcher. Data were collected from co-design videos, teacher interviews, and researcher reflections and field notes. These data were analyzed qualitatively using the Actor-Network theory (Latour, 2005), to examine how the setting (f2f, technology-mediated) influenced the teacher-researcher co-design discourse and interactions. Drawing from studies on telepresence (e.g., Rae, Venolia, Tang, & Molnar, 2015) and analyzing both the videos of the sessions and the transcribed interactions, we examined dimensions such as power dynamics and hegemony (e.g., who initiated discussions), participation of both teachers and researcher, and the nature of the co-design talk (e.g., pedagogical, design thinking, communicative, technical, knowledge co-construction) during the f2f and online (video) meetings.

All teachers consistently reported, and highly rated, the importance of the co-design context to their professional learning. In their interviews, they commented on how this collaboration differed from their usual adaptations of curricula and how it contributed to their professional learning and led to more sophisticated curricular materials for their students. The analysis of the co-design interactions provided evidence that teachers

participated as reflective practitioners, once given the opportunity to feel like an equally respected member of the design team. The teachers emphasized the socio-technical support provided by the researchers, while acknowledging the challenges that professionals face in such experiential approaches to learning due to conflicting responsibilities. The technology enabled continuous teacher collaboration and coordination of co-design; however, the teachers still pointed to the challenges around the use of technology, such as finding common time to meet due to hectic schedules. Accordingly, they sought different types of technology-mediated communication, such as instant messaging. There were important differences in how the various technologies contributed to the co-design process as might be expected given the affordances of each. Finally, data from the teacher interviews indicate that both the ability to creatively explore ideas in the supportive environment fostered by the research team and the joint development of something innovative with the potential to change current practice contributed to the teachers' feelings of ownership and feelings of being intellectual partners in the co-design process.

## **The agile process in collaborative co-design: Implications for community college developmental mathematics pedagogy**

Kimberley Gomez, Louis Gomez, Emily Pressman, and Katherine Rodela

This presentation reports on a project that used technology as a conduit for creating a design and implementation community among instructors of developmental mathematics courses in community college settings located across the United States. Developmental mathematics courses have been called “the graveyard of dreams and aspirations” (Merseeth, 2011). Over 60% of community college students in the U.S. take at least one developmental mathematics class before they can take credit-bearing courses, yet 80% of these students do not complete college-level mathematics courses within three years (Bailey, Jeong, & Cho, 2010). Many of these students—increasingly ethnically, linguistically, socioeconomically, and age-diverse—spend years repeating courses and may leave college altogether. Mathematics is inextricably coupled to being able to use and express mathematical reasoning and understanding through language in fields as diverse as nursing, environmental science, and medical technology. Instructors across the country teach these courses, often, like their K-12 colleagues, working independently and in isolation. On campus professional development opportunities may not address their specific concerns and are often diffuse (Murray, 2002). What is needed is a professional community experience in which instructors who share similar students, similar issues, and similar challenges are able to share their pedagogical strategies with colleagues locally and nationally. To address this need, we embarked on a two-year long project in which video-based technologies enabled collaborative design and communication about implementation experiences across 13 instructors of community college developmental mathematics courses located across the United States. All of the instructors were implementing Quantway developmental mathematics curricular lessons (Carnegie, 2014). The collaborative design was aimed at enhancing the lessons with additional language and literacy supports that would connect with students' language and literacy needs as well as with student workforce training programs offered in community colleges (e.g., healthcare, information technology, and environmental science). Our guiding hypothesis was that using iterative design cycles to engage community college faculty would offer key opportunities for faculty learning about how to support mathematics through language. Specifically, we hypothesized that engaging in design activity, such as iterative testing, influences change in instructor knowledge, beliefs, and attitudes, and in their professional experimentation with the designed content and materials.

Inspired by “agile software process” commonly used in software design, we chose an agile process to guide our design work because of its attention to cycle-time reduction, iteration, resource management, and collaboration (Agile Alliance, 2013). We used rapid and iterative cycles of enactment, analysis and refinement during which data were continually analyzed to make improvements to lessons in between instructor enactment of lessons. During a single agile cycle, two to three instructors taught a newly designed lesson, and we conducted a quick analysis of data (interviews, surveys, student work, videotapes) to determine the need for immediate, medium, and long-term revisions to the lesson. Once we determined changes, we redesigned the lesson quickly so that two to three instructors in a second agile cycle were able to test the redesigned lesson. This process continued until all the instructors in the enactment group had tested the lesson. To ensure that we were promptly learning about instructor in-the-moment changes, as well as instructors' post lesson enactment recommendations for changes, we employed classroom video observation (SWIVEL), post-enactment online surveys and video-based interviews with instructors immediately (within 24-36 hours) following lesson enactment and analyzed the nature of in-the-moment and/or instructor recommended changes. Once the changes were categorized as immediate (e.g., change some details of the materials), we determined if they called for intermediate (e.g., change a specific problem in a math lesson) or long-term change (e.g., shift the problem

context). Recommended changes and the redesigned lessons were posted to the virtual community website so that they were immediately available to all of the project's Quantway instructors.

Using Clark and Hollingsworth's (2002) professional growth analytic model, we analyzed the data to identify change in three instructors' experiences, focusing on (a) instructor knowledge, beliefs, attitudes or skills about supporting mathematics learning through literacy supports, and (b) classroom practice. Our findings suggest that participation in design, regardless of extent of involvement, led to instructor changes in practice and in beliefs about the role of literacy in mathematics. Although we did not collect process or outcome data from students, interview and survey data collected from the instructors suggest that the instructors believed that the design process, and designed materials, contributed to improved student outcomes.

We argue that design experiences help community college instructors address their students' language and literacy needs. The technology enabled typically isolated instructors to overcome physical separation and form a virtual collaborative design and implementation community in which they rapidly learned from each other's practice.

## References

- Agile Alliance, (June, 2013). "What is Agile Software Development?". Retrieved 11/7/18. <https://www.agilealliance.org/agile101/>.
- Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, 81(2), 132-169.
- Bereiter, C. (2014). Principled practical knowledge: Not a bridge but a ladder. *Journal of the Learning Sciences*, 23(1), 4-17.
- Bailey, T., Jeong, D. W., & Cho, S. W. (2010). Referral, enrollment, and completion in developmental education sequences in community colleges. *Economics of Education Review*, 29(2), 255-270.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15.
- Bransford, J. D., Derry, S., Berliner, D. & Hammerness, K. (2005). Theories of learning and their roles in teaching. In L. Darling-Hammond & J. D. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 40 - 87). San Francisco CA: Wiley.
- Brown, A.L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, 2, 141-178.
- Brown, A.L. & Campione, J. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 289-325). Mahwah, NJ: Erlbaum.
- Bryk, A., Gomez, L., Grunow, A., LeMahieu, P. (2015). *Learning to improve: How America's schools can get better at getting better*. Boston, MA: Harvard Education Publishing.
- Brubaker, J. R., Venolia, G., & Tang, J. C. (2012, June). Focusing on shared experiences: moving beyond the camera in video communication. In *Proceedings of the Designing Interactive Systems Conference* (pp. 96-105). ACM.
- Carnegie Foundation for the Advancement of Teaching. (2014). Pathways 2014-2015 Improvement Priorities. (Foundation memo, July 2014).
- Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, 18(8), 947-967.
- Coburn, C., & Penuel, W. (2016). Research-practice partnerships: Outcomes, dynamics, and open questions. *Educational Researcher*, 45(1), 48-54.
- Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*, 13(1), 3-21. <https://doi.org/10.1007/BF00988593>.
- Darling-Hammond, L., & McLaughlin, M. W. (1995). Policies That Support Professional Development in an Era of Reform. *Phi Delta Kappan* 76, 8: 597- 604.
- Gomez, K., Kyza, E.A. & Mancevice, N. (2018). Participatory design and the Learning Sciences. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.). (2018). *International Handbook of the Learning Sciences* (pp. 401-409). New York, NY: Routledge.
- Guskey, T. R., & Huberman, M. (1995). *Professional development in education: New paradigms and practices*. New York, NY: Teachers College Press.
- Hammer, D., Goldberg, F., & Fargason, S. (2012). Responsive teaching and the beginnings of energy in a third-grade classroom. *Review of Science, Mathematics and ICT Education*, 6(1), 51-72.
- Hatano, G., & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, and K. Hakuta (Eds.). *Child development and education in Japan* (pp.262-272). New York, NY: Freeman.

- Hmelo-Silver, C. E., Jung, J., Lajoie, S., Yu, Y., Lu, J., Wiseman, J., & Chan, L. K. (2016). Video as context and conduit for problem-based learning. In *Educational technologies in medical and health sciences education* (pp. 57-77). New York, NY: Springer.
- Joyce, B. R., & Showers, B. (2002). *Student achievement through staff development*. Arlington, VA: ASCD.
- Ko, M., Goldman, S. R., Radinsky, J. R., James, K., Hall, A., Popp, J., Bolz, M., George, M. (2016). Looking under the hood: Productive messiness in design for argumentation in science, literature and history. In V. Svihla & R. Reeve (Eds) *Design as scholarship: Case studies from the Learning Sciences* (pp.71-85). New York, NY: Routledge.
- Kyza, E. A. & Georgiou, Y. (2014). Developing in-service science teachers' ownership of the PROFILES pedagogical framework through a technology-supported participatory design approach to professional development. *Science Education International*, 25(2), 55-77.
- Kyza, E. A., & Nicolaidou, I. (2016). Co-designing reform-based online inquiry learning environments as a situated approach to teachers' professional development. *CoDesign*, 1-26.
- Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford: Oxford University Press.
- Levinson, R. et al. (2017). *Socio-Scientific Inquiry-Based Learning: connecting formal and informal science education with society*. PARRISE consortium [Retrieved on November 6, 2018 from [www.parrise.eu](http://www.parrise.eu)]
- Loucks-Horsley, S., Stiles, K., Mundry, S. E., & Love, N. B. (2009). *Designing professional development for teachers of science and mathematics (3rd ed.)*. Thousand Oaks, CA: Corwin Press.
- Merseth, K. K. (2011). Update: Report on innovations in developmental mathematics—Moving mathematical graveyards. *Journal of Developmental Education*, 34(3), 32-33.
- Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy*, 39(6), 751-760.
- Penuel, W., Fishman, B., Cheng, B., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation and design. *Education Researcher*, 40(7), 331-337.
- Potter, J., & Wetherell, M. (1987). *Discourse and social psychology: Beyond attitudes and behaviour*. London, UK: Sage.
- Rae, I., Venolia, G., Tang, J. C., & Molnar, D. (2015, February). A framework for understanding and designing telepresence. In *Proceedings of the 18th ACM conference on computer supported cooperative work & social computing* (pp. 1552-1566). ACM.
- Rehak, A. M., Gomoll, A. S., Hmelo-Silver, C. E., & Danish, J. A. (2016). Developing pre-service teachers' professional vision through collaborative multimedia artifacts. In C. Looi, J. Polman, U. Cress, & P. Reiman (Eds.) *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016 Conference Proceedings*, 12(1), 130-137. Singapore: International Society of the Learning Sciences.
- van Es, E. A., Cashen, M., Barnhart, T., & Auger, A. (2017). Learning to Notice Mathematics Instruction: Using Video to Develop Preservice Teachers' Vision of Ambitious Pedagogy. *Cognition and Instruction*, 35(3), 165–187. <https://doi.org/10.1080/07370008.2017.1317125>
- Van Merriënboer, J. J., Kirschner, P. A., & Kester, L. (2003). Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist*, 38(1), 5-13.
- Wang, M., Derry, S., & Ge, X. (2017). Guest Editorial: Fostering Deep Learning in Problem-Solving Contexts with the Support of Technology. *Journal of Educational Technology & Society*, 20(4), 162-165.
- Wittgenstein, L. (2009). *Philosophical investigations (4<sup>th</sup> edition)*. New York, NY: John Wiley & Sons.

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# Tools and Methods for ‘4E Analysis’: New Lenses for Analyzing Interaction in CSCL

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**Abstract:** This symposium aims to expand the use of and perspectives on Interaction Analysis (IA) and related methods in CSCL, and to explore new ways of collecting, editing, visualizing and sharing research data, including video and location-based data. We bring the development and use of novel digital tools and IA methods to the foreground and invite participants to join us in reflecting on and designing the next phase of IA in CSCL, which in keeping with the theme of the conference is coined *4E Analysis*. During the session, we will share, compare and contrast four different digital tools and new approaches to studying collaborative learning that have been recently developed by CSCL researchers from across three different countries and five universities.

## Introduction

For the past 20 years, CSCL and Interaction Analysis (IA) have developed in tandem, with the classic Jordan and Henderson (1995) article introducing IA as a method and an approach to studying ‘knowledge in use’ (Hall & Stevens, 2015) published the same year as the first CSCL conference in 1995. One of the crucial links between CSCL and IA has been the use of video data to capture and describe interaction in ways that support studies of collaborative learning – from early studies of classrooms with shared computer screens to current interests in hybrid settings that are ‘Embodied, Enactive, Extended and Embedded’ (4E). For example, recent studies employing forms of IA from the International Journal of Computer-Supported Collaborative Learning have explored the role of talk and gesture for a pair of students collaborating around a shared touch screen (Davidsen & Ryberg, 2017), the role of teacher support for students performing lab work in science classrooms (Furberg, 2016), as well as the dynamic talk and movement patterns of families visiting a museum (Shapiro, Hall & Owens, 2017; Roberts & Lyons, 2017).

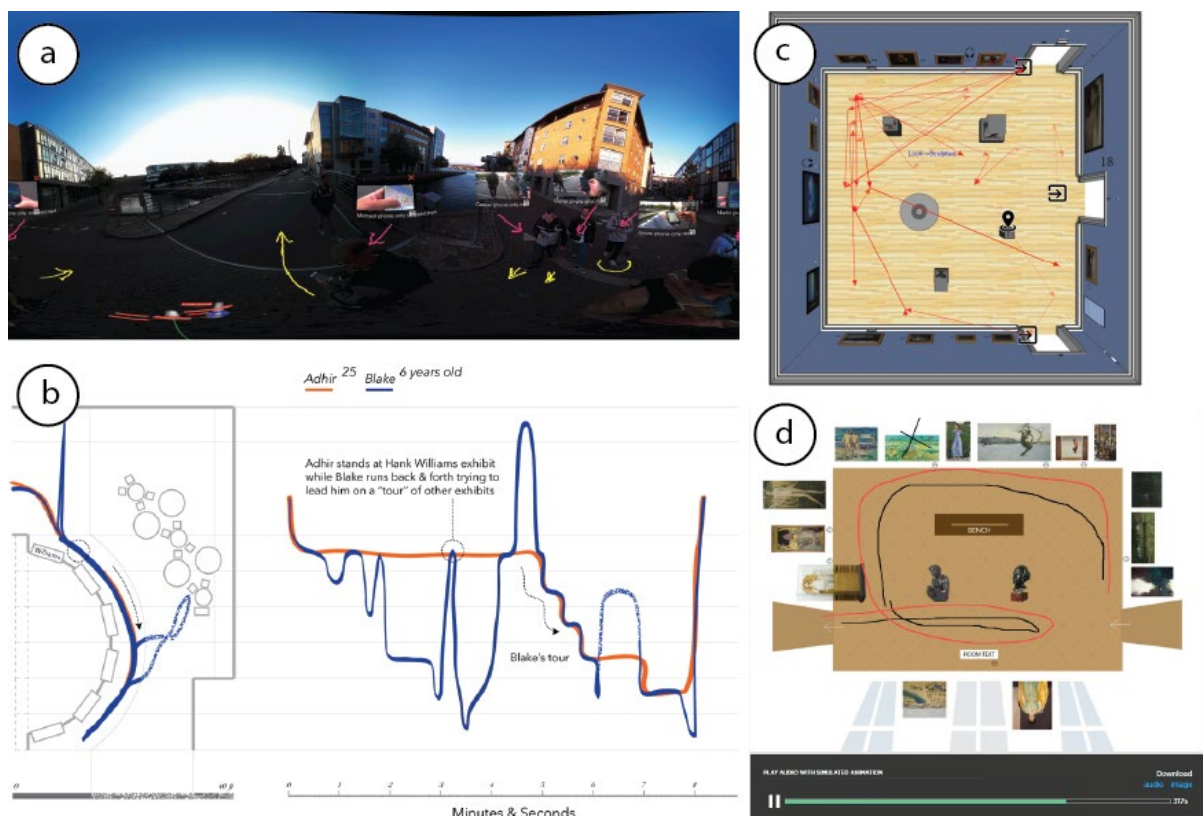
These studies show that the capability to collect, edit, visualize and share video data has expanded alongside other emergent data types and collection methods, including 360-degree video, wearable cameras, log data, location-aware technologies, as well as built and natural environments that are instrumented to link with mobile technologies. In CSCL research, such technological developments and new types of research data present a significant opportunity to extend the use of IA to explore embodied interaction, movement and learning processes from multiple perspectives, ‘scaling’ analytic attention in time, space (place), and social organization. Technological developments have opened a wider theoretical and analytical lens onto what constitutes situated and collaborative learning processes, allowing different types of questions to be posed. Some lenses are focused on ways of “representing and cataloguing choreographies of embodied interaction” for designing better support for mediated collaborative learning (Flood et al., 2015), while others are trained on “genres” of learning on the move to consider how people’s movement through built and natural environments can be both the means and content of learning (Hall, Marin & Taylor, 2017; Bang & Marin, 2017). At the same time, we suggest that a common interest in groups, collaboration and social interaction uniquely situates CSCL research in relation to mainstream developments in data collection and tracking tools that are focused on networks of individual behaviors.

However, a critical challenge for the CSCL community is access to new computational tools to support such work, as well as the development of norms and practices around their use (Wise & Schwarz, 2017). Many CSCL researchers are unaware of new computational tools to collect, select, organize, manage, visualize, and analyze different types of data corpora in ways that support both qualitative and quantitative research. Moreover, while CSCL researchers are developing new computational tools and modifying IA methods to suit their particular needs, they often do so in an ad-hoc manner, rendering innovations in tools and methods secondary to the empirical studies they are intended to support. As a consequence, new tools and modified methods are often developed independently, and remain obscured or hidden from the general CSCL community.

This symposium aims to expand perspectives on IA in CSCL, and to explore some of the challenges in responding to new ways of collecting, editing, visualizing and sharing research data, including video and location-based data. We bring the development and use of novel digital tools and IA methods to the foreground and invite participants to join us in reflecting on and designing the next phase of interaction analysis in CSCL, which in keeping with the theme of the conference is coined *4E Analysis*. During the session, we will share, compare and contrast four different digital tools and approaches to studying collaborative learning interactions and learning on the move that have been recently developed by CSCL researchers. We wish, in part, to begin a conversation with our fellow researchers about possible new arrangements for capturing and using multi-perspectival, multi-scalar records of cooperative human activity. We will use these tools/approaches a) to show how innovative analytic tools and techniques are contributing to deeper understandings of 4E learning, b) to raise and identify new questions for CSCL research including how such tools allow us to expand and extend our units of analysis across temporal, spatial and social scales and c) to discuss shared methodological challenges.

## Overview of symposium format

The symposium will feature 4 presentations followed by an extensive facilitated discussion with opportunities for audience interaction and participation. Following presentations, we will structure a panel discussion where the audience can both engage with authors through questions while also having opportunities to use tools/methods shown in the presentations. We invite audience members to also raise their own issues and questions about new forms of interaction analysis. In light of the recent UN report on accelerating climate effects of CO2 production, we will incorporate a virtual component to this symposium for those wishing to participate while reducing air-travel. Additionally, Professor Rogers Hall will serve as a virtual discussant to the symposium by identifying common challenges and future goals from across the 4 projects.



**Figure 1.** a) AVA360VR – Tool for analyzing and annotating 360 video footage in a VR environment, b) Interaction Geography Slicer (IGS) – Tool for linking movement and map data, to video and transcripts of social interaction, c) Visitracker - Software and tablet-based tool for observing and visualizing mediated interactions in museum spaces, d) Social Meaning Mapping (SMM)– Group interview method for ‘real-time’ recounting and drawing of embodied and embedded museum experience.

The above Figure 1 illustrates screenshots from the 4 different tools for studying collaborative learning interactions and learning on the move described more fully later in this proposal. The symposium will thus not merely present these 4 tools, but will emphasize looking across the approaches to support broader methodological comparison and reflection. For example, though each of the included tools direct analytic attention to participant movement, this feature of interaction is visible in different ways including 360 video footage as well as a variety of map visualizations that emphasize temporal relationships, mediated action, and participant narratives.

## International panel and areas of expertise

### Norway

**Rolf Steier** is an Associate Professor in the Department of Education at the University of Oslo. His research focuses on collaborative learning processes in a variety of contexts and disciplines including museums, classrooms, and professional design settings, with specialized interest in the relationship between face-to-face and embodied collaboration, and mediating technologies.

**Dimitra Christidou** is a senior researcher in the Department of Computer Science at the Norwegian University of Science and Technology where she is working for the H2020 COMnPLAY SCIENCE project.. Her research focuses on museum learning, visitor studies, multimodality, and embodied interaction. Dimitra holds a PhD in Museum Studies from University College London (UCL) and has working experience as a researcher in the museum sector in Sweden and Greece.

**Palmyre Pierroux** is Professor at the Department of Education, University of Oslo. Pierroux's research is focused on technology-enhanced learning in informal settings. She specializes in design-based research methods and leading projects based on research-practice partnerships with museums.

### Denmark

**Jacob Davidsen** is an Associate Professor in the Department of Communication and Psychology at Aalborg University. His research focuses on collaborative activities in different contexts and disciplines including architecture and design education and Problem Based Learning environments. He is specialized in embodied interaction analysis with a particular focus on collaborative activities.

### United States

**Ben Rydal Shapiro** is a Postdoctoral Fellow in the School of Interactive Computing at Georgia Institute of Technology. His research and design integrates approaches from the learning and social sciences, information visualization and architecture to study how people engage and learn in relation to the physical environment and to develop new types of learning environments and experiences.

**Rogers Hall** is a Professor in the Department of Teaching and Learning, Vanderbilt University. His research concerns learning and teaching in STEM conceptual practices, comparative studies of embodied action in these practices, and the organization and development of representational practices more generally.

## Paper 1: AVA360VR – Annotating, visualising and analysing CSCL processes in VR

Jacob Davidsen

With the recent advent of consumer 360-degree cameras and spatial microphones new opportunities for studying human interaction and collaborative learning processes arise. The 360-degree cameras offer a more holistic and environmentally sensitive record of collaborative learning interactions compare to traditional 2D flat recordings. With a 360-degree recording it is possible to navigate the field of view after the capture of the event, which can afford a better understanding of interaction in context and a more explorative attitude towards the analysis. Nevertheless, the existing tools supporting the process of transcribing and analysing embodied learning interactions (e.g. ELAN, Transana, etc) are not suited or build for working with 360-degree recordings. As a consequence and as part of our exploration of 360-degree cameras and spatial microphones over the last years, we have suggested a 'scenographic turn' in the analysis of human interaction (McIlvenny, 2018; Mcilvenny & Davidsen, 2017). While 360-degree video footage fosters new ways of annotating, visualising, analysing and

disseminating interaction analytic work, it is also clear that new tools are required for utilizing this technology for interaction analytical purposes.

As a response to the technological development in video technology and as part of our work under the banner of Big Video ([www.bigvideo.aau.dk](http://www.bigvideo.aau.dk)), we have developed a tool for working with 360 degree recordings (McIlvenny, 2018; Mcilvenny & Davidsen, 2017). AVA360VR (Annotate Visualise Analyse 360° video in VR) is a Unity based software allowing researchers to work with 360 video in a more ‘natural’ interface in virtual reality. Basically, AVA360VR is offering a more tangible and immersive engagement with current (and future) spatial video and audio recordings. As described by Mcilvenny (2018) some of the basic functions are “(a) scanning the field of view in 360°, (b) using the controllers, (c) using the timeline, (d) annotating, (e) inserting simultaneous video streams, (f) re-caming, and (g) deploying interactive transcript objects. Many of these remediate familiar operations – such as pointing, grabbing, drawing and watching two monitors – but with added functionality because of their virtualization”.

With AVA360VR we are seeking to take advantage of the developments in video technologies for enhancing the analysis of embodied interaction in CSCL environments. As noted by Flood, Neff and Abrahamson (2015) there is a need for CSCL to develop ways of “representing and cataloguing choreographies of embodied interaction” (2015, p. 96) in order to better design for collaborative embodied interaction in CSCL environments. However, as discussed by Davidsen and Ryberg (2017) the transformation of embodied interaction into transcripts (traditional or multimodal) is by no means doing justice to the simultaneous, creative and complex choreographies of intercorporeal interaction playing out between the collaborators in CSCL environments. With AVA360VR new opportunities for ‘cataloguing choreographies of embodied interaction’ is possible, without reducing it to traditional transcript text. It becomes possible to inhabit the data. At the symposium, AVA360VR will be demonstrated with data from architectural education, where a group of 1st year students are collaboratively preparing for a critique session.

## **Paper 2: Studying collaborative interaction across museum & city scales with the Interaction Geography Slicer (IGS)**

Ben Rydal Shapiro and Rogers Hall

Describing and representing collaborative interaction as people move across different physical environments is a significant challenge for many communities. For the computer-supported collaborative learning (CSCL) and learning sciences (LS) communities, this challenge is further complicated by the need to interpret collaborative interaction as people move across physical environments from a learning perspective. This paper illustrates a dynamic visualization tool we have developed and call the Interaction Geography Slicer (IGS). The IGS dynamically visualizes data including audio/video data and location-based data about people’s movement, conversation, and social media activity over space and time. Likewise, this paper uses the IGS to study collaborative interaction from a learning perspective across two different scales. The first scale is visitors’ collaborative interaction across museum gallery spaces. The second scale is students’ collaborative interaction as they create and follow historical walking scale tours of their local urban environment. To interpret collaborative interaction from a learning perspective at both scales, this paper draws from a growing body of research that views walking as a form of public discourse (see Marin, 2013; Zimmerman et al., 2016) where learning often arises either from moments where people “make places” to engage with entities or phenomena of interest (Lave, 1984; Ma & Munter, 2014; Christidou, 2018; Steier, 2014) or alternatively, designed pedagogical sequences where move through built and natural environments to learn (Taylor & Hall, 2013).

Findings from this paper show how the IGS provides new visualization and visual analytic techniques that advance different approaches to studying collaborative interaction from a learning perspective. In particular, at a museum scale, findings show how the IGS supports the characterization of interaction geography, an approach to describing, representing, and interpreting collaborative interaction as people move across physical environments (Shapiro, Hall & Owens, 2017; Shapiro & Hall, 2018). This approach encompasses units of analysis such as “engagement contours” and supports asking and answering new questions such as how young children use their families as resources for learning through their seemingly erratic movement patterns. At a city scale, findings show how the IGS supports a broader characterization of people’s interaction as Time Geography (Hagerstrand, 1970) in ways that highlight differences in how people learn from creating and following historical, walking scale tours. Moreover, findings show how the IGS supports traditional and new forms of interaction analysis on the move (Jordan & Henderson, 1995; Hall & Stevens, 2015) at both museum and city scales. Altogether, this work raises important questions for the CSCL and LS communities as to the strengths and weaknesses of different analytical approaches to studying collaborative interaction and ways of integrating different analytical approaches to study collaborative interaction in new ways.

## **Paper 3: Mapping mediated interaction in museums: Visitracker tool for ethnographic observations of visitors**

Rolf Steier and Palmyre Pierroux

Studies of museums as informal learning environments have identified the significance of talk, movement and physical orientation in mediating visitors' collaborative meaning making (Steier, Pierroux, & Krange, 2015). To capture visitors' interactions in these rich semiotic settings, learning researchers have employed methods and approaches from interaction analysis for the past twenty years (Leinhardt & Crowley, 1998; Rowe, 2003), furthering the development of innovative techniques for collecting and analyzing video data (vom Lehn & Heath, 2007). Findings from these studies have been particularly valuable for CSCL research on 'informal learning,' e.g., technology-enhanced learning on museum field trips (Bakken & Pierroux, 2015), and the design of texts, technologies and other contextual resources to adapt to personal knowledge and interests in different disciplines (Davis et al., 2015; Pierroux & Ludvigsen, 2013). At the other end of the methodological spectrum, there is an even longer history of *visitor studies*, with consultants continually refining methods and tools for 'T&T' studies (tracking & time) of visitors' movements. These studies are based on observations or other (digital) recordings of where individual visitors walk, where they stop, and how long they stay there (dwell time). These generally large datasets are considered valuable for practice, providing demographic and attendance information, mapping 'paths' and popular attractions, and indicating use of services. In this paper, we present a tool collaboratively developed over a ten-year period that combines insights and interests of *both research and practice*. Visitracker was inspired by paper-based protocols and developed into a tablet-based digital tool iteratively over several years with museum partners in Norway (Pierroux & Steier, 2016).

Visitracker is a portal and tablet application that was developed in a research project to record, log and visualize (anonymized) observations of visitor groups and their interactions, movements and use of resources in the physical spaces of the museum in real time. The aggregate data are recorded and visualized using maps and other graphical representations. Maps are a familiar representational tool in museum practice, used by exhibit curators and architects in the design of exhibitions, to make decisions about spatial arrangements and the sequencing of works on display. Maps are also used in the field of visitor studies to record visitors' movements and paths through a museum or gallery floor (Bitgood 1988). As mentioned, data in these studies are often used to address questions of traffic flow and circulation designs or spatial aspects that may relate to an exhibit's popularity. However, despite the potential to represent relationships between physical context and social learning interactions, maps are typically absent from sociocultural research data. Some research, such as classroom learning studies by Roth et al. (1999), have used maps to represent aspects of sociocultural research data. However, the use of maps as data is largely underutilized and unexamined from a perspective of mediated action. Maps may, by complementing other forms of data, visually highlight aspects of actions and meaning making not visible in the words of notes and transcripts.

Visitracker provides a visual overview of a physical context in which groups of visitors move and interact, and allows the researcher to document the location of the participants, their use of particular resources, and the activity. In contrast to visitor studies methods that note the time spent by a visitor standing in front of a display as an indicator of attention or learning, a researcher using Visitracker documents whether the visitor is looking at the exhibit, talking with a friend, pointing across the room, reading a text, listening to an audio guide, conversing with a friend, etc. The unit of analysis is expanded to include not just the physical location and time, but also the social aspects of group interaction and mediational aspects of resource use. By visualizing the pathways taken by groups of museum visitors and the types and locations of their interactions, we can pose new questions at a larger scale about which resources are made relevant, how multiple social interactions relate to each other in a given space, and how a sequence of actions may relate to different physical and social contexts. If a shared goal of visitor studies and museum learning research is to understand visitor experiences and meaning making processes, then new means of collecting, visualizing and sharing data using Visitracker contributes to advancing this aim.

## **Paper 4: Social Meaning Mapping: a digital tool for visitors to map their museum experience**

Dimitra Christidou

Social Meaning Mapping (SMM) is a qualitative tool embedded in the Visitracker app, designed as a post-visit research tool used during a researcher-led session for documenting/recording visitors' experience in one gallery room. For SMM, visitors are prompted to recount and recreate their movement through the room by drawing on

the digital surface of the tablet using resources from a toolbox available while also sharing their thoughts on their experience with the researcher and each other. SMM addresses a methodological challenge of incorporating visitors' own narrative understandings of their movements and meaning making processes into data collected by researchers through in-gallery observations (i.e. time and tracking studies).

The app allows visitors to depict their path either on a digital floor plan of the room they visited, or recreate their path on an empty canvas. As such, the dataset created through SMM is comprised of (i) digital trails that visitors draw by using the tablet, and (ii) audio-recordings of visitors' narrations regarding their experience in this room. SMM data can be complemented by the dataset collected through the other two methods for data collection available on Visitracker (i.e. survey and in-gallery observations). Visitracker portal makes it possible to display the drawing process on the tablet in synchronization with the audio recorded conversations (Figure 1d).

The design of SMM has been informed by relevant methods used in visitor studies approached now through a sociocultural lens (Wertsch, 1991), and the theory of navigational learning (Peterson and Levene, 2003). Particularly, SMM has been inspired by the Personal Meaning Mapping (PMM) tool, a well-established tool in visitor studies (Falk, Moussouri & Coulson, 1998; Adams, Falk & Dierking, 2003), and other similar approaches using visitor recall maps, or self-reported pathway maps (Rainbolt, Benfield, & Loomis, 2012) and visitors' drawings (Diamantopoulou, Insulander, & Lindstrand, 2012; Insulander & Selander, 2009).

In PMM approaches, a single visitor is usually invited to respond to a keyword written at the center of a blank sheet of paper and write words and phrases that are related to this keyword before and after the museum visit. Shifting the attention away from foregrounding individual and linguistic prompts, the SMM approach is designed to be used by groups of two to four visitors only post visit, enabling them to recollect, negotiate and visually co-construct their route, making the drawing task a prompt for a discussion recorded in the app. As a result, SMM marks a shift away from the usual quantitative approaches to data collected via PMM, which measure the extent of visitors' knowledge and attitudes based on the number and range of concepts/words written. SMM extends such 'reflective tracking' methodologies (Falk et al., 2007) by embracing a sociocultural perspective (Wertsch, 1991) which considers meaning making as mediated in and through social interaction and the use of cultural artefacts. Sociocultural perspectives place visitors' own experiences, and therefore their spoken and written self-reports, at the core of investigating their meaning making. By making available the possibility of drawing on a floorplan and using it as a prompt for visitors to talk about their embodied experience in the gallery room, SMM transforms static maps such as the floorplan image into 'dialectical artefacts' (Stahl, Ludvigsen, Law, & Cress, 2014, p. 239) produced by visitors in collaboration with each other and in interaction with the affordances of the SMM tool (i.e. tablet's screen, toolbox etc.). In this light, visitors' map making is seen as an 'act of representation' – that is, 'the act of highlighting aspects of our experience and communicating them to others and ourselves' (Enyedy, 2005, p. 427).

Data collected through SMM allows us to synthesize various aspects of visitor experience collected through different methods (i.e. observations, survey) and attend to the individual and social aspects of the visitors' experience (Grack Nelson & Cohn, 2015) as recounted and re-negotiated by visitors themselves. They further offer opportunities for visitors in groups to elaborate on each other's trail and exchange ideas, comments, and interpretations.

Trails are paths constructed by museum visitors, linking a series of encounters with individual artefacts, resources and other visitors, detailed through their own descriptions and interpretations recorded using Visitracker. Visitors are invited to 'see' and 'write themselves' on the floorplan by noting their movement while talking about their experience using the drawing tools available. As such, trails provide one way of linking artefacts and interpretation in a narrative through a process consisting of 'enacting' or creating trails, then editing, discussing and sharing them with other visitors in their group and the researcher. What is shared is not merely a list of resources, objects or places, but a path, which places these objects in a spatial, temporal, and/or categorical context. Additionally, trails are a tool for facilitating visitors' discussions about particular exhibits by indicating their position in the gallery and without needing to recall the names of the artists, or the titles of the paintings using art-related language.

## References

- Adams, M., Falk, J.H. & Dierking L.D. (2003). Things change: Museums, learning and research. In M. Xanthoudaki, L. Tickle, & V. Secules (Eds.), *Researching visual arts education in museums and galleries: An international reader* (pp. 15-32). Netherlands: Kluwer Academic Publishers.
- Bakken, S. M., & Pierroux, P. (2015). Framing a topic: Mobile video tasks in museum learning. *Learning, Culture and Social Interaction*, 5, 54-65.
- Bang, M. & Marin, A. (2015). Nature-Culture Constructs in Science Learning: Human/non-human agency and intentionality. *Journal for Research in Science Teaching*, 52(4), 530-544.

- Christidou, D. (2018). Art on the move: The role of joint attention in visitors' encounters with artworks. *Journal of Learning, Culture and Social Interaction*.
- Davidson, J., & Ryberg, T. (2017). "This is the size of one meter": Children's bodily-material collaboration. *International Journal of Computer-Supported Collaborative Learning*, 12(1), 65–90. <https://doi.org/10.1007/s11412-017-9248-8>
- Davis, P., Horn, M., Block, F. et al. "Whoa! We're going deep in the trees!": Patterns of collaboration around an interactive information visualization exhibit, *International Journal of Computer-Supported Collaborative Learning* (2015) 10: 53.
- Diamantopoulou, S., Insulander, E. & Lindstrand, F. (2012). Making Meaning in an Exhibition: Technologies, Agency and (Re-)design. *Designs for Learning*, 6 (1-2), 11–29.
- Enyedy, N. (2005). Inventing Mapping: Creating Cultural Forms to Solve Collective Problems, *Cognition and Instruction*, 23(4), 427–66.
- Erickson, F. *Talk and social theory: Ecologies of speaking and listening in everyday life*. Cambridge: Polity Press, 2004.
- Falk, J. H., Reinhard, E. M., Vernon, C. L., Bronnenkant, K., Deans, N. L., Heimlich, J. E. (2007). *Why zoos & aquariums matter: Assessing the impact of a visit to a zoo or aquarium*. Silver Spring, MD: Association of Zoos & Aquariums.
- Falk, J. H., Moussouri, T. and Coulson, D. (1998). The effect of visitors' agendas on museum learning. *Curator: The Museum Journal*, 41(4), 107–120.
- Flood, V. J., Neff, M., & Abrahamson, D. (2015). Boundary Interactions: Resolving Interdisciplinary Collaboration Challenges Using Digitized Embodied Performances. In O. Lindwall, P. Häkkinen, T. Koschmann, P. Tchounikine, & S. Ludvigsen (Eds.), *Exploring the Material Conditions of Learning: Opportunities and Challenges for CSCL* (Vol. Vol 1, pp. 94–100). Gothenburg: The international Society of the Learning Sciences.
- Furberg, A. (2016). Teacher support in computer-supported lab work: Bridging the gap between lab experiments and students' conceptual understanding. *International Journal of Computer-Supported Collaborative Learning*, 11(1), 89-113.
- Grack Nelson, A. & Cohn, S. (2015). Data Collection Methods for Evaluating Museum Programs and Exhibitions. *Journal of Museum Education*, 40(1), 27-36.
- Hagerstrand, T. (1970). What about people in regional science? *Papers in regional science*, 24(1), 7-24.
- Hall, R., & Stevens, R. (2015). Interaction analysis approaches to knowledge in use. In A. A. diSessa, M. Levin, & J. S. Brown (Eds.), *Knowledge and interaction: A synthetic agenda for the learning sciences* (pp. 72–108). New York: Routledge.
- Insulander, E. & Selander, S. (2009). Designs for learning in museum contexts. *Designs for Learning*, 2(2), 8-21.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, 4(1), 39-103.
- Lave, J., Murtaugh, M., & de la Rocha, O. (1984). The dialectics of arithmetic in grocery shopping. In B. Rogoff and J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 67–94). Cambridge, UK: Cambridge University Press.
- Leinhardt, G., & Crowley, K. (1998). *Museum Learning as Conversational Elaboration: A Proposal to Capture, Code, and Analyze Talk in Museums*. Museum Learning Collaborative Technical Report #MLC-01.
- Ma, J. Y., & Munter, C. (2014). The Spatial Production of Learning Opportunities in Skateboard Parks. *Mind, Culture, and Activity*, 21(3), 238-258.
- Marin, Ananda M. (2013) *Learning to Attend and Observe: Parent-child Meaning Making in the Natural World*. Ph.D. Dissertation. Northwestern University.
- McIlvenny, P. (2018). Inhabiting spatial video and audio data: Towards a scenographic turn in the analysis of social interaction. *Social Interaction. Video-Based Studies of Human Sociality*, 2(1). <https://doi.org/10.7146/si.v2i1.110409>
- McIlvenny, P. B., & Davidson, J. (2017). A Big Video Manifesto: Re-sensing Video and Audio. *Nordicom Information*, 39(2), 15–21.
- Nurse Rainbolt, G., Benfield, J.A., & Loomis, R.J. (2012). Visitor self-report behavior mapping as a tool for recording exhibition circulation. *Visitor Studies*, 15(2), 203–216. doi:10.1080/10645578.2012.715035
- Peterson, D. and Levene, M. (2003) Trail records and navigational learning. *London Review of Education* 1(3), 207-216.
- Pierroux, P., & Ludvigsen, S. (2013). Communication Interrupted: Textual Practices and Digital Interactives in Art Museums. In K. Drotner & K. Schröder (Eds.), *The Connected Museum: Social Media and Museum Communication* (pp. 153-176). London: Routledge.

- Roberts, J., Lyons, L. (2017). The value of learning talk: applying a novel dialogue scoring method to inform interaction design in an open-ended, embodied museum exhibit. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 343-376.
- Rowe, S. (2003). Visitors and Voices. *Journal of Museum Education*, 28(2), 3-7.
- Shapiro, B.R., Hall, R. & Owens, D. (2017). Developing & Using Interaction Geography in a Museum. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 377-399.
- Shapiro, B.R., & Hall, R. (2018). Personal Curation in a Museum. In Proceedings of the ACM on Human-Computer Interaction, Vol. 2, CSCW, Article 158 (November 2018). ACM, New York, NY.
- Stahl, G., Ludvigsen, S., Law, N., Cress, U. (2014). CSCL artifacts. *International Journal of Computer-Supported Collaborative Learning*, 9(3), 237-245.
- Steier, R. 2014. Posing the question: Visitor posing as embodied interpretation in an art museum. *Mind, Culture, and Activity*, 21(2), 148-170.
- Steier, R., Pierroux, P., & Krange, I. (2015). Embodied interpretation: Gesture, social interaction, and meaning making in a national art museum. *Learning, Culture and Social Interaction*, 7, 28-42.
- Taylor, K. H., & Hall, R. (2013). Counter-mapping the neighborhood on bicycles: Mobilizing youth to reimagine the city. *Technology, Knowledge and Learning*, 18, 1-2: 65-93.
- vom Lehn, D., & Heath, C. (2007). Social interaction in museums and galleries: A note on video-based field studies. *Video research in the learning sciences*, 287- 301.
- Wertsch, J.V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge: Harvard University Press
- Wise, A., & Schwarz, B. (2017). Visions of CSCL: Eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, 12, 423-467.
- Zimmerman, H. T., Land, S. M., Maggione, C., Ashely, R. W. & Millet, C. (2016). Designing outdoor learning spaces with iBeacons: Combining place-based learning with the Internet of Learning Things. *Proceedings of the Twelfth International Conference for the Learning Sciences*. Volume 2, 942-945.



# The Roles of Knowledge in Knowledge Creation

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**Abstract** Reading comprehension research of the 1970s established that prior world knowledge is a determiner of the acquisition of new knowledge, mainly by providing schemas into which new information may be entered. This should clearly apply to students creating knowledge by building on their existing knowledge and on knowledge gained from other sources. In addition, researchers on Knowledge Building have identified other kinds of knowledge useful in knowledge building, including knowledge of promisingness, knowledge about knowledge (epistemology), principled procedural knowledge, and knowledge about external expectations (such as curriculum standards and tests). This symposium brings together researchers who have studied various roles of knowledge in knowledge building, with the goal of at least organizing the distinct views but if possible producing an integrative framework for treating knowledge in creative work with ideas.

## Introduction

The importance of prior world knowledge in knowledge acquisition was firmly established by research during the 1970s (Schallert, 1982) and was explained by a theory that posited cognitive structures (schemas) acquired through meaningful learning, which provide frameworks for entering new information and integrating it as knowledge (Rumelhart, 1980). Since that time a number of constructivist educational approaches have arisen that seek to go beyond knowledge acquisition to some more active and creative engagement of students with knowledge and ideas. With it have come suggestions that prior knowledge can inhibit creative work with knowledge and that a limited amount of prior knowledge may be optimal (Simonton, 1999, p. 120). The implication is that, beyond some essential knowledge to build on, the rest of creative knowledge work is pure process. A different view, however, is that domain knowledge plays an active and vital role in work with knowledge and ideas (Weisberg, 1999), but that additional kinds of declarative knowledge become important when the emphasis shifts from knowledge acquisition to knowledge creation. These include (1) epistemology (knowledge about knowledge); (2) knowledge about how knowledge is created (e.g., Li & Kettinger, 2006); (3) knowledge of misconceptions, pitfalls, and promising inquiry paths within a domain; and (4) domain-specific “principled practical knowledge” (Bereiter, 2014), of which the most fully developed example is TRIZ (Orloff, 2013), a set of heuristics for solving engineering design problems. Finally, in education contexts there is the knowledge that teachers need in order to build a community that has knowledge creation as its organizing center.

This symposium brings together researchers who have investigated the roles of different kinds of declarative knowledge in the context of Knowledge Building, an educational approach in which collaborative knowledge creation is the goal and principal activity (Scardamalia & Bereiter, 2014). The purpose of the symposium is to elaborate the accounts of different kinds of knowledge functioning in knowledge building/knowledge creation and to work toward a coherent framework within which to pursue further research and development related to this important but relatively undeveloped line of research within the constructivist conceptual space.

One way of interpreting the “wide lens” theme of CSCL 2019 is that it calls for taking fuller account of the processes of human learning that machine learning, even in its most advanced forms, still lacks. Complexity

scientist Melanie Mitchell has said the barrier AI has not yet surmounted is “meaning.” The most serious failings she cites reflect inability of AI to understand what Karl Popper called the “problem situation,” and which he saw as essential to the creation and assimilation of new knowledge. Achieving understanding of a problem situation, however, invariably requires more than the “embodied, enactive, extended, and embedded” processes that distinguish human learning. It requires substantive knowledge. Knowledge, in its many forms and contexts, has been a perennial subject of research in the learning sciences. This symposium, nevertheless, can be claimed to have a “lens-widening” effect with respect to its uses in knowledge creation itself and in constructivist educational approaches. It does this by identifying a variety of kinds of substantive knowledge that can actually be put to use in ways that augment the remaining advantages human learners have over machines.

## Plan of the symposium

The plan of the symposium is to allocate four minutes to introductory comment and six minutes to each of six presentations. Following this will be a panel discussion, moderated by Marlene Scardamalia, in which authors of the six presentations will address possibilities of an ontology of types of knowledge involved in knowledge building/knowledge creation and ways of taking fuller advantage of them in education. The moderator will determine when to open the discussion to the audience but will allow a minimum of 8 minutes for it.

## Building on collective prior knowledge for knowledge building across school years

Jianwei Zhang and Jiyeon Lee

Building on what the learner already knows is a broadly accepted and practiced principle of learning. While existing notions of prior knowledge focus on existing knowledge of individual learners brought to a new learning context; research on knowledge creation/knowledge building in schools needs to expand this concept to include *collective prior knowledge*: knowledge built and accumulated by the community through its prior inquiry practices that may be transferred to the current knowledge work. Collective prior knowledge is not as simple as the sum of what each individual member knows and remembers. Rather, it is an emergent and social entity that primarily exists in the community’s social knowledge space as epistemic artifacts, discourse, and practices. In real-world knowledge-creating settings, members continually build on their team’s prior work—such as conceptual insights already gained, designs and tools created/used before, and cases and problems encountered—to support their new creative endeavors, transcending boundaries of time, space, and tasks. Research on Knowledge Building and CSCL has produced a strong account of how students advance their collective knowledge through interactive discourse (Bereiter, 2002; Stahl, 2006), building on one another’s ideas generated in the undergoing inquiry process. Extending such research, the notion of collective prior knowledge suggests a longer-term view of knowledge building and transfer: we need to investigate how students access and tap into their community’s previous knowledge work across school years for sustained knowledge building in the related problem spaces and domain areas. Such long-term build-on is possible with the support of online platforms in which students’ contributions and interactions are automatically archived. The challenges are to turn the detailed records of online interactions into an accessible/useable knowledge resource (Zhang, 2009), to enable cross-context fluidity, and to support students’ reflective creative efforts to build idea connections in their individual work and collaborative discourse. Herein we report an exploratory study that investigated the designs and processes to address these challenges.

This design-based research was conducted among a group of elementary school students during three successive school years as they studied in Grade 4, 5 and 6. In their science curriculum, students studied three interrelated areas: light in Grade 4, climate and environment in Grade 5, and astronomy in Grade 6. The science inquiry each year was supported with Knowledge Forum. In addition to the regular Knowledge Forum views (workspaces) where students pursued knowledge building discourse, a “super view” was created in the database of Grade 5 and 6 in which students revisited the syntheses of ideas from their previous years and posted new syntheses of their current inquiry. The syntheses were composed using a set of scaffolds to document the journey of thinking in each problem area: *Our research topic and problem(s), We used to think... now we understand, and We need deeper research*. The synthetic knowledge artifacts were used as a boundary-crossing (Akkerman & Bakker, 2011) support to enable students’ access and revisiting of their collective prior knowledge. Students individually read and built on the syntheses online, some of which were further discussed at whole class meetings as related to the current inquiry. Multiple sources of data—including online discourse

records, classroom videos, student interviews--were analyzed to examine the knowledge building interactions and idea build-on across school years, drawing a combination of qualitative and quantitative analyses.

Comprehensive data analysis is still underway. Preliminary findings identify several productive patterns by which students tapped into the ideas generated by their community in the previous school years to support their new inquiries. These included (a) carrying on prior concepts as the explicit focus of continued discussion, online and face-to-face, (b) reusing/embedding prior ideas (e.g. reflection of light) to support new inquiry and discourse to solve specific problems (e.g. how glacier melting affects climate change), and (c) reflecting on cross-domain connections to understand the whole picture and develop coherent understandings. As a student posted in the Grade 6 Super View when studying astronomy: *“A connection from grade 4 to grade 6 is that you need light to sustain a planet. If a planet has a source of light, it probably will have heat. Without light and heat, our planet would be cold and dark and we would all die. Luckily, our Earth has a source of light and heat which helps us maintain our lives.”* While the prior knowledge of the community was transferred to support the new inquires, some of the prior ideas were also re-examined and refined. For example, a student in Grade 6 revisited a notion many students had in Grade 5 that “greenhouse gases are bad” and clarified that “The Earth does need some greenhouse gases, but ... not too much.” In addition to building on content-specific ideas from the past, students also adapted their prior strategies and practices of knowledge building to support their current inquiry. In light of the findings from this and other studies, we designed a new online support—Idea Thread Mapper (Zhang et al., 2018)—to better support knowledge interaction across school years and communities.

## **The role of meta-knowledge about discourse in knowledge building**

Carol Chan, Yuyao Tong, and Jan van Aalst

The importance of dialogue in learning, thinking and understanding in online environments is well established in the CSCL literature. Current efforts to promote classroom dialogue and productive discourse have emphasized knowledge construction—in which students elaborate their ideas, provide reasons, query others’ standpoints and construct deeper understanding (Mercer & Littleton, 2007). Similarly, research on CSCL discourse has highlighted meaning making, inter-subjectivity and argumentation mediated by technology (Stahl, Koschmann & Suthers, 2014). However, discourse as an epistemic object of inquiry and a form of explicit knowledge, which students need for creative knowledge work, has received less attention.

Dialogue is pivotal as it underpins all knowledge disciplines; it is central to the development of scientific and systematic knowledge. In knowledge building, students engage in discourse similar to that which occurs in all knowledge disciplines. This discourse generates knowledge advancement; it involves the epistemic work of turning fragmented ideas into coherent explanations and theories for creative work. Current research in the learning sciences has emphasized discipline-based scientific discourse. We take the position that knowledge-advancing discourse moves beyond the expression of what is known and assertions of beliefs. Rather, it is progressive and ever-deepening with no-end-goals for creative knowledge work. Just as knowledge about knowledge (e.g., nature of science) is needed for scientific inquiry, students also need knowledge of discourse for knowledge creation. We call this meta-knowledge of discourse as it involves a meta-level of knowledge. Students’ knowledge about how knowledge is created through discourse would encompass epistemic components such as goals, functions, processes and standards/criteria. Central to this paper is that students need to develop an epistemic understanding of discourse; they need to develop their meta-knowledge of discourse and deploy this knowledge for productive knowledge building.

Preliminary findings from a study by Lin and Chan (2018) indicate that 5<sup>th</sup> graders who hold richer conceptions of discourse also have deeper scientific understanding. This presentation reports on design-based studies that investigated the development, characterization and effects of meta-knowledge about discourse in knowledge building. Data were drawn from 3 classes of grade 9-10 students, building knowledge about art and design over 2 school years. We examined how students engaged in collective inquiry supported by their meta-knowledge of discourse; how meta-knowledge about discourse is manifested; and what effects meta-knowledge about discourse has on students’ knowledge building. First, we created a knowledge-building environment for developing students’ meta-knowledge of discourse. Students’ engaged in collective inquiry and discourse about their ongoing Knowledge Forum discourse. Three views (discussions) in Knowledge Forum were designed to support inquiry about (a) visual arts, (b) the nature of discourse, and (c) collective knowledge advance. Classroom discussions typically focused on idea development; we added a meta-layer of explanation for idea improvement. Students’ prior knowledge about discourse was prompted through their analysis of Knowledge Forum discourse threads. Students engaged in meta-discourse using their knowledge about discourse to explain why and how certain Knowledge Forum inquiry is productive and what needs further knowledge work.

Knowledge about domain inquiry and nature of discourse was intertwined. Students also generated epistemic criteria and standards that were inquired into in relation to knowledge-building principles; their meta-knowledge about discourse was continually refined through collective inquiry. Second, multiple data including Knowledge Forum notes, interviews and open-ended questions were examined. We identified different kinds of meta-knowledge about discourse that evolved with our design: (a) epistemic goals—content-focused vs. theory building; (b) epistemic processes—interactive vs. emerging and non-ending processes; (c) epistemic criteria — creation of standards related to knowledge-building principles appropriated to their inquiry context. Students also demonstrated meta-strategic knowledge of how they could use their knowledge about principles to reflect on their ongoing inquiry. Third, students reflected on their evolving knowledge about discourse in their portfolios linking to domain knowledge. Coding showed that meta-knowledge about discourse on Knowledge Forum was associated with their portfolio scores and domain knowledge advances. Ongoing analyses are examining the interweaving of domain-specific and meta-knowledge of discourse for sustained growth. This study suggests the need to scaffold students' explicit knowledge about discourse and meta-level explanations for productive knowledge-building.

## Deepening knowledge of knowledge building

Seng Chee Tan

For more than three decades, researchers working on knowledge building have benefited from the theory and principles of knowledge building (Scardamalia, 2002; Scardamalia & Bereiter, 2015). In the spirit of knowledge building and taking a meta-level view, we could apply the *rise above* principle to knowledge building research to improve our understanding of knowledge building. One approach is to work within the 12 principles, apply and study learning design based on these principles of knowledge building with the ultimate goals of improving practices and gaining deeper understanding of these principles. This is the approach that much of research on knowledge building has taken. An alternative approach is to look beyond the knowledge building literature for innovative integration of ideas, which in essence, widens our resources for improving theory of knowledge building.

Examining beyond the knowledge building literature, we could identify at least two other perspectives of knowledge creation: organizational knowledge creation theory by Nonaka and Takeuchi (1995) and expansive learning in cultural-historical activity theory by Engeström (1999). A comparison of these different perspectives reveals differences in terms of their contexts, actors of knowledge creation, driving forces for knowledge creation, types of outcomes of knowledge creation, and knowledge creation processes (Tan & Tan, 2014). Paavola, Lipponen, & Hakkarainen (2004), for instance, examined knowledge building with these perspectives of knowledge creation and identified the critical roles of mediating artifacts in knowledge creation, leading to the development of principles for *triological* learning. We could extend such effort further to explore other questions. For example, the interplay of tacit and explicit knowledge forms the core of organization knowledge creation theory by Nonaka and Takeuchi, but the roles of implicit knowledge is not well explored in knowledge building literature. Current research tends to focus on explicit codified knowledge, which also forms the core of triological learning. Bringing the notion of tacit knowledge into knowledge building research triggers a series of questions: What roles does tacit knowledge play in knowledge building? Can tacit knowledge be codified and shared? Can we bypass the codification process to share and 'build on' tacit knowledge? If so, how should we design learning environments to facilitate this process? The issues of tacit knowledge has been discussed to some extent in the field of organization knowledge creation. Nonaka and von Krogh (2009) summarized some of the debates and clarified their positions. In essence, they take the view that not all tacit knowledge can be codified; tacit and explicit knowledge are on the same continuum and they play complementary roles. Nonaka and von Krogh acknowledge the social practice views (e.g., community of practice) of how implicit rules and knowing can be formed through apprenticeship or mentoring within a community, but presented the challenge of achieving the dual goals of conserving existing social practices versus achieving innovation and knowledge creation.

What do all these mean to knowledge building? As a start, they could provide inspiration to expand our research agenda. First, if we acknowledge that tacit and explicit knowledge co-exist in most learning situations, besides examining students' knowledge artefacts, we may want to explore other "tacit aspects" of learning in knowledge building. For example, in many knowledge building studies, field trips or group hands-on activities were included. Do these personal experiences relate to learning beyond those that can be examined through the students' knowledge artefacts? How do students feel as they engage in knowledge building and how do teachers feel as they facilitate the process (emotions in learning)? Do their feelings relate to the cognitive aspects of learning? Do students develop the identity of a knowledge builder? Second, if tacit knowledge can't be codified

totally, how do we design learning environments to facilitate such process? For subjects such as music and singing, which requires tacit embodied skills (exercising body internal “organs” to produce melodious voice), how do we support idea improvement? Would multimodal representations work? If so, how do we provide scaffolds in multimodal representations? Third, could knowledge building offer solutions to other perspectives of knowledge creation? For example, the practice of always seeking for idea improvement and rising above current level of understanding from knowledge building could be a possible approach to overcoming the challenge of “preserving culture and practices” versus innovative work suggested by Nonaka and von Krogh (2009).

## **Meta-knowledge to strengthen epistemic agency**

Marlene Scardamalia and Ahmad Khanlari

Knowledge Building as an educational approach has always emphasized turning progressively higher levels of agency over to students in the conduct of knowledge creation. This generally requires that students take a higher-level view of their work, which can be facilitated both by providing supports such as scaffolds and information they can discuss and formulate into “meta-knowledge” about their own knowledge building and about the problem domain in which they are working. In this symposium, Chan, Tong, and van Aalst report beneficial results from supporting students’ development of meta-knowledge about their knowledge-building discourse. In our laboratory, experiments have shown that children as young as age seven can make productive use of information about their use of Knowledge Forum “scaffolds” and about the domain vocabulary they are using and how this compares to the vocabulary used by experts (Resendes, Scardamalia, Bereiter, Chen, & Halewood, 2015). They can also profit from identifying “promising” ideas and making these objects of discussion (Chen, Scardamalia, & Bereiter, 2015). Research still in the offing will investigate ways students can make use of social and semantic network data in enhancing individual contributions to collective efforts (cf. Ma, Matsuzawa, Chen, & Scardamalia, 2016). Research to be reported in this symposium deals with students’ knowledge of misconceptions and the role this meta-knowledge can play in their knowledge building.

This research falls within the general area of “intentional conceptual change” (Sinatra & Pintrich, 2003). In a preliminary study we examined student use of scaffolds such as “*I need to understand*” and “*my problem of understanding*” to determine if students expressed uncertainty about ideas and theories they recorded in Knowledge Forum. Analyses suggest students have untapped awareness of misconceptions. Follow-up research will engage grade 5-6 students in identifying misconceptions about electricity in records of the online work of similar students in previous years. They will then carry out knowledge building of their own in this area, in an experiment that tests the effects of providing students with general versus domain-specific prior knowledge of common misconceptions. Our hypothesis is that providing students with the kinds of knowledge about misconceptions normally available only to their teachers will result in students taking an active role in preventing and remediating scientific misconceptions.

## **The role of domain-specific principled practical knowledge (PPK) in knowledge creation**

Carl Bereiter

When attention shifts from individual knowledge acquisition to extended programs of knowledge creation, challenges to creative thinking begin to take the form of obstacles, anomalies, and unsolved problems. Accordingly, the knowledge most needed for progress tends to be domain-specific and practical rather than generic or theoretical. This is what Bereiter (2014) has called “principled practical knowledge” or “PPK” and defined as “explanatorily coherent practical knowledge.” PPK is knowledge that, while not itself theoretical, meets scientific standards of coherence with empirical evidence and explanatory propositions in a domain. PPK is relevant to societal needs for creativity in two ways. First, many of the most important products of creative thinking are PPK—generalizable solutions to practical problems. Second, people need PPK that is helpful in their own creative work, PPK that enables them to go beyond brainstorming and tinkering. That is the role of PPK sketched here.

Although commercial booklists are full of books intended to help people do better, little of the knowledge conveyed is both principled and practical. Especially where creative work is involved, the principled and the practical seem to occupy different realms. There are, however, a few exceptions. Three examples are:

(1) Polya’s (1957) mathematical problem solving heuristics. These heuristics are very general, involving no particular mathematical knowledge. However, applying them well always requires linking them to

mathematical knowledge. Drawing a diagram or picture, for instance, can be helpful or misleading, depending on how well it reveals the essence of the problem. Polya used as an example solving a problem concerning the length of a diagonal in a three-dimensional space figure. A diagram could suggest right triangles as the source of missing values, but it is unlikely that, without some guiding concept, a student would draw a figure suggestive of this solution path. A more specific heuristic, useful in a variety of spatial and figural problems, both hypothetical and real-life, is *look for right triangles*. This is a different order of practical knowledge from the process-oriented heuristics of Polya and much of conventional instruction in creative thinking. Yet it is the kind of practical knowledge, closely tied to disciplinary knowledge, that can directly aid problem solving.

(2) Rhetoric. Many works intended to help people write better convey practical knowledge in the form of principles, but not “explanatorily coherent” ones. Instead, their advice is distilled from experience and supported by examples. In contrast, the work of Christensen (1968) provides an example of what PPK in writing might be. Christensen observed that the sentences of expert writers were distinguished by heavy use of “free modifiers”—modifying clauses or phrases put outside and usually after the main clause, rather than embedded in it. This finding led to an explicit rule: If you want to improve readability, avoid long noun clauses and instead modify the subject by attaching free modifiers at the end. As with Polya’s heuristics, this item of practical knowledge requires domain knowledge (in this case, syntactical) if one is to use it effectively.

(3) TRIZ. There is a substantial and growing body of domain-specific PPK for dealing with obstacles encountered in engineering design and invention. Called “TRIZ,” it is based on a set of 40 “principles,” derived by Altshuller (1984) from analyzing thousands of patents (which are creative almost by definition, being “non-obvious” solutions to problems). The principles are at about the same level of specificity as Polya’s “heuristics.” These, however, are refined into more specific heuristics adapted to particular problem areas. Two of the principles are “intermediary” and “cheap short-living objects.” Orloff (2013, pp. 71-75) showed how these can be applied to the problem of driving concrete pilings into the ground without damaging the pilings. The “intermediary” principle suggests putting something between the driver and the piling; the “cheap short-living objects” principle suggests sand. From that point on, straightforward engineering leads to a practical solution. Homer-Dixon (2006) has gone farther in the TRIZ direction by identifying solution paths capable of generating the know-how required for tackling civilization-threatening problems. TRIZ-type knowledge would find uses in education at the school level, especially in helping “maker” projects create new knowledge. What these examples suggest is that if useful PPK for knowledge creation is to be developed it will be within specific domains and will come about through analysis of problems and solutions occurring within those domains.

## **The role of teachers’ design knowledge in promoting creative work with knowledge and ideas**

Huang-Yao Hong, Pei-Yi Lin, Ching Sing Chai, Chin-Chung Tsai, and Yibing Zhang

Design mode of thinking is the central epistemic stance that the Knowledge Building pedagogy rests upon (Bereiter & Scardamalia, 2003). To foster such epistemic stance in teaching and learning, teachers need to themselves adopt such a stance in lesson design and enactment. Teacher education focused on lesson content and activities does not normally meet this need. Instead, we propose that teacher education should be conceptualized and operationalized to foster teacher’s design fluency, where design knowledge is prioritized over curriculum specified teaching knowledge, recognizing and extending idea promisingness as the key competence and epistemic/pedagogical framing as the means for responsive Knowledge Building. Building on our research and experience in helping teachers develop design knowledge over the past 10 years in Taiwan, Singapore, and China, in this presentation, we will (1) propose a conceptual framework to foster teachers’ design knowledge for Knowledge Building, and (2) showcase how design thinking by teachers leads to design thinking by their students.

McKenney, et al. (2015) define design knowledge as “different kinds of knowledge resources and aspects of knowing that enable intelligent and fluent design work by teachers across situations and contexts” (p.7). There are three essential features outlined in this definition: design knowledge resources, design thinking as a way of knowing, and design fluency. Corresponding to Chai, et al.’s (2018) idea of technological pedagogical and content knowledge (TPACK), we identify three main types of knowledge resources for teachers to engage in productive design work, including the heuristics about the 12 Knowledge Building principles (Scardamalia, 2002), technological knowledge about Knowledge Forum tools, and the generic curriculum knowledge and specific subject matter knowledge. We posit that whether teachers are able to responsively and flexibly draw upon various types of knowledge sources to design Knowledge Building activities for students is a key to effective lesson design.

Second, design thinking as a way of knowing can be developed using ideas drawn from existing design schools, such as Stanford's D. School. Examples could include (1) empathizing with students' potential for and difficulty in Knowledge Building; (2) defining and progressively solving emerging problems derived from student Knowledge Building; (3) continually generating and tinkering with diversified design ideas; (4) producing and refining lesson design as a prototype; (5) testing, reflecting, and redesigning for further improvement of previous lesson design.

Third, design fluency can be manifested in the evolutionary process of teachers' design ideas (Hong & Sullivan, 2009), especially within a teacher community where teachers work together to reflect on their actions and practices in fostering Knowledge Building. During iterative lesson design, enactment, and reflective consolidation process, teachers' design fluency are embodied in the forms of design talk, feedbacks, and explanations to support students' Knowledge Building activities during co-design discussion. The development of design ideas can change over time both in quantity and quality. Quantitatively, we expect that there will be diversified design ideas proposed and shared within teachers' design community. Qualitatively, we assume that there will be progressive rise-above effort to produce more promising design ideas emerging from teachers design talks, feedback, reflection, etc. Efficiency of producing diversified ideas and efficacy of improving the explanatory coherence of design ideas will be two critical dimensions to measure teachers' design fluency. At the same time, whether teachers are able to bring the three types of knowledge sources mentioned above into a more integrated design knowledge also plays an important role to assess their design fluency for fostering effective Knowledge Building activities.

Eventually, as outcomes of sustained design activities, we expect teachers to gradually develop what Hatano and Inagaki (1986) called "adaptive expertise" on one hand and more informed design epistemology on the other hand. As for students, we expect that teachers' design effort would lead to invention and knowledge creation by their students (Lahti & Seitamaa-Hakkarainen, 2014).

## References

- Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81* (2), 132-169.
- Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Bereiter, C. (2014). Principled practical knowledge: Not a bridge but a ladder. *Journal of the Learning Sciences, 22*, 4-17.
- Bereiter, C., & Scardamalia, M. (2003). Learning to work creatively with knowledge. In E. D. Corte, L. Verschaffel, N. Entwistle & J. v. Merriënboer (Eds.), *Unravelling basic components and dimensions of powerful learning environments* (pp. 55-68). Oxford, UK: Elsevier Science
- Chai, C. S., Koh, J. H. L., & Teo, Y. H. (2018). Enhancing and modeling teachers' design beliefs and efficacy of technological pedagogical content knowledge for 21st century quality learning. *Journal of Educational Computing Research*. <https://doi.org/10.1177/0735633117752453>.
- Chen, B., Scardamalia, M., & Bereiter, C. (2015). Advancing knowledge building discourse through judgments of promising ideas. *International Journal of Computer-Supported Collaborative Learning, 10* (4), 345-366.
- Engeström, Y. (1999). Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. In Y. Engeström, R. Miettinen, & R. L. Punamaki (Eds.), *Perspectives on Activity Theory* (pp. 377-404). Cambridge: Cambridge University Press.
- Hatano, G., & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma & K. Hakuta (Eds.), *Child development and education in Japan* (pp. 262-272). New York: W. H. Freeman and Company.
- Hoadley, C. M. & Linn, M. C. (2000). Teaching science through online peer discussions: SpeakEasy in the Knowledge Integration Environment. *International Journal of Science Education, 22*, 839-857.
- Hong, H. Y., & Sullivan, F. R. (2009). Towards an idea-centered, principle-based design approach to support learning as knowledge creation. *Educational Technology Research and Development, 57*(5), 613-627.
- Lahti, H., & Seitamaa-Hakkarainen, P. (2014). Designing teaching—teaching designing: Teacher's guidance in a virtual design studio. *Journal of Learning Design, 7*(1), 10-26.
- Lin, F., & Chan, C.K.K. (2018). Promoting elementary students' epistemology of science through computer-supported knowledge building discourse and epistemic reflection. *International Journal of Science Education, 40* (6), 668-687.
- Ma, L., Matsuzawa, Y., Chen, B., & Scardamalia, M. (2016). Community knowledge, collective responsibility: The emergence of rotating leadership in three knowledge building communities. In Looi, C. K., Polman, J. L., Cress, U., and Reimann, P. (Eds.). *Transforming learning, empowering learners: The*

- International Conference of the Learning Sciences (ICLS) 2016, Volume 1, pp. 615-622. Singapore: International Society of the Learning Sciences.*
- McKenney, S., Kali, Y., Markauskaite, L., & Voogt, J. (2015). Teacher design knowledge for technology enhanced learning: an ecological framework for investigating assets and needs. *Instructional science, 43*(2), 181-202.
- Mercer, N. & Littleton, K. (2007). *Dialogue and the development of children's thinking: A sociocultural approach*. London: Routledge.
- Nonaka, I., & Takeuchi, H. (1995). *The knowledge creating company: How Japanese companies create the dynamics of innovation*. New York, NY: Oxford University Press.
- Nonaka, I., & von Krogh, G. (2009). Tacit knowledge and knowledge conversion: Controversy and advancement in organizational knowledge creation theory. *Organization Science, 20*(3), 635-652.
- Orloff, M. A. (2013). *Inventive thinking through TRIZ: A practical guide*. New York, NY: Springer.
- Paavola, S., Lipponen, L., & Hakkarainen, K. (2004). Models of innovative knowledge communities and three metaphors of learning. *Review of Educational Research, 74*(4), 557-576.
- Resendes, M., Scardamalia, M., Bereiter, C., Chen, B., & Halewood, C. (2015). Group-level formative feedback and metadiscourse. *International Journal of Computer-Supported Collaborative Learning, 10*(3), 309-336.
- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67-98). Chicago: Open Court.
- Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences (2nd ed.)* (pp. 397-417). New York: Cambridge University Press.
- Sinatra, G.M., & Pintrich, P.R. (Eds.). (2003). *Intentional conceptual change*. Mahwah, NJ: Erlbaum.
- Simonton, D. K. (1999). *Origins of genius: Darwinian perspectives on creativity*. New York: Oxford University Press.
- Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. Cambridge, MA: MIT Press.
- Stahl, G., Koschmann, & Suthers, D. (2014). Computer-supported collaborative learning. In R.K. Sawyer (Ed.) *The Cambridge handbook of the learning sciences* (pp. 479-500). Cambridge: Cambridge University Press.
- Tan, S. C., & Tan, Y. H. (2014). Perspectives of knowledge creation and implications for education. In S. C. Tan, H. J. So, & J. Yeo (Eds.), *Knowledge creation in education* (pp. 11-34). Singapore: Springer.
- Zhang, J. (2009). Toward a creative social web for learners and teachers. *Educational Researcher, 38*, 274-279.
- Zhang, J., Tao, D., Chen, M-H. Sun, Y., Judson, D., & Naqvi, S. (2018). Co-organizing the collective journey of inquiry with Idea Thread Mapper. *Journal of the Learning Sciences, 27*, 390-430.



# Theorizing and Measuring Collective Productive Disciplinary Engagement

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**Abstract:** This symposium aims to explore current research working toward conceptualizing and measuring productive disciplinary engagement (PDE) contextualized in diverse learning and project contexts. Disciplinary engagement is critical for fostering students' deep, integrated understanding of STEM content and disciplinary practices. However, there are significant challenges to reaching this engagement quality, with CSCL environments providing opportunities and supports for engagement, but also posing challenges. This symposium aims to account for recent developments, as presenters showcase rich range in exploring application of PDE in diverse domains, grade bands, and learning contexts. The presentations also showcase a range of methods to analyze PDE as collective, situated, cross-contextual, dynamic, and generative.

This symposium aims to explore current research working toward conceptualizing and measuring productive disciplinary engagement (PDE) contextualized in diverse learning and project contexts. This topic is particularly relevant for computer-supported collaborative learning with its focus on coordinating efforts to build shared knowledge with the use of technology support (Roschelle, 2013). Consistent with the theme of the conference, we consider the complex ecosystems of collaborative learning that are embedded within disciplinary ideas and practices. Disciplinary engagement is critical for fostering students' deep, integrated understanding of STEM content and disciplinary practices. Since the early days of reform-based curricula involving inquiry and problem solving, we have been aware that "sustaining the doing, supporting the learning" is necessary to reap the benefits of these challenging learning environments (Blumenfeld et al., 1991). That is, students need to engage in ways that translate their motivations into generative learning with benefits for a greater likelihood of transfer to subsequent educational and professional contexts. There are significant challenges to reaching this deep-level engagement, such as the necessity to coordinate joint activity during cognitively demanding tasks. CSCL environments provide opportunities and supports for engaging in these kinds of tasks, but can also pose challenges (Jeong & Hmelo-Silver, 2016).

We draw from Engle & Conant's (2002) definition of PDE as making collective intellectual progress related to core ideas and disciplinary practices during authentic tasks. PDE exemplifies developments in the learning sciences, including a situative view of engagement, as (1) negotiated and constructed in particular activity systems and (2) comprised of instructional opportunities that support and constrain engagement (Greeno, 2006).

This view of engagement significantly extends research which has been grounded in an individual difference paradigm and has been conceptualized as general sense making (e.g., Zimmerman, 1990). Thus, these developments advance engagement as embedded within domain-specific and disciplinary contexts, and central to and inseparable from learning (Gresalfi, et al., 2009). Here, the quality of collective persistence in the face of challenge, positive affect and interest in the ideas and doing of activity, and interpersonal interactions while making meaningful connections is central to what students come to understand; highlighting the various interdependencies of learning processes, a central aim of CSCL research.

Now 15 years after the introduction of PDE, this symposium aims to present the frontiers of the research and account for developments, as the presentations examine PDE in a range of CSCL environments. We strive to build on a literature which has been limited to a focus on definition within single and illustrative cases to broaden the analytic and empirical landscape. Toward that end, we bring together four research groups showcasing rich range in exploring application of PDE in diverse domains (science, mathematics, engineering, educational psychology), grade bands (middle school through University) and learning contexts (after school programs, inquiry and problem solving curricula, online CSCL, as well as across resources and contexts). The presentations also showcase a range of methods to analyze PDE as collective, situated, cross-contextual, dynamic, and generative. Each presenter will introduce their (1) guiding framework for theorizing collective PDE, as contextualized in particular tasks, domains, instructional settings and disciplinary practices; (2) observable indicators of disciplinary engagement in the collective; and (3) analytic foci, making explicit the affordances of rich analysis for understanding collective engagement. As called for in the CSCL 2019 theme, these varied efforts to foster and study PDE have been carried out in contexts that are intended to support embodied, enactive, extended, and/or embedded CSCL. First, Gresalfi and her colleagues investigate the role of design features, alongside teachers and peers as relational resources, for *jointly* fostering persistence in the face of challenge for children in a computer science camp. Second, Damşa and Palonen consider the interrelationships of engagement dimensions for within and between group interactions during software engineering courses. Using social network analysis alongside qualitative content analysis, they track the change in density and the nature of collaborative engagement, among dimensions, over time. Next, Rogat and colleagues showcase their theoretical framework instantiated in a rubric using quality ratings to examine five dimensions of PDE during collaborative group exchanges, to contrast two case groups during a common collaborative task across two time segments. Subsequently, Hickey and colleagues extend the PDE design framework to be inclusive of expansive framing, by which learners engage with conceptual and disciplinary material in terms of their own personal and cultural orientations within three different undergraduate and graduate online CSCL contexts. Finally, our discussant addresses how these papers have collectively advanced what we understand about PDE within CSCL contexts.

## **Same place, new rules: The joint accomplishment of engagement**

Melissa Gresalfi, Amanda Bell, Corey Brady, and Lauren Vogelstein

We face a documented shortage of computer scientists. By 2024, 1.1 million jobs are predicted in computing fields (Lockard & Wolf, 2012), but in 2015, fewer than 17,000 people graduated with computer science-related degrees; of those, fewer than 3,000 were women. Just 7% of workers in computing in 2014 identified as Black and 7% as Hispanic (Beckhusen, 2016). Clearly, the challenge we face is not only to encourage more people to engage in computing, but also to ensure that the diversity of our community is reflected in the field. To address this challenge, many suggest introducing students to Computer Science (CS) well before college. However, bringing computational thinking (CT) into K-12 contexts comes with its own potential challenges. Without careful attention to pedagogy and design, we might ultimately teach computational thinking in schools in ways that exacerbate current trends, contributing to the same K-12 participation gaps in interest and identity that we see in other STEM related fields. Thus, it is imperative that we look to the lessons learned about designing for equitable participation in these other fields as we seek to understand how to connect CS to K-12 contexts.

Research on students' mathematics learning has demonstrated how different designs support different forms of knowing. These same studies have established that the patterns we associate with who is good at math and who wants to persist at mathematics is as much a function of the way mathematics is taught than of mathematics itself. This is not to say that the field of mathematics has solved the problem of participation—quite to the contrary (Martin, Gholson, & Leonard, 2010). However, when we look at classrooms that reorganize the teaching of mathematics so that engaging the discipline is more than remembering facts and answering questions quickly, we find that very different patterns in interest and engagement emerge (Boaler & Greeno, 2000; Boaler & Staples, 2008). In contrast, a fast-paced, competitive environment turns off many students from the discipline.

It would be easy for this very same scenario happening with respect to Computational Thinking as so much of CT content might reasonably be organized into a set of facts and rules to be taught and practiced.

However, CT also involves practices of design (Kafai, 2016) that requires the understanding and principled adaptation of underlying facts and rules. Teaching students a set of rules that can then be applied is the version of teaching that is popular (and largely unsuccessful) in math classrooms; teaching students a set of design practices that create a need for CT concepts is a version of teaching that is being explored, with success, in math classrooms.

This study seeks to better understand how to support rich engagement with CT through the design of activities that leverage programming as a means of enacting expressive visual displays and effects. We conceptualize engagement as a collective act between person and context, seen as an interplay between the affordances of a learning environment and whether and how students act on those affordances. In previous work (Gresalfi, 2015; Gresalfi & Barab, 2011) we distinguished between different forms of agency that primarily focus on following rules and procedures, from more productive disciplinary engagement (Engle & Conant, 2002), which we see as involving consequential engagement (considering the implications of disciplinary decisions) and critical engagement (using those consequences to make decisions about how to best solve problems). In prior work, we have focused on the role of tasks in supporting student engagement; here we expand that analysis by considering the role of other students in the broader activity system.

We focus on eight students from two classrooms who are enrolled in a week-long day camp and who work both individually and collectively using NetLogo (Wilensky, 1999) to design images and representations of their own choosing. Specifically, our goal is to explore: 1) How the design of particular activities supports student engagement with the practices of CT, and in particular, what forms of agency are supported through their design; and 2) How others in the room become resources for inspiration, influence, and assistance throughout the camp. We focus on four students who mostly sat together throughout the week to understand both individual trajectories of participation, and how those trajectories connected and supported one another.

Data for this analysis draw on screen captures of students' work, videotapes of whole class discussions, and transcripts of interviews conducted at the beginning and end of the camp. Our analysis began by looking for changes in student activity across the week, and then focused on specific types of episodes. We sought to understand: 1) the nature of students design work (for example, what seemed to launch an idea? What was the focus of their attention, such as aesthetics or functionality?); 2) what happened when students encountered a challenge; and 3) what seemed to sustain their engagement over long periods of time. In examining these episodes, we attended to the interaction among students' ideas, their use of the tools and resources provided in the programming environment, and feedback they received from the environment and from others in the class.

Findings from these case analyses suggest a coherence amongst the eight focal students in their persistence in the face of challenge, their willingness to ask and offer assistance to others, and their commitment to achieving aesthetic and representational goals. These involved a routine back and forth between exploring the affordances and possibilities of the NetLogo environment, setting a representational or expressive goal that connected to personal interest, and then making different modifications to both that ended with a satisfactory final product. Interviews with students made it clear that they found this kind of activity to be novel, enjoyable, and validating; they routinely contrasted the practices of the camp with those at school. Students expressed that such practices transformed their experience of problem solving: "Cause usually, for me... if I make a mistake, people get onto me about it. And when you're kind of coding... ..If you make a mistake, nobody's there to pressure you about it, honestly. I mean, if you make a mistake, you can go back and fix it, and then you can also have somebody help you...and that's nice." They also expressed that the camp repositioned their relationships with teachers and students: "the teachers are really nice to you. I didn't get along with many teachers before and now I do. So, it helped me get along with teachers better too. I'm not a bad kid."

## Forms of collaborative engagement in software engineering education

Crina Damşa and Tuire Palonen

Whereas teaching and learning activities used to be guided by clearly defined, generally accepted knowledge and a structured curricula, today, learning entails a dynamic body of knowledge and constant efforts for accessing and making meaning of resources. In this rather complex landscape, students are expected to participate actively and engage in various ways with knowledge contents and various resources, with peers and/or knowledgeable others. Such engagement involves different layers, such as the epistemic (engagement with the knowledge of the domain), relational (engagement with people – peers, teachers, experts, etc.) and regulative, or procedural (Damşa, 2014; Kumpulainen, 2013). In software engineering, at *epistemic* level, research emphasizes the need for students to understand shifting conceptual knowledge and developing the capacity to apply technical skills fluently, challenges often addressed by exposing students to authentic projects for creating software products. At *social-relational* level, engagement implies taking initiative to connect to resources of both intellectual and digital-

material, but also human nature. The learning and collaboration resources provided by the course/program, such as peer or teachers, is often complemented by expertise held by knowledgeable others or entities outside the course boundaries, such as (in the case of software engineering) programmers platforms, professional programmers and even clients. Finally, at *regulative* level, organizing, self-managing and sustaining own or groups' learning activities places a good deal of responsibility on students. Various studies have shown students' strategies but also challenges to manage collaborative work in general, and advanced co-creation practices especially (Järvelä et al., 2016). Considering the complexity engagement as a phenomenon, more research is needed to understand the nature of these processes, in order to generate pedagogical solutions that support and empower students in their learning.

The current study aimed to generate better understanding of: a) whether the characteristics of the students' epistemic and social network are indicative of engagement and b) what types of engagement characterizes the co-creation process. The expectation was that the social network characteristics are related to the co-creation process and the way students engage and contribute to it. Conceptually, this study builds on sociocultural perspectives to learning to conceptualize engagement as a process that involves learners' sustained and situated thought and action in relation to knowledge contents, social relations and digital-material resources. This process does not take place in a vacuum, but is framed by various aspects of the learning environment (tasks, resources, guidance, etc.), of the social environments (interactions, relations), time-space affordances and constraints, and the capacity of individual/group to assemble these elements (Markauskaite & Goodyear, 2017).

This study employed a design-based approach in a case context. Participants were twenty-three second-year media engineering international students (three female and twenty-one male, average age 23.4 years, SD 2.8) from a university of applied sciences in Finland enrolled in a major in Media Engineering. The *Media Design and Integration* course is a second year undergraduate course aiming to support students to understand the design process of different digital products, emphasizing their full lifecycle; course activities were eight lectures and eight laboratory meetings. A *collaborative task* (in groups of three to four) was designed together with the teacher and required the groups to design a digital prototype of a 're-use library'. The task was complemented by discussions about design methods, and facilitated through face-to-face meetings during lab sessions, online collaboration through wiki and a discussion platform, and access to various sources of information and experts.

Mixed methods, consisting of a combination of qualitative and quantitative methods, were employed for ensuring (data) triangulation. Seven groups were followed intensively. A pre- and post- *networking questionnaire* was applied to gather data on the knowledge and social networking practices of students, inside and outside the class community. *Individual interviews* enriched the perspective on the possible individual networks. Event sampling through *weekly diaries* was used to collect data about students' work and interactions outside laboratory sessions, while *audio-recording of all the group discussions* documented the groups actual verbal behaviours. The drafts and the final version of the shared product, i.e. drawings, sketches, pictures, final prototypes were also gathered. *Social network analysis* and *qualitative content analysis* (see Damşa, 2014) were applied, in which the characteristics of students' network and the indication of engagement and knowledge co-creation were examined in depth. The group products were scored using an evaluation instrument developed in collaboration with the teacher.

The preliminary findings show a rather low average density of the networks (especially of the knowledge network) in the pre-test, which indicate that collaborative engagement of epistemic kind was minimal at class level. The pooled two 'superdimensions': Knowledge network (Collaboration, Advice, Epistemic input) and Social network (Emotional support and Informal network) did not show a denser network in the post-test. It is confirmed by students in interviews that they received most advice and ideas from the teachers, or others, and less from peers in class; but that under way intensive collaborative engagement at epistemic level (i.e., exchange of ideas, elaboration and development) occurred within groups. The results concerning social interaction and are not as radical, although they seem to follow the same trend. By the end of the course, social interaction has moved from between-group-interaction to inside-group-interaction. The qualitative findings support the finding that a more intensive epistemic engagement is indicated in the preliminary phase of the collaborative project, when groups discussed various ideas and alternatives; it diminished towards the end, where division of labour occurred and the interaction was minimal. At relational and regulative level, higher level of engagement was identified in some individual students who managed the process of collaboration and the group sticking to the plan, although not in all groups. One of the reported challenges was the lack of experience with collaborative work and the need to find strategies on the way. This has led to a lower level of engagement from some group members.

This study indicates the variety in the way engagement can materialize, but also the challenges that can occur for students in this regard, even in a rather 'common' collaboration task. Further analyses and research is recommended to identify types of task design and appropriate guidance that can support students to understand the nature, strategies and benefits of engagement.

## Examining group Productive Disciplinary Engagement

Toni Kempler Rogat, Britte Haugan Cheng, Anne Traynor, Temitope F. Adeoye, Andrea Gomoll, Cindy E. Hmelo-Silver, and Patrik Lundh

This project extends Engle and Conant's (2002) conceptualization of students' productive disciplinary engagement (PDE) by characterizing the shared, multifaceted, and dynamic nature of engagement in the context of collaborative groups. Specifically, this project developed a rubric for describing group PDE in STEM contexts, used to analyze video data and ultimately, as part of real-time classroom observation by researchers and practitioners. The purpose of this work is theoretical development (i.e., specifying this extended definition PDE), as well as methodological development, in order to document patterns of PDE in classroom activities, specifically those that integrate disciplinary content and practices in instruction.

This work draws from and extends two bodies of theoretical and empirical work. First, we draw from engagement research stemming from an individual difference paradigm that conceptualizes engagement as multifaceted, reflective of students' classroom experience, and malleable in context (Fredricks, et al., 2004). A multifaceted conceptualization enables a systematic observation of the dimensions of engagement that make-up PDE, with an eventual goal of examining interrelations and patterns of student engagement towards PDE (i.e., trajectories). Second, we extend prior conceptualizations of PDE (Engle & Conant, 2002). We extend these two paradigms by 1) specifying PDE as a dynamic construct, evolving and devolving over time (Skinner & Pitzer, 2012) and 2) integrating situative perspectives of engagement (Hickey, 2003). Here, a situative view understands engagement as negotiated and constructed in activity systems comprised of instructional opportunities that support and constrain engagement, given curriculum materials, teacher scaffolds, tasks, and interactions among learners (Greeno, 2006). Because PDE reflects students' participation within the social contexts of classroom activity, we extend prior work by providing necessary theoretical specification and methodological approaches to enable a broader analytic focus that encompasses collaborative groups over time. Moreover, our focus on social and disciplinary engagement facets extends extant frameworks aligned with our focus on collaborative groups contextualized in STEM content and disciplinary practices. Here, we aimed to illustrate the affordances of this conceptualization and measurement of collaborative group PDE by examining the changing nature of student engagement with implications for PDE for two contrasting collaborative groups contextualized in the same curriculum, lesson, domain, and disciplinary context.

Opportunities for and measurement of group PDE are situated in joint collaborative activity. In our work, PDE is contextualized in collaborative tasks involving modeling, design, and argumentation in middle school math, science, and engineering. We draw on a rich corpus of video data collected in 4 projects where group work in these contexts was central to unit goals and what groups came to understand. The range in domain, disciplinary practices and curricular features (e.g., technology tools, scaffolds) has enriched our theoretical development efforts. Data presented here were collected as part of The Promoting Reasoning and Conceptual Change in Science (PRACCIS) project, which developed inquiry-based units to encourage students' scientific reasoning (Chinn et al., 2008). In PRACCIS, collaborative groups develop, evaluate, and revise explanatory models. The video data from the project include filmed class sessions covering three curricular units in two classes from each of four teachers. We present codes of video recordings of two groups collaborating in a lesson occurring later in the curriculum.

The developed rubric encompasses five engagement facets using 3-point quality indicators, these include: *Behavioral engagement* (on-task joint participation); *social engagement* (responsive, equitable coordination), *emotional engagement* (socio-emotional climate), *metacognitive engagement* (shared content, task and disciplinary regulation), and *disciplinary engagement* (integrated conceptual and disciplinary contributions on a larger consequential task), with high-level ratings assumed to promote PDE. The rubric includes a designation of group structure (i.e., pairs; full group), and task characteristics.

Using the developed rubric two coders coded 8 video clips (approximately five-minute segments of each of 2 student groups). Coders achieved inter-coder reliability of 68%, after discussing discrepant codes on 4 clips and then jointly the remaining 4 clips. Codes of the jointly coded 4 video clips are presented here to illustrate the rubric's affordances for studying the dynamic nature of engagement and potential for comparing groups. Analysis of this small set of illustrative codes is visual, based on the presented graphs.

As can be seen in Figure 1, patterns of engagement remain relatively stable across these two, consecutive video segments. Group A exhibits high levels of social and emotional engagement, but do not progress beyond minimal disciplinary engagement. This pattern is a counter-example to common intuition that more social cohesion among groups and positive, emotional engagement, are key contributors to PDE. Similarly, Group B,

exhibits a higher form of disciplinary engagement in the second segment, despite the stable and more moderate nature of the other 4 dimensions of engagement, including, social and emotional engagement.

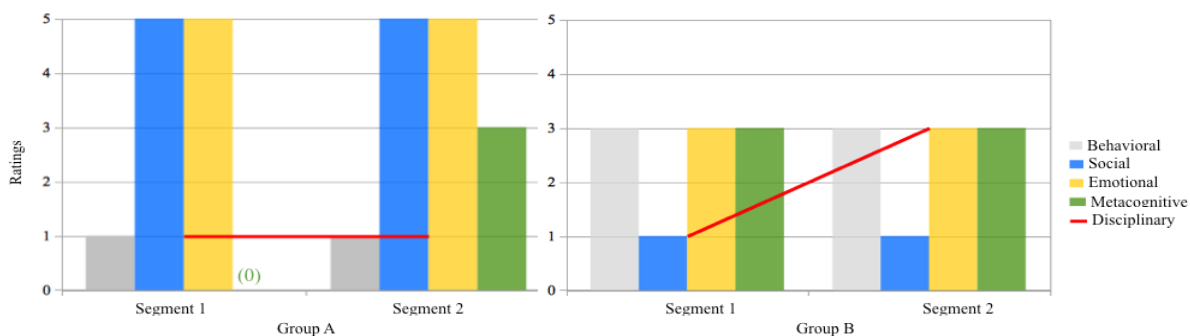


Figure 1. PDE codes of Group A and B across 2 consecutive segments.

This small, but illustrative data set highlights the ability of the new rubric to capture the temporal nature of group engagement in STEM practices and, more importantly, to identify patterns of engagement behaviors and their development. When used to code multiple segments of student collaboration, the rubric developed in this project has the potential to document rich patterns that can be examined, identifying how PDE evolves or is disrupted, as a function of group or task characteristics.

## Expansive framing for equitable PDE in online CSCL contexts

Daniel Hickey, Christopher Andrews, Grant Chartrand, and Rebecca Itow

As illustrated by this symposium and other prior presentations and publications, Engle's notion of *productive disciplinary engagement* (PDE) has been embraced by some in the CSCL community. However, Engle's subsequent pedagogical framework for supporting PDE known as *expansive framing* (e.g., Engle, et al., 2012) has yet to be embraced by the by the CSCL community and has mostly been studied in conventional settings (e.g., Engle, et al., 2011). This presentation will summarize examples, tools, and findings from an extended program of research using expansive framing to support PDE in online CSCL contexts. This work shows that expansive framing is a relatively straightforward framework for supporting PDE and shows promise for equitably engaging diverse learners.

The presentation will first describe a template that has been used to support expansive framing in a range of collaborative online courses and has been extensively refined over the last decade. This template insistently frames disciplinary engagement using learner-generated events, places, people, and topics beyond those presented by course. Building on the work described in Hickey and Rehak (2013), this engagement is initially supported by a simple routine whereby learners publicly rank the relevance of carefully-curated elements of disciplinary knowledge and justify those rankings by drawing on their own professional, personal, and cultural orientations. This engagement occurs on commentable web-based pages (e.g., wikis or Google Docs) that are *public* to the class. These artifacts support collaborative *local* interaction (Hall & Rubin, 1998) via threaded discussions directly on those artifacts. Building on Gresalfi et al., (2009), this individual and social engagement are informally assessed with public reflections on four important aspects of PDE: *contextual*, *collaborative*, *consequential*, and *cultural* engagement. These reflections support PDE by (a) summatively assessing prior engagement, (b) proleptically motivating that engagement, and (c) formatively assessing disciplinary understanding. This disciplinary understanding is then formatively assessed via *private* self-assessments; where appropriate, disciplinary achievement is eventually summatively measured via *discreet* tests.

Examples and evidence from secondary, undergraduate, vocational, and graduate courses will be presented to illustrate three recent extensions of this program of research. The first extension is the addition of cultural engagement to the aforementioned reflections. This new reflection is intended to encourage learners to expansively frame their engagement in terms of their own personal and cultural orientations (Gutierrez & Rogoff, 2003). Analyses of prior courses suggested that organizing engagement primarily around professional orientation fostered inequities by privileging the engagement of more privileged learners from professional backgrounds and may have discouraged culturally-oriented critiques of disciplinary knowledge and practices. Analyses of several recent courses shows that this additional reflection fosters productive engagement in the intersection of disciplinary knowledge, disciplinary practice, and issues of power and privilege (e.g., Esmonde & Booker, 2017).

This engagement, in turn, supports important discussions of equity and justice that many learners might otherwise find uncomfortable.

The second extension of this program of research expansively frames collaborative engagement via web-based annotations of course readings using *Hypothes.is*. Students in an online undergraduate educational psychology course communally annotated 24 assigned readings using prompts that were intentionally worded to support expansive framing. Students' discourse in 460 threaded annotations were coded for enlistment of aspects of expansive framing (i.e., time, place, topic, participants, and accountability) and the degree to which those annotations were expansive. This confirmed that nearly every learner routinely enlisted most aspects (particularly topics and participants; accountability was notably less frequent) and showed that expansiveness of interactions was significantly correlated ( $r = .71$ ) with performance on an open-ended exam that required learners to apply course topics to imagined teaching contexts. Interpretive qualitative analyses yielded evidence that expansively-framed interactions were indeed productive in that students made numerous connections between disciplinary knowledge and their nascent disciplinary practices. These connections are indicative of *generative* learning that will presumably transfer readily to subsequent educational, personal, and professional contexts. This study resulted in promising initial evidence that this straightforward method supported expansive framing in this context, and resulted in a coding scheme that should be useful for studying expansive framing in many contexts.

The third extension of this research is a new self-report survey of students' perceptions of their framing of engagement in both conventional and online courses. Building on Lam and colleagues (2014) and Zheng, et al. (in review), an initial set of items for each of the aspects of expansive framing were drafted and then refined in cognitive interviews with two subjects. The resulting set of items will be completed by at least 5,000 students in both conventional and fully online colleges as experimental items in the Spring 2019 administration of the National Survey of Student Engagement (NSSE; Kuh, 2003). This presentation will focus on exploratory and confirmatory factor analyses of the hypothesized aspects of expansive framing, demographic and institutional factors in framing, and correlations between aspects of expansive framing and other dimensions of student engagement captured by NSSE.

## References

- Beckhusen, J. (2016). *Occupations in information technology*: US Department of Commerce, Economics and Statistics Administration, US Census Bureau.
- Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, *26*, 369-398.
- Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing in mathematical worlds. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 45-82). Stamford, CT: Ablex.
- Boaler, J., & Staples, M. (2008). Creating mathematical futures through an equitable teaching approach: The case of Railside school. *Teachers College Record*, *110*, 608-645.
- Chinn, C. A., Duschl, R. A., & Duncan, R. G., Buckland, L. A., & Pluta, W.P. (2008). A microgenetic classroom study of learning to reason scientifically through modeling and argumentation. In *ICLS 2008, Proceedings of International Society of the Learning Sciences*. Raleigh, NC: Lulu.
- Damşa, C. I. (2014). The multi-layered nature of small-group learning: Productive interactions in object-oriented collaboration. *International Journal of Computer-Supported Collaborative Learning*, *9*, 247-281.
- Engle, R. A., & Conant, F. C. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emerging argument in a community of learners classroom. *Cognition and Instruction*, *20*, 399-483.
- Engle, R. A., Lam, D. P., Meyer, X. S., & Nix, S. E. (2012). How does expansive framing promote transfer? Several proposed explanations and a research agenda for investigating them. *Educational Psychologist*, *47*, 215-231.
- Engle, R. A., Nguyen, P. D., & Mendelson, A. (2011). The influence of framing on transfer: Initial evidence from a tutoring experiment. *Instructional Science*, *39*, 603-628.
- Esmonde, I., & Booker, A. N. (Eds.) (2017). *Power and privilege in the learning sciences: Critical and sociocultural theories of learning*. New York, NY: Routledge.
- Greeno, J. G. (2006). Learning in activity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 79-96). Cambridge: Cambridge University Press.
- Gresalfi, M. S. (2015). Designing to Support Critical Engagement with Statistics. *ZDM - The International Journal on Mathematics Education*, *47*, 933-946.
- Gresalfi, M. S., & Barab, S. A. (2011). Learning for a reason: Supporting forms of engagement by designing tasks and orchestrating environments. *Theory into practice*, *50*, 300-310.



- Gresalfi, M., Barab, S., Siyahhan, S., & Christensen, T. (2009). Virtual worlds, conceptual understanding, and me: Designing for consequential engagement. *On the Horizon*, 17, 21-34.
- Gresalfi, M., Martin, T., Hand, V. & Greeno, J. (2009). Constructing competence: an analysis of student participation in the activity systems of mathematics classrooms. *Educational Studies in Mathematics*, 70, 49-70.
- Gutiérrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher*, 32(5), 19–25.
- Hall, R., & Rubin, A. (1998). There's five little notches in here: Dilemmas in teaching and learning the conventional structure of rate. In J. G. Greeno & S. V. Goldman (Eds.), *Thinking practices in mathematics and science learning* (pp. 189–235). New York, NY: Routledge.
- Hickey, D. T. (2003). Engaged participation versus marginal nonparticipation: A stridently sociocultural approach to achievement motivation. *Elementary School Journal*, 103, 401-429.
- Hickey, D. T., & Rehak, A. (2013). Wikifolios and participatory assessment for engagement, understanding, and achievement in online courses. *Journal of Educational Multimedia and Hypermedia*, 22, 407-441.
- Järvelä, S., Järvenoja, H., Malmberg, J., & Isohätälä, J. (2016). How do types of interaction and phases of self-regulated learning set a stage for collaborative engagement? *Learning and Instruction*, 43, 39-51
- Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of CSCL Technology: How can technology support collaborative learning. *Educational Psychologist*, 51, 247-265.
- Kafai, Y. B. (2016). From computational thinking to computational participation in K-12 education. *Communications of the ACM*, 59(8), 26-27.
- Kuh, G. D. (2003). What we're learning about student engagement from NSSE: Benchmarks for effective educational practices. *Change: The Magazine of Higher Learning*, 35(2), 24-32.
- Kumpulainen, K. (2014). The legacy of productive disciplinary engagement. *International Journal of Educational Research*, 64, 215–220.
- Lam, D. P., Mendelson, A., Meyer, X. S., & Goldwasser, L. (2014). Learning alignment with expansive framing as a driver of transfer. In J. L. Polman, E. A. Kyza, D. K. O'Neill, I. Tabak, W. R. Penuel, A. S. Jurow, K. O'Connor, T. Lee, & L. D'Amico (Eds.), *Proceedings of the International Conference of the Learning Sciences* (pp. 689-696). Boulder, CO: International Society of the Learning Sciences.
- Lockard, C. B., & Wolf, M. (2012). Occupational employment projections to 2020. *Monthly Lab. Rev.*, 135, 84.
- Markauskaite, L., Goodyear, P. (2017). *Epistemic fluency and professional education: Innovation, knowledgeable action and actionable knowledge*. Dordrecht: Springer.
- Martin, D. B., Gholson, M. L., & Leonard, J. (2010). Mathematics as gatekeeper: Power and privilege in the production of knowledge. *Journal of Urban Mathematics Education*, 3(2), 12-24.
- Roschelle, J. (2013). Special issue on CSCL: Discussion. *Educational Psychologist*, 48, 67-70.
- Skinner, E. & Pitzer, J. (2012). Developmental dynamics of student engagement, coping and everyday resilience. In S.L. Christenson, A.L. Reschly & C. Wylie (Eds). *The Handbook of Research on Student Engagement* (pp. 21-44).
- Wilensky, U., & Resnick, M. (1999). Thinking in levels: A dynamic systems approach to making sense of the world. *Journal of Science Education and Technology*, 8, 3-19.
- Zheng, K., Engle, R. A., & Meyer, X. S. (2012). Student responsiveness to the teachers expansive framing. Presented at the annual meeting of the *National Association for Research in Science Teaching*, 2012, Indianapolis.
- Zimmerman, B. J. (1990). Self-regulating and academic achievement: An overview. *Educational Psychologist*, 25, 3–17.



## Understanding CSCL through the lens of research syntheses

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**Abstract:** Computer-supported collaborative learning (CSCL) forms a diverse field with researchers from different backgrounds using a variety of learning theories and research methods to design and analyze CSCL learning environments. The dynamic and active features of the field can lead to confusion about its identity and conclusions that can be drawn from the outcomes of CSCL research. Syntheses of CSCL research can help to answer questions about the prevalent topics and outcomes in the field. There are a number of synthesis methods to choose depending on the methods used in the primary studies as well as goals of the synthesis. Meta-synthesis is also available to better integrate findings obtained using different research methods. This symposium showcases a spectrum of different synthesis methods used in CSCL. Benefits and disadvantages of the synthesis methods will be discussed along with the question of how different synthesis methods can be used to inform each other.

The field of computer-supported collaborative learning (CSCL) brings together researchers from diverse disciplines (Computer Science, Psychology, Education, Linguistics, etc.) with diverse learning theories. A broad spectrum of different research methods is used in the field of CSCL depending on considerations such as the specific research goals, the maturity of the theories, the complexity of the problems and the researcher's epistemological orientation. Thus, CSCL is a dynamic and active research community and a wealth of CSCL research has been conducted to reveal the mechanisms of successful CSCL (King, 2007; Scardamalia & Bereiter, 1994). In order to achieve a more comprehensive and precise conclusion about CSCL mechanism, structured research synthesis are needed that integrate the rich amount of primary studies about specific topics in CSCL. However it also became of a source of confusion and disagreement about integrative conclusions that can be drawn from CSCL research (see also Wise & Schwarz, 2017).. Goals and motivations of the synthesis may dictate the use of quantitative or qualitative synthesis methods, which, in turn, limit the type and scope of conclusions that can be drawn from them. These goals might be the generation of innovation, the building of theories, finding evidence for specific hypotheses, or informing policy and practice in education. However, even when the most adequate synthesis method might have been selected to integrate primary research done in a specific area of CSCL, challenges still remain. For instance, deciding for meta-analysis means the exclusion of a part of primary studies. Qualitative syntheses, in spite its depth and insights, lack the precision of meta-analyses. This means that even the most adequate synthesis method may lead to biased conclusions about CSCL research.

This symposium showcases a spectrum of syntheses used in the field of CSCL which all have the common goal to integrate CSCL research and to contribute to the understanding of the CSCL community and its research outcomes. Firstly, three papers will be presented that depict a bibliometric analysis, a qualitative systematic review and a quantitative meta-analysis all conducted in the field of CSCL. Secondly, the fourth paper will introduce meta-synthesis as a method to integrate quantitative and qualitative research outcomes and a way to overcome the disadvantages of using only one particular synthesis method.

More specifically, the first paper by Håklev et al. used bibliometric analysis to get a better understanding of the CSCL researcher community. In this paper, ICLS and CSCL proceedings are analyzed to uncover and portray patterns in co-authorship, authors' field of research, geographical location and commitment to the community. While qualitative analyses are quite common in CSCL research, few qualitative syntheses exist. In the second paper, Wan and Wan instead present a qualitative systematic review to uncover how phenomenography, a specific qualitative research method, is used in the field of CSCL. This paper presents how

a novel qualitative research method is adopted by the field of CSCL, the depth of explanation of qualitative syntheses, and makes suggestions how phenomenography could be utilized to synthesize CSCL research. The third paper by Radkowsch et al. represents the use of quantitative meta-analysis in the field of CSCL. Their choice of synthesis method was justified by the substantial amount of quantitative experimental studies already available. More specifically they synthesized experimental studies about the effects of CSCL scripts as a scaffold to enhance collaborative learning. Their findings provide a strong empirical argument for the effectiveness of CSCL scripts against the critic – raised in the controversial debate within the CSCL field – that CSCL scripts may be too constraining and thus ineffective. In the fourth paper, Hmelo-Silver and Jeong showcase a way to synthesize qualitative and quantitative primary studies in evaluating the outcomes of STEM CSCL. The study provides one model of meta-synthesis that takes into account both quantitative and qualitative outcomes. It aims to integrate CSCL research outcomes both from quantitative and qualitative studies and thus overcome some of the existing synthesis methods that solely uses either quantitative or qualitative outcomes. Continued efforts are needed to synthesize CSCL research outcomes across different theoretical and methodological boundaries.. Taken together, the current symposium will showcase available synthesis techniques and provide a forum to reflect on their advantages and limitations. It can help us better understand which synthesis method might be adequate for the different research goals and motivations and how the various syntheses can inform each other and the field in general.

## **A bibliographic analysis of our community through the lens of ICLS and CSCL proceedings**

Stian Håkleiv, Léonore Valentine Guillain, and Nour Ghalia Abassi

The CSCL community has over time developed a shared set of theories and concepts which are constantly being referenced and built-upon. However, as a community that both draws from multiple disciplines (such as computer science, psychology, and education), and that interacts with rapidly changing technological affordances, it needs to constantly reposition and reframe itself relative to other communities and disciplines. CSCL community members act as bridges, bringing new ideas, concepts and methods into the CSCL community, by co-authoring with authors that would not consider members of the CSCL community, or citing research from other communities. One way to better understand the development of our community is through a bibliometric analysis of conference proceedings.

Using bibliometric and social network analysis approaches to analyze the growth and structure of academic disciplines and communities have a long history. Descriptive statistics of authors lets us understand who contributes to a given conference, which universities and groups they represent, which geographical locations are represented, and how this changes over time. Co-authorships and citations can be seen as indicators of how well members of a field are connected (Kienle & Wessner, 2006), and let us detect links and bridges with other communities (Kärki, 1996). Applying text analytics methods to the article contents can be used to detect semantic clusters within the community, but also to track the appearance of new topics of interest over time (Ding, Chowdhury, & Foo, 2001).

Bibliometric signals alone do not tell the whole story. They can be enhanced by other data, such as an early analysis by Kienle and Wessner (2006) which included both conference proceedings, lists of participants and Program Chairs, as well as e-mail surveys and an analysis of policy documents to understand how the community was developing. They describe a burgeoning international community at an early stage of growth, with few core members, and conference participation highly dependent on participation in large grants or shifting institutional policies. Later studies have tended to look at CSCL literature spread over a larger set of journals and conferences. For example, Jeong, Hmelo-Silver, and Yu (2014) manually coded empirical CSCL studies according to research designs, settings, data, and analyses, and identified four distinct theory-method clusters. Tang, Tsai, and Lin (2014) used co-citation analysis of CSCL literature to automatically extract intellectual sub-fields, and pivotal papers that served as bridges between sub-fields. Others have used completely different data sources, such as Sommerhoff, et al. (2015), which analyzed the curricula from 75 learning science programs.

We propose to narrow our focus to the two bi-annual conferences as the flagship events of our society – the research that is published there reflects both what researchers in the community choose to work on, and what kind of research is selected by the peer-review process. We propose the following Research Questions: a) How can we describe the CSCL conference authors in terms of fields, geographical location and commitment to the community, b) How is CSCL as a knowledge field structured in terms of collaboration with local and international partners from within and outside the community, c) What is the relationship between CSCL and ICLS, the two conferences that are hosted by the same society?

We have analyzed 446 papers (including full, short, posters, and symposia) from CSCL 2015, ICLS 2016, CSCL 2017, and ICLS 2018. From each paper, we extract authors, use e-mails to determine institutional affiliation, and parse citations. The five countries with the most author contributions (counting each co-authored paper separately) are United States, Germany, Canada, Israel and Singapore. The number of US authors had a large spike in 2018 (2015: 8%, 2016: 20%, 2017: 16%, 2018: 57%). That year, ICLS was co-located with Learning at Scale, and Artificial Intelligence in Education, and this probably led to a number of people who would not otherwise have attended the conference submitting papers. Perhaps these other two conferences are traditionally more US-centric, and this led to the large growth in US contributions. This large growth mainly came from universities that had not presented during the previous three years' conferences. Analyzing the data from CSCL in 2019 and ICLS in 2020 will help us understand whether 2018 was an aberration, or the beginning of a trend.

To investigate the extent to which researchers think of themselves as members of the ISLS, and attend both conferences (CSCL and ICLS), or primarily identify with one of the two communities, we look at research groups that have been present at all four conferences (36), or all CSCL/no ICLS (12), or all ICLS/no CSCL (58). This indicates that there is a large number of research groups that identify with ICLS and not CSCL. In future work, we will extend the number of years analyzed, and also look at differences in citation patterns and semantic content between authors that are identified as mainly-ICLS, mainly-CSCL, or both.

We were able to extract 13,047 unique authors from the citations in the papers analyzed. Of these, 1009 authors have published at one of the four conference proceedings. To understand which external disciplinary communities that ISLS researchers connect with, we wanted to identify the most commonly cited authors from outside of the CSCL/ICLS communities. To do this, we excluded all authors that had published at one of the four conferences, or that had any cited work in CSCL, ICLS, International Journal of CSCL, or Journal of the Learning Sciences. We further split this into works written before 2010, and after 2010, to get one list of historical influences, and another with currently active researchers who are highly cited by CSCL/ICLS researchers, but do not attend our conferences. The five most highly cited researchers before 2010 was E. Wenger, L. S. Vygotsky, S. Papert, C. Goodwin and B. Rogoff. The most highly cited authors of publications published after 2010 were C. Goodwin, J. P. Gee, J. S. Krajcik, B. J. Fishman, and M. Windschitl.

By continuing to add data from past proceedings, and extending our analysis, we will be able to say more about the difference research published at CSCL and ICLS, the structure of research group collaborations, the emergency and popularity of certain topics over time, and the links between the CSCL/ICLS literature and other fields/conferences, and how that might be changing over time. We might also connect the bibliometric analysis to other sources, such as the data on Learning Science programs by Sommerhoff et al (2015) – how do course curricula affect future graduates' research topics? Because of the public nature of publications, we will make our full dataset of parsed metadata available, as well as all the code used to generate our findings. We hope that this will encourage other groups to extend or question our analysis.

## **Systematic review about the use of phenomenography in educational technology studies**

Sally Wai-Yan Wan and Sancia Wai-San Wan

There has been a rise in the demands of looking for 'appropriate' research methodology to investigate how educational technology is used so as to search for 'better' ways for sustainable development in the field. Some scholars described the potentials of phenomenography as 'opening a new territory' (Bruce, 1999) that explores the understandings of a phenomenon in the use of computer-supported collaborative learning (CSCL) for informing educational practice from a second-order perspective, rather than a first-order perspective that cannot reveal the phenomena as it is understood (Rovio-Johansson & Ingerman, 2016, p. 261). Phenomenographic research helps 'to bridge the gap between research and practice' that puts an emphasis on collective meaning and identification of conceptions in an empirical manner (Johnston & Salaz, 2017).

Phenomenography is 'a research method for mapping the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of, and various phenomena in, the world around them' (Marton, 1986, p.31). The essential facets of phenomenography include categories of description (different ways of understanding), structural aspect (combinations of features discerned and focused upon by the subject), referential aspects (a particular meaning of an object), outcome space (logical relations of categories of description). Phenomenography is not only a research approach but also serves for the purpose of informing curriculum and pedagogical design in CSCL practices (Åkerlind, 2012), which potentially offers theoretical and methodological advantages for explaining difference and change in individuals' conceptions, keeping aware of such contradictions in understanding of learning experiences, and allowing for opportunities for self-reflection.

To find out how this relatively novel method is applied in CSCL research, in this study we chose systematic review for assessing how previous phenomenographic studies in CSCL were conducted. Two research questions guided the study: (1) How is phenomenography applied in studying CSCL? and (2) What are the key limitations and possible future development in the use of phenomenography in CSCL studies?

## **Data collection and analysis**

We initially identified the relevant papers from the Social Science Citation Index (SSCI) journals with keyword search (e.g. phenomenographic study) in the journal websites. We did a quantitative content analysis according to the origin of study, year of publication, targeted groups, essential facets of phenomenography, data collection method, research trustworthiness, targeted groups in the study, research questions, objectives of the study, and limitations of study. We then conducted a qualitative thematic analysis in identifying patterns.

## **Findings**

A total of 32 papers were reviewed and most were conducted in Australia, Taiwan and UK respectively. Most of them were found in higher education. 'What' and 'how' questions were commonly found in the research questions, where more focus was on studying students' conceptions, experiences and learning approaches whilst fewer studies were done to explore that of teachers. The basic facets of phenomenography such as referential and structural aspects of conceptions and experiences of the use of CSCL pedagogies were addressed. However, 'outcome space' was not presented in nearly half of the reviewed studies. The paper by Limbu and Markauskaite (2015) demonstrated a good example about the key facets of phenomenography, in which their study revealed the outcome space of the students' conceptions of online collaborative writing (OCW) with four categories of descriptions (referential aspect), namely (A) Division of work to complete the task; (B) Combination of expertise to produce a good end product; (C) Fusion of ideas and insights to enable deeper understanding; and (D) Development of new skills and attitudes for collaborative work, whilst dimensions of variations (structural aspect) involved five aspects: the outcome of OCW, learning from each other, the nature of the OCW process, the intensity of interaction and the values and commitment of participants. This review explored how the phenomenography as a research method in primary studies can inform the field of CSCL, where the reviewed papers revealed the usefulness of phenomenography in understanding of learning and teaching, informing pedagogical design and helping evaluating the learning outcomes, as well as providing information for teacher professional development. On the other hand, this review further led us to reflect how qualitative syntheses can help explore the phenomenographic method in studying CSCL. Limitations were commonly identified and addressed in these studies: (1) Small sample size may restrict understandings of the phenomena; (2) Diversity in study participants' backgrounds and experiences that could not be captured in the different contexts within the study and could not be classified into single categories of descriptions; and (3) Ineffective application of research methods and techniques affecting the findings of the study.

## **Our reflection**

The systematic review study guides us in future research by filling in research gap by comparing students and teachers' conceptions and experiences in CSCL and exploring their conceptions and experiences of CSCL in primary and secondary education. Attention should be paid to the data analytical procedures including trustworthiness and the creation of outcome space. More significantly, there can be possibilities of applying phenomenography as a tool to synthesize qualitative research in CSCL with reference to structural and referential aspects of the past CSCL studies so as to generate a new understanding of what learning conceptions and experiences in the previous CSCL studies and inform future CSCL development. There are still limitations in this systematic review. Due to that only SSCI papers were selected for this review, other papers using phenomenography were not covered. The study relied on those papers addressing limitations and contributions of the study for analysis and this thus restricted the deliberations of insights as gained from the papers. This study depends on the analysis of qualitative aspect of the papers and this may cause the 'bias' in the synthesis of the results of this study.

## **Good for learning, bad for motivation? A meta-analytic counter-argument on a widespread position regarding CSCL scripts**

Anika Radkowsch, Freydis Vogel, and Frank Fischer

In collaborative learning, learners often have difficulties to use expedient activities which are expected to induce cognitive elaboration, such as explaining or negotiating cognitive conflicts. CSCL scripts were designed as

scaffold to guide learners through collaborative practices that are beneficial for learning collaboration skills as well as domain learning by inducing learners to engage in specific collaborative practices repeatedly (Fischer, Kollar, Stegmann, & Wecker, 2013). To explain why studies about CSCL scripts show heterogeneous results, the risk of overscripting learners by too coercive guidance undermining learners' self-determination and motivation is most prominently quoted. In a recently published qualitative approach collecting widespread views of experts in the field, Wise and Schwarz (2017) conclude with this overscripting explanation. They emphasize that rare positive effects of CSCL scripts are restricted to learn collaboration skills only at the expense of learners' agency and motivation. Other positive effects of CSCL scripts are mostly neglected while negative effects are emphasized. Interestingly, the very idea of overscripting came from a contribution by Dillenbourg (2002) to Paul Kirschner's inauguration event at the Open University of the Netherlands. The idea, however plausible it may have appeared then was not backed up by empirical findings. We argue that a scientific community should develop strategies of evidence generation and accumulation that go beyond re-stating an opinion for 15 years. It seems to be a questionable practice to base the knowledge of a scientific community on the aggregation of repeated opinions. Since many experimental studies have been conducted on the effect of CSCL scripts on learning quantitatively synthesizing the effects by conducting a meta-analysis seems to offer better evidence. In contrast to narrative reviews and intuitive summaries of widespread opinions, meta-analyses allow to weigh the individual effects based on their precision giving more weight to the more precise studies. A recent quantitative meta-analysis about CSCL scripts partially contradict the qualitatively drawn conclusion showing overall positive effects of CSCL scripts on learning (Vogel, Wecker, Kollar, & Fischer, 2017). However, the widely proposed negative influence of CSCL scripts on motivation was not analyzed and a great amount of new studies about CSCL scripts have been conducted since then. Thus, the research question of this study is: What is the overall effect of collaborative learning with CSCL scripts compared to collaborative learning without CSCL scripts on domain learning, collaboration skills, and motivation?

## Method

A comprehensive literature search was conducted on ERIC and ISI Web of Science using the search terms "(scaffold\* OR script\*) AND (learn\* OR know\*) AND (collaborat\* OR cooperat\*) AND (computer\* OR CSCL OR techno\*)" resulting in  $N = 624$  articles. The criteria-oriented coding for inclusion (e.g., experimental variation of the factor CSCL script) led to a final sample of 41 articles reporting 43 studies involving 4,414 participants. The data for the calculation of effect sizes was extracted. Using the effect size Hedge's  $g$ , the standardized mean difference between groups was calculated. All analyses were based on the random-effects model.

## Results and conclusions

The overall effects show that in general collaborative learners who are scaffolded by CSCL scripts outperform learners who are not scaffolded by CSCL scripts with respect to their domain learning ( $g = 0.29, p < .01, k = 45$ ) and their collaboration skills ( $g = 0.73, p < .01, k = 18$ ). No significant effect on motivation was found ( $g = 0.07, p = .57, k = 6$ ). All tests for publication bias were not significant. In line with prior findings, the results show that the positive effects of CSCL scripts on domain learning and collaboration skills stay robustly constant when including the outcomes of more recent studies about learning with CSCL scripts. Our results do not support the criticism that CSCL scripts negatively influence the learners' motivation and hence lead to either no learning or learning only on the expense of learners' motivation. This indicates that learners might not feel less autonomous when interacting with CSCL scripts. However, the reduction in autonomy might be compensated through a gain in the feeling of competence. The small number of primary studies analyzing learners' motivation is a major concern and, given the persistent criticism of overscripting, future research about CSCL scripts should by default include the measurement of different dimensions of motivation.

With respect to the question of the symposium our findings support the position that meta-analyses can substantially contribute to the accumulation of scientific knowledge. Using meta-analysis as a method was not only useful to synthesize existing findings, to assess the robustness of effects and to test hypotheses. It also helped to substantiate a counter-argument against the summarizing position about the malfunction of CSCL scripts recently published by Wise and Schwarz (2017). According to our meta-analytic integration of primary studies, there is a positive effect of CSCL scripts on domain learning which is basically ignored by Wise and Schwarz. Moreover, the meta-analytic integration found no evidence at all for a negative scripting effect on motivation where Wise and Schwarz concluded that overscripting in this very sense (i.e., scripts reduce motivation) is one of the main issues for CSCL scripts. The learning sciences are a field of empirical research (Hoadley, 2018; Sommerhoff et al., 2018). We are hence convinced that meta-analyses of quantitative or qualitative studies are useful and needed to disqualify or support widespread opinions.

## Connecting the diversity of CSCL research through meta-synthesis

Cindy E. Hmelo-Silver and Heisawn Jeong

There has been little systematic review of CSCL in STEM that has integrated across qualitative and quantitative research. Our motivation for this research was in particular to better understand the compound resources that comprise CSCL (Roschelle, Bakia, Toyama, & Patton, 2011): collaboration, technology, and pedagogies used (Hmelo-Silver & Jeong, 2016; Kirschner & Erkens, 2013). We wanted to address the questions of 1) How do different combinations of CSCL technologies, pedagogies, and collaboration modes co-vary in CSCL and 2) For these different combinations, is CSCL effective, broadly construed and what factors support or impede the effectiveness of CSCL. This task requires synthesizing diverse CSCL research outcomes while paying attention to factors that support and impede different approaches to CSCL.

Our review uses meta-synthesis as a way to address these questions. Meta-synthesis is a methodology that uses both qualitative and quantitative studies as sources of data and allows for the integration of research across qualitative and quantitative studies (Suri & Clark, 2009; Bair, 1999). Our initial rationale was that any review of CSCL would need to take into account the diversity of methodological approaches in the CSCL community (Jeong, Hmelo-Silver, & Yu, 2014) and thus was well suited for this approach. Another key rationale for choosing this method was that the CSCL community considers a broad range of outcomes from traditional individual pre-post test measures to artifacts to engaged participation (McKeown, Hmelo-Silver, Jeong, Hartley, Faulkner, & Emmanuel, 2017). Meta-synthesis is an interpretive approach concerned with understanding and describing key points and themes across multiple kinds of studies and thus well suited for achieving our goal.

To guide our systematic review of CSCL literature in STEM domains, we defined CSCL as two or more people using technology to work together toward a shared learning goal, and used this definition while searching and screening papers. We searched through two databases, ERIC and Web of Science, in addition to seven key journals regarded by experts to be major outlets for publishing CSCL research (Jeong et al., 2014). Over 1,500 qualitative and quantitative papers focusing on various education levels published between 2005-2014 were screened to ensure each paper met the following criteria: (a) STEM education, (b) empirical research. Out of these papers, 708 papers met our criteria and were then coded for a range of study characteristics; educational level, collaboration type, pedagogy, and technology (e.g., Jeong et al., 2014). Earlier synthesis in which we had coded the study characteristics of the dataset in Jeong, Hmelo-Silver and Yu (2014) confirmed that CSCL used a diversity of qualitative and quantitative methods, and thus was ideally suited for this approach.

We used Latent Class Analysis (LCA) to examine how these three characteristics of CSCL designs covaried to help address research question 1 and to form a framework for sampling from the large number of papers to address question 2 (Hagenaars & McCutcheon, 2002). The LCA identified six thematic clusters ranging in size from 38- 246 papers of which the four largest were interpretable. Cluster one (n=246), Face-to-Face Collaborative Inquiry with Dynamic Feedback (F2FCI), emphasizes papers using face-to-face collaboration, inquiry and exploration pedagogies, and dynamic or other tools. Cluster two (n=74), Synchronous Collaboration (SC), emphasizes papers using synchronous collaboration and communication technologies. Cluster five (n=154), Asynchronous Teacher-Structured Discussion (ATD), emphasizes papers using asynchronous collaboration, discussion or teacher-structured pedagogies, and asynchronous communication technologies. Finally, cluster six (n=145), Online Generative Inquiry (OGI), emphasizes papers using asynchronous or face-to-face collaboration, inquiry and exploration or teacher-structured pedagogies, and sharing and co-construction technology. Larger proportions for a particular code tend to dominate the cluster membership and, therefore, can be used to label and describe the cluster. There was still variability within clusters, which was used to identify an appropriate number of papers to for stratified random sampling, with adjustments to match the demographic characteristics and study designs of the overall cluster. Nonetheless, this synthesis has demonstrated that there are particular combinations of CSCL that vary based on technologies, pedagogies, and modes of collaboration.

For the meta-synthesis that focused on research question 2, we first synthesized findings in each cluster based on the outcomes and overarching theme(s) indicating under what circumstances CSCL may or may not be effective based on the papers sampled for each cluster. To make this process tractable we first annotated the articles sampled for each cluster and then proceeded to create outlines that emphasized what was effective, what was not effective, and any implications. Once we synthesized each cluster, we then looked for themes and patterns across the clusters and compared outcomes across technology, collaboration, and pedagogy. In particular, we looked for indicators of effectiveness broadly construed and patterns that suggested particular factors that supported or impeded effective CSCL.

Addressing the second research questions, our results show generally positive effects of CSCL on content, skills, and affective indicators. These indicators refer to either gains from pre to post intervention or qualitative demonstrations of improvement on these indicators. The strongest evidence comes from the clusters

that use CSCL with inquiry and exploration. These clusters tend to present results that include processes and outcomes more uniformly and provide more detail on their intervention. Although such outcomes are important, designers and researchers need to focus more on the functions that CSCL technologies provide in learning environments and how those are appropriated towards instructional goals. Across clusters, results demonstrate that scaffolding and feedback in different combinations were important for positive learning outcomes (McKeown et al., 2017). However, feedback that was poorly timed or excessive sometimes impeded learning. In addition, certain technologies lend themselves better to particular communication channels and/or pedagogical goals. Finally, we found that different learning environments are used for different learners. For example, simulations were often used in face-to-face inquiry learning environments with younger learners whereas asynchronous threaded discussions were commonly used with more mature learners.

Overall, our study helped us understand the workings of CSCL as a compound resource and how different components may interact with each other. Our approach to research synthesis met the goals of synthesizing research across qualitative and quantitative research methods, examining how technologies, pedagogies, and modes of collaboration cluster together. Using cluster analysis helped us to sample systematically from a literature that was too vast for an exhaustive narrative review. The qualitative and quantitative papers outcomes helped inform each other. Experimental, quasi-experimental, and pre-post test designs provide useful details about what was learned but may not represent the full range of what it means to learn, engage, collaborate productively or be motivated. Qualitative studies can help provide these alternate lenses that look directly at participation and collaborative activity. These different research designs and analytic methods can provide opportunities to triangulate findings as they did in Cluster 1 and highlight factors that might explain the findings (e.g., the kinds of feedback that are useful). This diversity in research also leads to some of the limitations of meta-synthesis. In trying to be open to a range of outcomes, we found that different clusters often used different types of research designs and indicators of effectiveness, making it hard to draw broader conclusions across clusters. Design-based and other mixed methods research are helpful in bridging this gap as is more research that considers the different stakeholders in CSCL. For example, there is little research on the role of teachers in CSCL though their role is clearly important. In addition, future research needs to consider the multiple outcomes that are valued in CSCL (e.g., knowledge, affective, collaboration skills). Although it is challenging to synthesize across such diverse set of studies, but continued efforts toward meta-synthesis are needed to understand CSCL in its full complexity.

## References

- Åkerlind, G. S. (2012). Variation and commonality in phenomenographic research methods. *Higher Education Research & Development*, 31(1), 115-127.
- Bair, C. R. (1999, November). *Meta-synthesis*. Paper presented at Annual meeting of the Association for the Study of Higher Education, San Antonio, TX.
- Bruce, C. S. (1999). Phenomenography: Opening a new territory for library and information science research. *The New Review of Information and Library Research*, 5(1), 31-48.
- Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. P. Kirschner (Ed.), *Three worlds of CSCL: Can we support CSCL?* (pp. 61-91). Heerlen: Open University of the Netherlands
- Ding, Y., Chowdhury, G. G., & Foo, S. (2001). Bibliometric cartography of information retrieval research by using co-word analysis. *Information processing & management*, 37(6), 817-842.
- Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist*, 48 (1), 56–66.
- Hagenaars, J. A., & McCutcheon, A. L. (2002). *Applied latent class analysis*. New York: Cambridge University Press.
- Hoadley, C. (2018). A short history of the learning sciences. In *International Handbook of the Learning Sciences* (pp. 11-23). Taylor and Francis. <https://doi.org/10.4324/9781315617572>
- Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of CSCL Technology: How can technology support collaborative learning. *Educational Psychologist*, 51, 247-265.
- Jeong, H., Hmelo-Silver, C. E., & Yu (2014). An examination of CSCL methodological practices and the influence of theoretical frameworks 2005–2009. *International Journal of Computer-Supported Collaborative Learning*, 9(3), 305-334.
- Jeong, H., Hmelo-Silver, C. E., & Yu, Y. (2014). An examination of CSCL methodological practices and the influence of theoretical frameworks 2005–2009. *International Journal of Computer-Supported Collaborative Learning*, 9(3), 305–334.

- Johnston, N., & Salaz, A. M. (2017). Using phenomenography to bridge the gap between research and practice: a meta-analysis of three phenomenographic studies. *Information Research*, 22(4). Retrieved on November 15, 2018 from: <http://InformationR.net/ir/22-4/rails/rails1614.html>.
- Kärki, R. (1996). Searching for bridges between disciplines: an author co-citation analysis on the research into scholarly communication. *Journal of Information Science*, 22(5), 323-334.
- Kienle, A., & Wessner, M. (2006). The CSCL community in its first decade: development, continuity, connectivity. *International Journal of Computer-Supported Collaborative Learning*, 1(1), 9-33.
- King, A. (2007). Scripting collaborative learning processes: A cognitive perspective. In F. Fischer, I. Kollar, H. Mandl, & J. M. Haake (Eds.), *Scripting computer-supported collaborative learning - cognitive, computational, and educational perspectives* (pp. 13-37). New York, NY: Springer.
- Kirschner, P. A., & Erkens, G. (2013). Toward a framework for CSCL research. *Educational Psychologist*, 48, 1-8.
- Limbu, L., & Markauskaite, L. (2015). How do learners experience joint writing: University students' conceptions of online collaborative writing tasks and environments. *Computers & Education*, 82, 393-408.
- Marton, F. (1986). Phenomenography: A research approach to investigating different understandings of reality. *Journal of Thought*, 21(3), 28-49.
- McKeown, J. M., Hartley, K. A., Faulkner, R. T., Hmelo-Silver, C. E., Jeong, H., & Emmanuel N. (2017). A meta-synthesis of CSCL literature in STEM education. In B. K. Smith, M. Borge, E. Mercier, & K. Y. Lim. (Eds.) *Proceedings CSCL 2017 Volume 1*, (pp. 439-486). ISLS. Philadelphia PA.
- Miyake, N. (2007). Computer supported collaborative learning. In R. Andrews & C. Haythornwaite (Eds.), *Sage Handbook of E-learning Research* (pp. 248-266). London UK: Sage.
- Roschelle, J., Bakia, M., Toyama, Y., & Patton, C. (2011). Eight issues for learning scientists about education and the economy. *Journal of the Learning Sciences*, 20, 3-49.
- Rovio-Johansson, A., & Ingerman, Å. (2016). Continuity and development in the phenomenography and variation theory tradition. *Scandinavian Journal of Educational Research*, 60(3), 257-271.
- Scardamalia, M., & Bereiter, C. (1994). Computer Support for Knowledge-Building Communities. *The Journal of the Learning Sciences*, 3(3), 265-283. [www.jstor.org/stable/1466822](http://www.jstor.org/stable/1466822)
- Sommerhoff, D., Szameitat, A., Vogel, F., Chernikova, O., Loderer, K., & Fischer, F. (2018). What Do We Teach When We Teach the Learning Sciences? A Document Analysis of 75 Graduate Programs. *Journal of the Learning Sciences*, 27(2), 319-351.
- Sommerhoff, D., Szameitat, A., Vogel, F., Chernikova, O., Loderer, K., & Fischer, F. (2018). What Do We Teach When We Teach the Learning Sciences? A Document Analysis of 75 Graduate Programs. *Journal of the Learning Sciences*, 27(2), 319-351.
- Suri, H., & Clarke, D. (2009). Advancements in research synthesis methods: From a methodologically inclusive perspective. *Review of Educational Research*, 79, 395-430.
- Tang, K.-Y., Tsai, C.-C., & Lin, T.-C. (2014). Contemporary intellectual structure of CSCL research (2006-2013): a co-citation network analysis with an education focus. *International Journal of Computer-Supported Collaborative Learning*, 9(3), 335-363.
- Vogel, F., Wecker, C., Kollar, I., & Fischer, F. (2017). Socio-cognitive scaffolding with collaboration scripts: a meta-analysis. *Educational Psychology Review* 29(3), 477-511. doi: 10.1007/s10648-016-9361-7
- Wise, A. F. & Schwarz, B. B. (2017). Visions of CSCL: eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, 12, 423-467.
- Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, 12, 423-467. 10.1007/s11412-017-9267-5



# Designing for Productive Problem Posing in Informal STEM Spaces

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**Abstract:** This symposium offers a look across several sites of informal STEM learning for moments of productive problem-posing. Despite the importance of problem-posing in both academic and applied STEM fields, students are rarely offered robust opportunities to define their own paths through these domains. When they are, it is often in the context of informal spaces—museums or after-school clubs—and is frequently less well-defined. This symposium brings together three case studies—one of younger students in guided play and two of slightly older youth in object-directed play. By putting these in-depth analyses in conversation with one another, we hope to highlight important commonalities in order to distill possible design recommendations for creating more opportunities for productive, and creative, disciplinary engagement.

## Overview of the symposium

The focus of this symposium is on the affordances of large-scale, collaborative, object-driven spaces for STEM-relevant problem-posing. In this symposium we attempt to bring together research on embodied cognition and the affordances of large-scale designs for disrupting traditional, classroom-based STEM tasks with work on informal learning environments that highlights the potential of student-defined, interest-driven engagement. We take as a starting point the idea that different environments make unique contributions to learning, and are best designed with an eye toward how the different pieces of a learning ecology might complement each other (Knutson & Crowley, 2001; Ito et al., 2013). Thus, informal learning environments are not meant to replace but instead to enhance and supplement more formal designs. In particular, we address the observation that formal, standards-driven, compulsory classrooms are well-tuned for breadth of conceptual coverage, but often miss opportunities to develop skill-sets and dispositions better approached through more ill-structured tasks (Lampert, 1990). At the same time, lack of detail about what it takes to design for these broader goals in ill-structured tasks often leads museums and other informal environments back to fun and engaging fact-delivery systems (Griffin, 1994; Olson, 1999).

In particular, skills-based K-12 education tends to focus on familiarizing students with prescribed standards and codified strategies such as standard algorithms (Stigler & Hiebert, 1999). Even museums sometimes revert to hands-on ways of delivering established information, such as “Can you guess?” flip charts and other kinds of simplistic interactive exhibits, often because the work of designing for “minds-on” as well as “hands-on” interaction is so complex (Allen, 2004). Advanced participation in math and science, however, involves not just executing on known problems, but actually posing novel, discipline-relevant problems and inventing strategies for solving them (Lakatos, 1976; Sinclair, 2004). And while progress is being made on these fronts in reform efforts like Project-Based Learning (e.g., Boaler, 1997; Boaler & Selling, 2017) and Teaching Mathematics for Social Justice (Gutstein, 2003), naturalistic studies in informal environments can offer a different vantage points for would-be designers.

## Contribution of each paper to the broader discussion

Each of the case studies presented in this symposium offers a different perspective on, and context for, looking at problem-posing in interest-driven environments. From one angle, each paper represents a different case of students who invent and attempt to solve a novel problem that has potential relevance to STEM learning. Each environment is of course embedded in a set of cultural expectations, but in most cases participants are either explicitly encouraged to develop their own problems, or at least free from any negative consequences for doing something other than what the designer intended. From another angle, each of these circumstances has a strong set of both material and participatory constraints and affordances—one under the watchful eye of parents (paper one), one dictated by peer-defined social structures (paper two), and one by adult guidance (paper three)—that mediate emergent goals and solution paths.

We have two goals in bringing these papers into conversation with this symposium: 1) to present an existence proof that self-directed problem posing is not beyond the grasp of even young children, nor is it confined to a particular kind of setting, and 2) to look across sites with significant variation in an attempt to

distill broader design principles than might be warranted by a single small-scale study. To this end, we include several (possibly idealized) cases where youth (papers one and two) are essentially left alone with an object or objects and follow emergent goals that are more or less well defined, as well as one with younger children (paper three) in which facilitation was key. Finally, our goal in bringing these papers together is to highlight commonalities and differences across these cases in an effort to create humble theory about different kinds of material and social design choices for productive problem posing.

## Discussant

To help facilitate this comparison, we also bring in Lauren Vogelstein, whose work on physical research in a dance company, and the affordances of large-scale object-mediated dance for developing mathematical intuitions and observations (Vogelstein, Brady, & Hall, 2017 & 2019), will offer another unique perspective on this work. In particular, her work on ensemble mathematical learning has shown how the embodiments of people-plus-prop systems, in which the manipulation of large-scale geometric figures necessitates performances by an ensemble, create a distributed problem posing environment. More specifically, the ensemble necessity of these set-ups requires full participation to animate ideas, which provides a rich physical substrate (Goodwin, 2017) for participants to manipulate. For example, a quartet of STEM educators choreographing a performance with a 7' x 7' silver Mylar sheet proposed ideas for coordinated ensemble performances with slight changes to what had previously been enacted by the ensemble in order to create new movements that made aesthetically pleasing manipulations of the square prop. In this example, the ensemble nature of the activity forced participants to make their ideas visible through partial enactments as they planned their choreography. Through this process the choreography became increasingly more complex, eventually surpassing their understandings as they performed a double reflection over both of the diagonal lines of symmetry of the square prop and were unable to replicate the choreography. These STEM educators came across an interesting problem through a process of aesthetically driven physical brainstorming, in which ideas were enacted as an ensemble, and the proposals to manipulate these actions became new forms of choreography. In her ethnographic work with a professional dance company, Vogelstein has also begun to articulate a similar process the dancers call “physical research” in which problems are iteratively posed by a choreographer and refined as dancers propose responses collectively with their bodies. Thus, she brings a perspective on ensemble learning (Ma & Hall, 2018; Ma 2017) to complement the other in- and out-of-school perspectives represented in the symposium.

## **Paper one: Manifesting mathematics: How playful engagement facilitates emergent problem finding**

Lara Jasien

### Overview and background

While school mathematics in the U.S. often can be adequately described as learning definitions and practicing procedures (Stigler & Hiebert, 1999), authentic engagement in STEM requires creative problem finding (Einstein & Infeld, 1938; Lakatos, 1976). For mathematicians, this kind of problem finding can be the product of playful exploration (Sinclair, 2004), where mathematicians tacitly ask themselves what is possible and what is interesting within a particular mathematical system. Yet, for many students, school mathematics feels like all work and no play (e.g., Boaler & Greeno, 2000; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), and indeed it is often organized for such work-like experiences (Jacobs, Hiebert, Givvin, Hollingsworth, Garnier, & Wearne, 2006; Litke, 2015). Yet, the distinction between work and play is pivotal for problem finding and solving: while work involves an individual structuring their activity to fit the environment (as in school), play involves the individual structuring the environment to suit their activity (Elkind, 2008). Thus, play environments provide an ideal context to examine children’s informal mathematical problem finding, as play allows children to exercise their agency in ways that shape what is possible. In this study, I examine children’s play at a mathematical playground that supports children to create patterns, designs, and representations with novel materials at four different exhibits, in search of moments where they explore what is possible and pursue activities in ways that they find interesting.

### Theoretical framework

Mathematical activity in play looks much different than mathematical activity in school, as the tools, representations, and indeed, the problems look very different. Thus, accounting for mathematical activity in an empirical study of play requires methods typically not employed in accounts of school learning. This study is premised on the assumption that studies of mathematical learning should account for whatever participants

consider relevant as they engage in their own meaning-making processes (Jordan & Henderson, 1995). Methodologically and theoretically, this means that attention must be paid to human language, actions, and the representations that they produce, as these are all embodiments of mathematical activity (Hall & Nemirovsky, 2012). Thus, in this study, I examine how (and what kinds of) mathematics emerge through what DeFreitas and Sinclair (2014) call material entanglements—the interlacing of gestures, talk, emotion, and tools that co-constitute mathematical concepts. The products of these material entanglements, and thus of all mathematical activity, become a “site of agency” (p. 85), as they becomes tools to support future thinking.

In the kind of play under scrutiny in this study, this means that the patterns, designs, or representations that players produce carry with them traces of mathematical concepts that were co-constituted through human interaction with materials. Thus, I analyze how two 12 year old girls engaged with four different mathematical objects throughout their 36 minute stay at a mathematical playground. By attending to what the girls produced, their trajectory of attempting to use the materials for their own purposes, and their informal evaluations of their activity, I am able to make claims about the richness of their engagement in relation to the affordances of the mathematical playground, including but not limited to the design of the materials and the open participation structure where two pre-teens can explore together, set their own goals, and compare and evaluate their own activity.

### Case study and preliminary findings

Notably, these two participants are part of a larger data corpus of 345 children between the ages of 4 and 16, with the majority of participants between 7 and 12 years old ( $n = 279$ ). Analysis of these children has shown that the two focal participants’ activity is unique in how long they engaged at each exhibit (longer than typical), but not unique in the nature of the designs they produced in their play. Because their parallel play generated rich data, and because their engagement with the materials looks quite different from each other and thus represents a spectrum of engagement at the mathematical playground, they have been selected for a close analysis that gives rich understanding of the phenomenon (i.e., a revelatory case, Yin, 2003). The final paper will contain data to situate the focal participants within the larger corpus in relation to the patterns, designs, and representations they produce at each exhibit.

By attending to the multimodal engagement of two focal participants, I find that problem finding can be a generative process that leads to the emergence of mathematical meanings in play, even for children as old as 12 years of age. This analysis sheds light on the problems that children and adolescents can and do find for themselves when given opportunities rich and open enough to support meaningful engagement, and thus broadens what we can imagine as possible in mathematics education.

## **Paper two: “Our boat is magic”: Emergent social goals break open the black box**

Katherine Chapman

### Overview and background

The broader study from which this analysis derives focuses on a week-long sailing camp where students ages eight to eleven participated across two parallel learning sites: a living museum dedicated to maritime heritage, in which the students learned to rig and sail small boats in pairs, and an informal science institution, in which students investigated some of the principles of weather and physics that might help them in their sailing. In the episode presented here, students played with model boats on a small, manufactured pond. These boats function precisely the way the larger sailboats that the youth were learning to sail do, except that they do not have rudders; the only way to steer the boat is by adjusting the sails. Thus, designers conjectured that this would be a fun, slightly simplified context for exploring “points of sail”—the ideal position for a sail in coordination with orientation toward the wind.

Initial curricular design included a discussion of the proper points of sail before introducing the model boats, but one instructor decided that it might be more meaningful for the students to derive the points of sail themselves from observing the model boats. In essence, this on-the-fly adjustment was aimed at addressing a common observation from classroom studies that the “use of direct instruction in the face of a novel toy or problem can limit exploration and learning” (Weisberg et al., 2013). This is in contrast with informal environments such as informal science institutions or makerspaces where “we see amazing focus, creativity, persistence, and pride developing in people of all ages as they draw on their understanding and imagination to develop and pursue an idea and to make something concrete (even if ephemeral) that represents their ideas and understanding” (Petrich et al., 2013, 51-52).

## Theoretical framework

Where cognitive learning theories such as Constructivism view learning as “building knowledge structures irrespective of the circumstances of the learning” (Papert & Harel, 1991), situative theorists consider learning to be inextricably tied to the circumstances of learning, which include the learner’s prior experiences as well as the tools and other resources of the learning environment (Werscht, 1998). From this perspective, the tools and materials, but also the goals and participation structures, fundamentally change the nature of what is learned. I take a situative perspective in this analysis, with particular attention to another important affordance of so-called “authentic” learning environments—not just the what, but also the why:

“For instance, whereas a hands-on circuit activity might be employed in a classroom to teach about electricity, the circuitry knowledge we observed in the makerspaces was used to make a night-light, customize a bike, fix a game controller, and photograph the Earth from space” (Sheridan et al., 2014, 528).

In order to provide an account of the depth of the phenomenon, I use principles of Interaction Analysis (Jordan & Henderson, 1995) to develop small-scale theory largely from video data.

## Data collection and analysis

Camp involved twenty youth who moved between whole-group engagement and frequent partner work. In particular, group discussion was encouraged during the “science” portion of the curriculum, and the sailboats they were learning to operate virtually required two sailors. The model boat episode was introduced as a collaborative group activity, but the students quickly paired themselves off. The activity was also introduced by the instructors as an opportunity to try to “figure out” how the sail position influences the direction that the boat sails in, and challenged students to try to sail their boats all the way across the pond. Almost none of the students appeared to engage in either of these activities at first, however.

Data collection was designed as pilot data for a broader study. As such, all sampling was based on convenience. From within the four focal students represented in the corpus, the present case was selected because the student wearing the camera consistently narrated his own thinking to his partner, almost as he might have during a think-aloud interview protocol. Review of other focal cases suggests that this student was not anomalous in general engagement, only more forthcoming in his narration. Still, future research will aim to confirm generalizability by comparing more cases. The focal student in this case—Wally (a pseudonym)—chose to work with one other student during the model boat activity. Analysis is confined to Wally’s contributions, however, since I had not obtained consent for analyzing the other student’s participation.

## Case study

Wally initially appeared to ignore instructors’ suggestions to try to sail the model boat directly across the pond, or to make any systematic investigation into how the boat moves. Over the course of fifteen minutes, he watched the boat take off from the side of the pond, ran around to retrieve it, and watched it sail off again, without making any substantial adjustments to sail position. They did adjust the direction the boat was pointed in when it was released—it appeared that the students thought this might influence the movement of the boat—but in general they were relatively content to try the same thing again and again. As the activity progressed, Wally began commenting on this confusion, albeit in a friendly way, saying things like “our boat is magic—it just turns to the side all the time”. This sense that the reasons for the behavior of the boat are an impenetrable “black box”—that the boat itself is “magic”—would be a troublesome place to leave the lesson from the perspective of the stated learning goals. At roughly fifteen minutes into their exploration, however, there was some commotion among the students. It seemed one of the students had declared himself a pirate and started trying to attack other boats. At this point, Wally began to more concertedly focus on adjusting the sail position and make observations about the resulting movement of the boat. It seemed that the introduction of piracy—and the resulting goals to either counter-attack or retreat—provided an emergent urgency, after which Wally attempted a more systematic exploration of the affordances of the model boats.

## Findings and next steps

Comparison of this case with the other three focal cases revealed a similar pattern—students began the activity by simply “messing around” (Ito et al, 2009) with the model boats, ignoring the adults’ framing of the activity for the most part. It was only after the emergent social goal of dealing with the pirate became salient that students made a more concerted effort to systematically test and catalog small changes in their efforts to sail the model boats.

This finding is especially important for two reasons. First, object play has been studied extensively in young children, though it is frequently assumed to drop off, and its educational utility is less clear for late elementary and middle school students. This episode suggests that the typical progression—from “what can this object do?” to “what can I do with it?” (Hutt, 1966)—holds for older youth as well, at least when emergent goals are present. Furthermore, instructors present during this model boat activity quickly called the episode to a close once the piracy appeared, since it seemed to them to be getting out of hand (and they did not want the model boats being damaged by intentional crashes). It was only upon revisiting the data that it became clear that this emergent social structure was actually facilitating deeper engagement with precisely the kind of observations the activity was meant to target in the first place.

## **Paper three: It's a pizza!: Invented problems and meanings in early childhood mathematical play**

Paul N. Reimer

### **Overview and background**

Enactive and embodied perspectives shed new light on the importance of early childhood play. Vygotsky (1978) suggested play was derived from imaginative situations wherein rules emerge as children negotiate their actions based on situational constraints. Recent views of cognition imply a similar reliance on objects, materials, movements, and interactions to assist learners in forming meaningful interpretations of their activity (Núñez, Edwards, & Matos, 1999; Varela, Thompson, & Rosch, 1991). These perspectives are uniquely suited to provide explanations for meaning-making in early childhood play, as they have highlighted the interconnectedness of these resources and, drawing on biological roots, have suggested that human bodily experiences form the basis of conceptual understanding.

Early childhood educators face challenges when attempting to enact play-based pedagogies. Head Start programs, in particular, encounter a tension when considering opportunities for children's self-directed play in light of accountability for children's academic readiness (Walter & Lippard, 2017). To address this challenge, we are engaged in a multiyear partnership with two Head Start preschool centers to explore opportunities for informal mathematics learning in various seeded interest areas that encourage mathematical play (Wager, 2013). These interest areas provide a rich context to study 1) how young children interact with simple, yet carefully-designed objects, 2) the meanings children develop as they interact with materials and peers in play, and 3) the various roles adults enact as they seek to participate in play spaces with children. In particular, we are interested in how children decide what to do with objects and how they use novel ways to generate norms in their play. This work is held together by a persistent tension between what exists and what is possible: "The combination of a concrete embodied situation with alienated virtual meaning is the freedom-engendering paradox of play" (Stewart, Gapenne, & Di Paolo, 2010, p. 77).

### **Data collection and analysis**

For this study, we analyzed preschool children's (n=12) play as they engaged in sessions of self-directed play in several interest areas within preschool classrooms at two Head Start centers. In particular, we were interested in how children attended to existing constructions or comments made by adults or peers, how children used these to develop norms of play, how they embraced ambiguity by giving new meanings to existing creations, and how their actions arose from the designed objects or ideas they developed while interacting with the objects.

### **Case study**

In one play session, two adults invited children to play. One adult made a star with three red hexagons and silently moved it into the playspace. The adults played with the blocks, typically creating small designs out of adjacently placed blocks of different colors and shapes. Children began to play with the blocks by collecting blocks of the same color. One child decided blocks needed to touch on congruent sides and began to place blocks side by side. Another picked up blocks and enacted movements with them appropriate for the meaning he had attached to the objects. For, example, he said “I'm making a PacMan” as he held up a block and moved it in a chomping manner. After a few moments, he began to negotiate a balancing activity by stacking blocks on top of each other.



**Figure 1.** From left: Dalia joining play and taking the star, but in moving it the star comes apart; Dalia orienting blocks within a boundary; Dalia coordinating actions with adult; Dalia adding yellow whiskers to make a “kitty-cat”.

After two minutes of play, Dalia and another child joined the playspace (Figure 1). Dalia noticed the star the adult had made. Dalia took the star, but in moving it the star came apart. Through several attempts she put it back together. Dalia then created another copy of the star, rotating pieces to determine how to form the star. She then used a similar approach with the yellow blocks, rotating the blocks to tile. The adult asked her, “What are you making?” Dalia answered, “A pizza.” Dalia then completed a tiling with blue blocks and put two yellow triangles on top of the completed blue block figure. “It’s gonna be a kitty-cat,” she said.

### Findings and next steps

Analysis of this play interaction suggests that Dalia’s play was led by both meaning and actions derived from the objects (e.g., Do these fit together?) and imagined meanings (e.g., “It’s a pizza.”). Our results suggest that an adult may enact roles in children’s play that support these developing meanings 1) as a co-enactor in play, 2) as a reflective partner who provides feedback-oriented prompts (e.g., Does that fit?), 3) as a co-participant in action through coordinated movement (e.g., A “many hands” approach), or 4) as a re-opener of play (e.g., What might happen if?). We concluded that opportunities for mathematical thinking existed in carefully-designed interest areas that allowed children to enact playful interpretations of activity based on bodily interactions with objects and imagined meanings.

### References

- Allen, S. (2004). Designs for learning: Studying science museum exhibits that do more than entertain. *Science Education*, 88 (Suppl 1), S17-S33
- Boaler, J. (1997). *Experiencing school mathematics; Teaching styles, sex, and settings*. Buckingham, UK: Open University Press.
- Boaler, J., & Selling, S. K. (2017). Psychological Imprisonment or Intellectual Freedom? A Longitudinal Study of Contrasting School Mathematics Approaches and Their Impact on Adults' Lives. *Journal for Research in Mathematics Education*, 48(1), 78-105. doi:10.5951/jresmetheduc.48.1.0078
- De Freitas, E., & Sinclair, N. (2014). *Mathematics and the body: Material entanglements in the classroom*. New York, NY: Cambridge University Press.
- Elkind, D. (2008). The Power of Play: Learning What Comes Naturally. *American Journal of Play*, 1(1), 1-6.
- Goodwin, C. (2017). *Co-operative action*. Cambridge University Press.
- Griffin, J. (1994). Learning to learn in informal settings. *Research in Science Education*, 24, 121 – 128.
- Gutstein, E. (2003). Teaching and learning mathematics for social justice in an urban, Latino school. *Journal for Research in Mathematics Education*, 34(1), 37-73. doi:10.2307/30034699
- Hall, R., & Nemirovsky, R. (2012). Introduction to the special issue: Modalities of body engagement in mathematical activity and learning. *Journal of the Learning Sciences*, 21(2), pp. 207-215.
- Hutt, C. (1966). Exploration and play in children. In *Symposia of the Zoological Society of London* (Vol. 18, No. 1, pp. 61-81).
- Ito, M., Baumer, S., Bittanti, M., Cody, R., Stephenson, B. H., Horst, H. A., ... & Perkel, D. (2009). *Hanging out, messing around, and geeking out: Kids living and learning with new media*. MIT press.
- Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., Schor, J., Sefton-Green, J. & Watkins, S. C. (2013). *Connected learning: An agenda for research and design*. Irvine, CA: Digital Media and Learning Research Hub.
- Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in children’s self-competence and values: Gender and domain differences across grades one through twelve. *Child development*, 73(2), 509-527.

- Jacobs, J. K., Hiebert, J., Givvin, K. B., Hollingsworth, H., Garnier, H., & Wearne, D. (2006). Does eighth-grade mathematics teaching in the United States align with the NCTM Standards? Results from the TIMSS 1995 and 1999 video studies. *Journal for Research in Mathematics Education*, 37(1), 5–32. doi:10.2307/30035050
- Jordan, B., & Henderson, A. (1995) Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39-103.
- Kirsh, D. (2010). Thinking with the body.
- Knutson, K., Crowley, K., Russell, J.L., & Steiner, M.A. (2001). Approaching art education as an ecology: Exploring the role of museums. *Studies in Art Education: A Journal of Issues and Research*, 52(11), 310-322.
- Lakatos, I. (1976). *Proofs and refutations: The logic of mathematical discovery*. Cambridge, UK: Cambridge University Press.
- Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*, 27(1), 29-63.
- Litke, E. G. (2015). *The state of the gate: A description of instructional practice in algebra in five urban districts* (Doctoral dissertation). Retrieved from <http://nrs.harvard.edu/urn-3:HUL.InstRepos:16461050>
- Ma, J. Y. (2017). Multi-Party, Whole-Body Interactions in Mathematical Activity. *Cognition and Instruction*, 35(2), 141-164.
- Ma, J. & Hall, R. (2018). Learning a part together: Ensemble learning and infrastructure in a competitive high school marching band. *Instructional Science*.
- Núñez, R. E., Edwards, L. D., & Matos, J. F. (1999). Embodied cognition as grounding for situatedness and context in mathematics education. *Educational Studies in Mathematics*, 39, 45–65.
- Olson, J. K. (1999). A qualitative analysis of the field trip experience: A formal trip in an informal setting. In *National Association for Research in Science Teaching Annual Meeting*, Boston.
- Papert, S., & Harel, I. (Eds.). (1990). *Constructionism. Interactive Learning Environments* (Vol. 1, pp. 518–32). Westport, CT: Ablex Publishing.
- Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In M. Honey & D. E. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 50–70). Routledge.
- Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the Making: A Comparative Case Study of Three Makerspaces. *Harvard Educational Review*, 84(4), 505–531.
- Sinclair, N. (2004). The roles of the aesthetic in mathematical inquiry. *Mathematical Thinking and Learning*, 6(3), pp. 261-284.
- Stewart, J., Gapenne, O., & Di Paolo, E. A. (Eds.). (2010). *Enaction: Toward a new paradigm for cognitive science*. The MIT Press. <https://doi.org/10.7551/mitpress/9780262014601.001.0001>
- Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. Simon and Schuster.
- Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. Cambridge: MIT Press. <https://doi.org/10.1111/j.1468-0149.1965.tb01386.x>
- Vogelstein, L., Brady, C., & Hall, R. (2017, June). *Mathematical Reflections: The Design Potential of Ensemble Performance*. In *Proceedings of the 2017 Conference on Interaction Design and Children* (pp. 583-588).
- Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press. <https://doi.org/10.2307/3726822>
- Wager, A. A. (2013). Practices that support mathematics learning in a play-based classroom. In *Reconceptualizing Early Mathematics Learning* (pp. 163–181). Springer Netherlands. [https://doi.org/10.1007/978-94-007-6440-8\\_9](https://doi.org/10.1007/978-94-007-6440-8_9)
- Walter, M. C., & Lippard, C. N. (2017). Head Start teachers across a decade: Beliefs, characteristics, and time spent on academics. *Early Childhood Education Journal*, 45(5), 693–702. <https://doi.org/10.1007/s10643-016-0804-z>
- Weisberg, D. S., Hirsh-Pasek, K., & Golinkoff, R. M. (2013). Guided Play: Where Curricular Goals Meet a Playful Pedagogy. *Mind, Brain, and Education*, 7(2), 104–112.
- Wertsch, J. V. (1998). *Mind As Action*. New York: Oxford University Press.
- Yin, R. K. (2003). *Case Study Research: Design and Methods*. London: Sage.

# Personal Embodiment, Social Enactment: Collaborative Learning With Body Technology

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**Abstract:** New technological developments in wearables, motion sensors, health trackers, and a host of other devices hold the tentative promise of making embodiment visible, sharable, archivable, aggregable, and analyzable not only for individuals but also for groups. In this symposium we bring together various projects involving “body technology” to promote embodied learning in *collaborative* contexts, where collaboration is a core part of the embodied learning. This session explores the theories, designs, epistemologies, research methods, and outcomes of different, but related, models by addressing issues such as the affordances of body technologies designed for individual versus collaborative use, the relationship between individual insight from embodied experience versus social meaning from shared experience, and the role of embodiment in youths’ design of body technologies.

## Introduction

The notion of “hands-on learning” has been around for more than a century as a pedagogical strategy, employed from early childhood through higher education and beyond (Chickering & Gamson, 1987; Dewey, 1938; Montessori, 1917). But as they take place in educational environments, these types of activities have historically been practiced in service of the cognitive goals of thinking, understanding, and problem-solving. It is only fairly recently that learning researchers have begun to view the body itself as a site of learning, examining how movement and gesture can not only contribute to cognition, but actually constitute thinking and problem solving in their own right (Alibali & Nathan, 2012; Hall & Nemirovsky, 2012; Stevens, 2012; Wilson, 2002). Looking more deeply at the nature of knowledge itself, we find that many kinds of knowledge and basic orienting concepts are grounded in our individual physical and embodied realities. Mathematical ideas of grouping, boundaries, figure rotation, and other foundations are based in our sense of being and acting in the physical world (Lakoff & Nuñez, 2001). Many of our linguistic metaphors for dealing with complex and intangible phenomena are spatial (e.g., human emotions are “up” or “down”) or physical (e.g., a political alliance is “fragile” or “strong”), precisely because less explanation is required when these metaphors are in use; we seem to “just know” (Lakoff & Johnson, 2008). Yet while our experience of embodiment is inherently personal, it directly informs how we interact and collaborate socially in communities of learning.



This symposium contributes to our understanding of the nexus of personal embodiments and collaborative engagement through designs of and with body technologies. While embodied ways of learning and understanding are powerful, they can also be somewhat ephemeral—critical in the moment of insight, but fleeting. Further, embodiment is highly personal and subjective; communicating experienced physical phenomena is challenging enough in medical settings when the topic is immediate (Heritage & Robinson, 2006), let alone metaphorical and situated in a domain like math or science. Now, however, new technological developments in wearables, motion sensors, health trackers, and a host of other devices hold the tentative promise of making embodiment visible, sharable, archivable, aggregable, and analyzable for both individuals and groups (Lee, 2015). In this symposium we bring together various projects involving “body technology” to promote embodied learning in a *collaborative* context. Body technologies in our work include GPS, movement-trace games and simulations, health monitor devices, and wearable/programmable e-textiles. Some of our projects are based on individual learners with personalized, single-user technologies but who experience their use as a collaborative experience with peers. Others are individual learners creating collaborative or linked products together. Still others are pairs or groups of learners engaged in a collaborative experience with a body-sensing technology for multiple users at once. This session explores the designs, epistemologies, research methods, and outcomes of all these different, but related, models by addressing the following questions: 1) What are the affordances of body technologies designed for individual versus collaborative use, and what challenges exist for researchers in trying to design for personal and social learning when using these tools? 2) What is the relationship between individual insight from embodied experience versus social meaning from shared experience or enactment? What are the roles of body technologies in these phenomena? 3) What kinds of learning in this research are more individual, more collaborative, both, or neither? How do we know? How do we study learning in these ways? What does learning mean in these contexts? 4) What are implications for the design of embodied learning, when we consider how learners can collaborate and construct both personal and social meanings?

## Objectives

Together, these contributions aim to provide a single venue for advancing understanding of embodiment with body technologies in collaborative contexts. The papers included in this session consider ways that embodiment facilitates collaboration as well as ways to design intentionally for collaboration with tools that promote embodiment. The papers consider a number of types of body technologies productively utilized for collaborative learning, such as personal medical technology used to manage everyday family practices (Lee et al.); mobile technologies that facilitate nontraditional forms of collaboration (Taylor et al.); and the tool designs that create opportunities for social dependencies and synergistic gestures (Lindgren et al.). Two papers explicitly consider the role of embodiment in students’ designs of technologies, including collaborative, motion-sensitive electronic textile designs (Lui et al) and game designs that rely on playtesting (Litts et al.). One paper compares two different technological/representational systems to understand the “social” affordances of different collaborative embodied learning environments (Danish et al.). This symposium will provide opportunities to examine similarities and differences in approaches to body technologies that facilitate collaboration.

## Session format

To promote active and productive discussion and future collaborations, the symposium will be conducted as an interactive demonstration. The chair will begin by introducing the theme of the session, sharing considerations of theory and design in embodiment and collaboration. Brief (1-minute) teaser introductions followed by posters and, where possible, body technologies will provide attendees ample opportunities to examine and discuss the varied designs and approaches of the presenters, and to synthesize with attendees’ own expertise in a way that traditional talks do not allow. The symposium will close with an open discussion period, in which the discussant, an expert in embodied learning, action and inscription in a variety of educational contexts, will synthesize ideas around the main themes and areas of interest that emerged during the session and provide questions for the final discussion between authors and audience.

## Data records from children with Type 1 diabetes: Objects for conversation and family sense-making

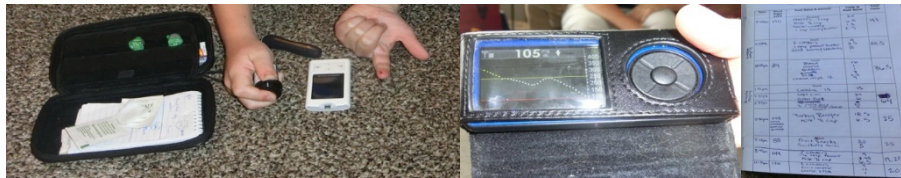
Victor R. Lee and Ilana Dubovi

New technologies are making bodily activity more accessible as objects for inspection in designed learning spaces (see Lee, 2015 for examples). The value of using records of bodily activity as objects of inspection presumably taps into embodied understandings that youth already have and can be connected to disciplinary ideas and

practices. Yet beyond these deliberate designer-driven uses, there are also cases where archives of bodily experiences produce records for inspection and sense-making that are not directly tied to a priori learning goals but still lead to consequential learning and collaborative sense-making discourse and interaction. One of those, to be discussed in this presentation, is the work a family does to manage the health of a child who has been diagnosed with type 1 diabetes (T1D).

Living with T1D involves monitoring of blood sugar levels, deliberate decision-making and planning for diet and exercise, and regular introduction of artificial insulin into the bloodstream. Because it is a chronic illness, it serves as a disruption in practice and routine that necessitates introduction of quantification practices. It serves as a context for expansive learning (Engestrom & Sannino, 2010) that necessitates the creation of new representational infrastructures by families and caretakers (Hall, Stevens, & Torralba, 2002). The work described in this presentation is an accounting of how data related to the management of T1D are stored and mobilized for everyday sensemaking activities by families and youth.

In this study, data were obtained from 5 families with children under the age of 12 who had type 1 diabetes through meetings and visits ranging from one and three times for each family (Lee, Thurston, & Thurston, 2016). For four of those families, we conducted observations and interviews at the home of those families and photo-documented artifacts that were used in their diabetes management. One finding was the development of custom data logs as one form of representational infrastructure that four out of five families used to track blood sugar levels as measured from glucometers and from continuous glucose monitors (see Figure 1).



**Figure 1.** A glucometer being used to get a blood sugar reading (left), a continuous glucose monitor (center) and a homemade data logging system (right).

For two families that will be discussed, these logs served as important supports and motivators for discussions about the child's health and what was influencing changes in blood sugar readings. This representational form served as a source for investigating measurement discrepancies and supporting claims. In one family to be discussed, the two parents had both logged that they had administered the same amount of insulin for their child on different days, yet they noticed that the resulting blood sugar levels were quite different. This led them to question how they were dosing and the eventual discovery that they were measuring the meniscus (i.e., fluid curvature in a measurement vial) of insulin in different ways. In another family, the logs served as a guide for a parent to select meal options when the other parent, who typically did the family meal planning, was unavailable. In addition, that family used the data they stored in their handwritten log of digitally obtained data as justification for certain intuitions that they had about the impact of certain foods on the child's blood sugar levels.

In both families, the child was reportedly more adept at early numeracy skills. The parents spent a substantial amount of time teaching their children to recognize numerical readings of their own blood sugar data and to notice trends such as blood sugar "going down" or "going up", through spontaneous quizzing as part of monitoring. Through studies like this one, we gain some insight into what families do to retain and respond to personal data and how disciplinary ideas and practices—such as numeracy, logging, measurement, body systems, and nutrition—are established and drawn upon for coordinated action as a result of the disruption of disease diagnosis.

## **Collaborative design of wearable technologies: How embodied gestures support computational learning and creativity**

Debora Lui, Lindsay Lindberg, Deborah A. Fields, Mia Shaw, Gayithri Jayathirtha, and Yasmin Kafai

While much existing embodiment research focuses on the *use* of wearable technologies for learning, there is less work that highlights the role of embodiment within the *design* of these body-based technologies which incorporate sensors into clothing or other wearable accessories in order to make them interactive. Here we position embodiment as an essential component within a student-centered, collaborative design process of developing wearable technology. The distributed nature of cognition (Hutchins, 1995) will be taken up with the perspective that physical gestures structure thinking and action during meaning making (Goodwin, 2000) as we share instances of youth collaboratively designing and constructing wearable body technologies such as light-up hoodies or

music-playing gloves. Blending semiotic resources, including computational design and conversation, with physical embodiments as tools for sensemaking (Kirsch, 2011), we ask about the role of physical body movement and collaborative sensemaking in supporting student understanding of computational concepts, with the development of personalized, computational artifacts.

The study took place during a four-day summer STEM program at a local science museum. Four groups consisting of 3-4 high school students and 1 adult co-designed interactive musical wearable artifacts using an Arduino-based Circuit Playground electronic textiles kit and a piece of clothing (e.g., hoodies, gloves). Drawing upon artifacts, interviews, and video recordings, we developed four case studies of the groups highlighting their design process. Through an inductive analysis, we developed coding themes based on how students used embodiment to understand computational concepts in the design of their interactive wearable artifact.

Across all four groups, we found that students' uses of physical gestures were central to the creation of their musical wearable artifacts and tightly intertwined with their engagement with computational concepts and one another. Introducing materials like gloves and hoodies (objects intended for functional use and movement) privileges physical, embodied participation with computational strategies by both instructors and students. Students' gestures could be categorized in three ways. First, students employed gestures to help *envision the design of their wearable artifact*. During the brainstorming phase, students acted out different series of possible 'trigger' gestures for teammates (e.g., waving hand) and verbally described different possible resulting actions ("now the lights blink"). Here, the gestures allowed students to simulate abstract computational sequences, to ideate upon new creative possibilities of computational action and also communicate their ideas to other peers. Second, students used gestures to *solidify their understanding of a computational concept*. This included, for instance, hand movements first demonstrated by the instructor and later taken up by students while programming a motion sensor to help concretize abstract ideas, such as quantifying space in terms of the three dimensions, determining conditional logic or system inputs and outputs. Finally, gestures were also utilized to help *calibrate parts of their computational design*, particularly programming motion and light sensors, where the degree of movement determined the threshold values for sensor activation. Collaboratively, students performed motions that activated sensors repeatedly (whether flipping a hood off their heads or waving their hands) as part of the process of calibrating their readings and programming these into their artifacts.

Moving beyond the individual, the embodied actions above served as tools for collaborative sensemaking and provided communicative and ideational support in service of creating a wearable technology. An understanding of how embodiment can serve these dual roles is especially timely because of the increased efforts to bring digital fabrication tools into schools (Peppler, Halverson, & Kafai, 2016), where students are not only users but designers of wearable technologies. We illustrate how privileging intentional physical movements in service of computational design can support collaborative work during the brainstorming and computational phases of development, thereby expanding opportunities for physical and cognitive participation, engagement in computing, and expressive agency.

## **Collective embodied activity and how different concepts map to social exploration**

Joshua A. Danish, Noel Enyedy, Megan Humburg, Bria Davis, and Xintian Tu

In our work, we have developed a Learning in Embodied Activity Framework (LEAF; Danish et al., under review). Our goal in doing so is to build upon prior findings about how the body supports individual cognition (Lindgren & Johnson-Glenberg, 2013) and extend these with a theoretical framework—activity theory (Engeström, 1987)—which explicitly addresses the sociocultural nature of individual learning and the unique characteristics of collective group activity into a combined framework. Within this framework, we view embodiment as supporting learning for both individuals and collective groups, and we believe it is important to explore how these two levels influence each other; individual experiences inform and are informed by collective activity. We are particularly interested in supporting collective embodied activities where participants coordinate their actions to learn about complex phenomena.

We believe collective activities are important because they place the role of social interaction as central to the embodied modeling process. The opportunity to include multiple participants within embodied activities also paves the way to supporting whole-class activities in ways that are often elusive for designs that only support individual students or dyads. For example, our work with the Science through Technology Enhanced Play (STEP) mixed reality environment has explored how students learn about states of matter (Danish, Enyedy, Saleh, Lee, & Andrade, 2015) and honeybees (Danish, Humburg, Tu, Davis, & Georgen, 2018). In the case of the states of matter unit, students took on the role of water particles and embodied their motion relative to each other. The STEP system tracked students' movement and fed it into a projected simulation so that students could see virtual

particles moving as they moved. Importantly, their speed and distance relative to each other produced different states of matter: being near and stationary produced ice; slightly closer but moving produced water; moving fast and far apart produced gas. The simulation displayed each state, helping students to engage in inquiry about the relationship between particle motion and state by moving around and with each other (Danish et al., 2015). In the bees unit, students behaved as honeybees searching for nectar around the hive, with bee avatars that flew around a field of flowers in the simulation, mirroring students' movements around the classroom. As the students-as-bees visited flowers, they discovered whether there was good nectar. Through iterative experimentation, students came to appreciate that they could most efficiently collect nectar if they coordinated their activity with other bees and shared the location of good nectar (Danish et al., 2018).

The goal of the present analysis is to contrast these prior implementations with an eye towards unpacking how the different content areas afforded different forms of collective action, placing interaction and social interpretations into distinct but complementary roles within the inquiry process. For example, students in the particle simulation had to continuously attend to each other's behavior and motion in order to achieve a specific result. Their every embodied movement influenced their relative position, potentially changing the state of matter being collectively created and thus making it crucial for them to be continuously aware of their peers. Planning in this context took on a unique tenor as students had to continuously coordinate their ongoing activity. In contrast, the honeybees could spend extended periods of time ignoring their peers. However, the moments in which coordination became necessary were far more salient and crucial. This led to alternative forms of planning, and very different reflective practices as students had to attend to a few salient interactions with peers rather than continuous ones. In this paper, we further unpack how these different content topics provide unique opportunities for connecting the individual and social dimensions of embodied cognition and suggest implications for the design and analysis of future systems.

## **SensEscapes: Learning and making public history in mobile collocated interactions**

Katie Headrick Taylor, Adam Bell, Erin Riesland, Maria Hays, and Deborah Silvis

Mobile devices are antithetical to “promoting collaborative interaction in varied contexts” (CSCL Conference Theme, 2019), or so recent news stories would have us believe (e.g., Bowles, 2018). Those tiny screens inhibit a shared gaze on activity, distance users from the places they inhabit, and *immobilize* bodies to statues posed with heads down, hands gripping edges of a phone. So designing “collocated interaction” or copresent technology use toward a shared objective, seems like a lost cause.

It is within this design space that we offer a more nuanced, perhaps optimistic, version of mobile collocated interaction for teaching and learning public history in an undergraduate course. While our designed activity, that we call “SensEscapes,” encountered the kinds of obstacles to collaboration mentioned above, we also saw *openings* for novel relationships between bodies, local histories, places, and tools. These openings, we argue, are untenable when seated at a desk, in a classroom, and without a mobile device in hand.

Our design of SensEscapes is guided by theories of embodied learning (e.g., Lindgren & Johnson-Goldberg, 2013) and learning on the move (e.g., Taylor & Hall, 2013). SensEscapes invited students to engage their senses (ie., smell, sight, hearing, touch) for learning about the neighborhood surrounding their public university, and the histories that moved institution and community together and apart over time. Small groups of approximately five students used a mobile mapping application, Siftr™, to find locations within a six-block area, read a short history about each location, then create a geotagged digital artifact at each spot. Siftr allowed for student groups to encounter past histories and document multi-sensory experiences using (analog and digital) mobile tools. After visiting and completing tasks at five locations, students returned to the classroom to share stories and photos mapped to a base layer of the neighborhood.

In our analysis of video records of student participation during SensEscapes, we found that mobile collocated interaction took the form of *static collaboration*. By static collaboration we mean that the typical social cues of “good” collaboration upon which the learning sciences place high value—gestures, shared eye gaze, touching and pointing to the same representation—were absent. However, evidence of effective and high levels of collaboration took other forms. While individuals kept their eyes on their own smartphone screen, they verbalized clarifying questions about the task as a bid for assistance from other members of the group. Upon reaching a location, groups frequently stood in a tight U-shape on the sidewalk, moving only for postural tuning to help a co-participant or get clarification from a neighbor's screen. With the visual field occupied, it was not uncommon for students to note fleeting smells or sounds while working on their phones. Students achieved

focused interactions (e.g., Goffman, 1963) largely without looking at one another or seeing the same thing at the same time.

Our design of SensEscapes intended to teach students about their university community through embodiment, so our initial analytic lens was ill-equipped to see inertness as a legitimate state of collaborative learning in place. Using more typical qualities of collaboration from an interaction analysis frame, students' participation in SensEscapes looked divorced from place and one another *because of* the mobile devices. Yet, we knew from students' reflections after the activity that learning and engagement were high. We resituated our analytic lens to the context; by paying close attention to convergent talk and device use, and postural tuning to allow for quick glances to a neighbor's screen, it was evident the mobile device set up micro-mobilities (Luff & Heath, 1998) important for building shared understandings of the place, on the move. Still, our findings also point toward redesigns in both the mobile application and the overall activity that diminish the time spent in the digital world and increase time spent with the landscape.

## Calibrating personal gestures within a collaborative embodied STEM simulation

Robb Lindgren, James Planey, and Jason Morphew

Recent research has shown significant learning and engagement gains for single-user embodied simulations where a participant mobilizes their body to make predictions and structure their reasoning around a science domain such as planetary astronomy (e.g., Lindgren, Tscholl, Wang, & Johnson, 2016). In particular, our lab has shown benefits of a gesture recognition system that adapts to a learner's personal gestural representation of simulation functions (Junokas, Lindgren, Kang, & Morphew, 2018). At the same time, embodied learning simulations are often best situated within social learning environments such as classrooms and museums where there is an opportunity to work collectively and construct shared representations (Enyedy, Danish, Delacruz, & Kumar, 2012). Our current efforts are focused on embedding a scheme for personalized gestures within collaborative simulation tasks such that a learner keeps their ideas about STEM grounded in their own bodily but must still calibrate their actions with the simultaneous embodied expressions of other learners.

The current multiplayer version of our ELASTIC<sup>3</sup>S simulation tasks require students to collaboratively problem-solve to explore complex dynamic systems such as the greenhouse effect, predator-prey interactions, and chemical equilibrium. Within the simulations, each student is able to control the rate of change of a variable which has an effect on the equilibrium of a system. In order to compare the effect of two simultaneously changing rates, students work collaboratively to reach and maintain an equilibrium point. We aimed to facilitate collaboration by providing each student with a portion of the information through the use of a three-screen projection system (Figure 2 middle and right). Information about the students' individual actions are projected onto the left and right screen, whereas information about the system threshold and equilibrium is displayed on the center screen (Figure 2 left). For example, within the greenhouse effect simulation pairs of students were asked to reach and maintain different levels of carbon dioxide in the atmosphere and to explore the effects on the global temperatures, sea level, and ice cap size. One of the individuals in the dyad controls the rate at which carbon dioxide entered into the system through increases or decreases in the number of factories, while the other student controls the rate at which carbon dioxide leaves the system through increases or decreases in the amount of photosynthetic biomass.



**Figure 2.** Left: Center sim screen showing change CO<sub>2</sub>. Middle: Two participants controlling rate with an invented gesture. Right: Two participants controlling rate by showing a line slope with their arms.

Preliminary pilot sessions with the climate change simulation have demonstrated the potential to establish a collaborative environment that fosters communication while critically engaging with the science content. When presented with the tasks within the simulation, pilot participants have primarily taken one of two approaches, either initiating a collaborative dialog immediately after the task is presented in an attempt to plan

and coordinate their inputs based on their understanding of the system, or immediately beginning to modify their inputs to the system separately with individual observations and struggles ultimately initiating a productive collaborative dialog. Both resulted in participants reaching their goal and reflecting upon their process.

Personalized embodied interactions can be a powerful approach to cultivating new, grounded understandings of complex domains, but new technologies should aspire to support these interactions in a collaborative context where dependencies are apparent and gestures can be synergistic.

## **Computing reality through collaborative, embodied debugging: How learners design and debug mixed reality games**

Breanne K. Litts and Chase K. Mortensen

Embodied cognition (Wilson, 2002) suggests that humans often work out their thinking by interaction with the world through bodily or physical interactions. Mixed reality technologies (Milgrim & Kishino, 1994), which overlay or integrate digital objects or interactions with the real world, afford unique contexts to examine how learners engage in embodied cognition. Scholars (e.g., Lindgren & Johnson-Glenberg, 2013) not only recognize the potentially transformative impact of how these technologies afford *embodied learning*, but also encourage research and design considerations for such activities. At present, though, most of these efforts are thinking about how to design *for* learners, but we also see the value of thinking about how to equip learners to design *with* mixed reality technologies. Thus, in this study, we explore how learners engage in collaborative embodied learning when designing their own mixed reality location-based games.

In partnership with a local makerspace, we conducted two afterschool workshops with 19 middle school aged participants (3 girls, 16 boys, ages 10-13) in a rural city in the Western United States. Over the course of 12 hours (six 2-hour sessions), learners designed mobile, location-based games with mixed reality technology about local plants and animals. Learners engaged in a design process of research, storyboarding, digital construction, playtesting and debugging, including several iterations of outdoor collaborative debugging sessions during which learners playtested each other's games and exchanged feedback. We collected a range of data including in-process video and audio recordings, design artifacts, photographs, field notes from at least three researchers, and final reflective interviews with learners. In this paper, we focus our analyses on the outdoor collaborative debugging sessions across all participants. We constructed cases (Stake, 1995) from each session of outdoor collaborative debugging and compared across cases (Miles, Huberman, & Saldaña, 2013) to illustrate the ways in which youth engaged in and embodied designing *with* location-based mixed reality technologies.

Findings provide insights for how learners make sense of the mapping of game content and mechanics onto physical location and place through both experienced and observed embodiment. When playtesting others' games, learners experienced embodied design by moving around the physical world to collect digital items. For example, Peter, a 12-year-old Caucasian boy, playtested Doug's, a 12-year-old Caucasian boy, game, entitled "Wolf Quest", which challenges a player to "catch squirrels, like the lowest-ranking animal... you can use them to capture higher level class levels of animals" (Interview, 04/05/2017). While playing, Peter exclaimed "I'm drowning in squirrels!" and explained to Doug that he should change the game's algorithm to reduce the number of squirrels and make them spawn further from the player, because it was "drowning" the player making it too easy to level up. When others playtested their games, designers were able to observe how the player embodies their design. For instance, after a collaborative outdoor debugging session, Gracie, a 10-year-old Hispanic girl, reflected on observing others who sprinted around to try to play her game: "It's not working very way, it makes [him] go way waaay over there!... I made it too far" (Audio Recording, 03/16/2017). After debugging the issue, she explained how she leveraged this mechanic to increase difficulty in her game over time, "For the like three levels it's gonna be pretty easy, but then the items are gonna be harder to catch: it's gonna be further away from you, you're gonna have less time" (Interview, 03/30/17). Through observation and feedback, Gracie built an understanding of how players embody her design and how to leverage the development platform's computational algorithm to align with her design goals.

These cases illustrate how learners across the workshop embodied each other's location-based mixed reality games in collaborative outdoor debugging sessions, and how debriefing with feedback supported designers' computational and design understandings. This not only highlights how the collaborative moments shifted learners' designs, but also demonstrates the value of equipping learners as designers of mixed reality technologies, especially in support of embodied learning.

## **References**

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the learning sciences, 21*(2), 247-286.

- Bowles, N. (2018, October 26). A dark consensus about screens and kids begins to emerge in Silicon Valley. *The New York Times*. Retrieved from <https://www.nytimes.com/2018/10/26/style/phones-children-silicon-valley.html>
- Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE bulletin*, 3, 7.
- Danish, J. A., Enyedy, N., Saleh, A., Lee, C., & Andrade, A. (2015). *Science Through Technology Enhanced Play: Designing to Support Reflection Through Play and Embodiment*. Paper presented at the Exploring the Material Conditions of Learning: The Computer Supported Collaborative Learning (CSCL) Conference, Gothenburg, Sweden.
- Danish, J. A., Humburg, M., Tu, X., Davis, B., & Georgen, C. (2018). *Modeling bees by acting as bees in a mixed reality simulation*. Paper presented at the Intl Conference of the Learning Sciences, London, England.
- Dewey, J. (1938; 2007 ed). *Experience and education*. Simon and Schuster.
- Engeström, Y. (1987). *Learning by Expanding: An Activity - Theoretical Approach to Developmental Research*. Helsinki: Orienta-Konsultit Oy.
- Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review*, 5(1), 1-24. doi:<https://doi.org/10.1016/j.edurev.2009.12.002>
- Enyedy, N., Danish, J. A., Delacruz, G., & Kumar, M. (2012). Learning physics through play in an augmented reality environment. *International Journal of Computer-Supported Collaborative Learning*, 7, 347-378.
- Goffman, E. (1963). *Behavior in Public Spaces*. New York: The Free Press.
- Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of pragmatics*, 32(10), 1489-1522.
- Hall, R., & Nemirovsky, R. (2012). Introduction to the special issue: Modalities of body engagement in mathematical activity and learning. *Journal of the Learning Sciences*, 21(2), 207-215.
- Hall, R., Stevens, R., & Torralba, T. (2002). Disrupting representational infrastructure in conversations across disciplines. *Mind, Culture, and Activity*, 9(3), 179-210.
- Heritage, J., & Robinson, J. D. (2006). The structure of patients' presenting concerns: physicians' opening questions. *Health communication*, 19(2), 89-102.
- Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA, US: The MIT Press.
- Junokas, M. J., Lindgren, R., Kang, J., & Morpew, J. W. (2018). Enhancing multimodal learning through personalized gesture recognition. *Journal of Computer Assisted Learning*.
- Kirsh, D. (2011). How marking in dance constitutes thinking with the body.
- Lakoff, G., & Johnson, M. (2008). *Metaphors we live by*. University of Chicago Press.
- Lakoff, G., & Núñez, R. E. (2000). *Where mathematics comes from: How the embodied mind brings mathematics into being*. Basic Books.
- Lee, V. R. (Ed.) (2015). *Learning technologies and the body: Integration and implementation in formal and informal learning environments*. New York, NY: Routledge.
- Lee, V., Thurston, T., & Thurston, C. (2017). A Comparison of Discovered Regularities in Blood Glucose Readings across Two Data Collection Approaches Used with a Type 1 Diabetic Youth. *Methods of Information in Medicine*, 56(open), e84-e92. doi:10.3414/ME16-02-0047
- Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher*, 42(8), 445-452.
- Lindgren, R., Tscholl, M., & Wang, S., & Johnson, E. (2016). Enhancing learning and engagement through embodied interaction within a mixed reality simulation. *Computers & Education*, 95, 174-187.
- Luff, P., & Heath C. (1998). Mobility in Collaboration. In S. Poltrock & J. Grudin (Eds), *Proceedings of the 1998 Conference on Computer Supported Cooperative Work* (pp. 305-314). ACM: Seattle.
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2013). *Qualitative data analysis: A methods sourcebook*. SAGE Publications, Incorporated.
- Montessori, M. (1917). *The Advanced Montessori Method*..(Vol. 1). Frederick A. Stokes Company.
- Peppler, K., Halverson, E., & Kafai, Y. B. (Eds.). (2016). *Makeology: Makerspaces as learning environments* (Vol. 1). Routledge.
- Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: SAGE.
- Stevens, R. (2012). The missing bodies of mathematical thinking and learning have been found. *Journal of the Learning Sciences*, 21(2), 337-346.
- Taylor, K.H. & Hall, R. (2013). Counter-mapping the neighborhood on bicycles: Mobilizing youth to reimagine the city. *Technology, Knowledge, & Learning* 18(1-2), 65-93.
- Wilson, M. (2002). Six views of embodied cognition. *Psychonomic bulletin & review*, 9(4), 625-636.





# Posters



# Effects of a Digital Guided Peer Feedback System on Student Learning and Satisfaction

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**Abstract:** This study investigates the effects of a digital guided peer feedback on students' learning and satisfaction. Participants were 203 students who were randomly assigned to groups of three. students were asked to explore various perspectives, and the 'pros and cons' on the topic of 'Genetically Modified Organisms (GMOs)'. The findings show that the digital module fosters students' learning and satisfaction.

**Keywords:** attitudinal change, digital learning module, learning, peer feedback, student satisfaction

## Introduction

Digital learning modules are increasingly introduced in higher education, including in the life sciences (Noroozi & Busstra et al., 2012). They provide students with various modes of information presentation, such as texts, exercises, graphs, diagrams, animations, pictures etc., that can support students' learning. The use of such modules can also be challenging especially in real educational settings in which motivational aspects for learning are crucial. An approach to stimulate motivation for students to embrace such modules in their courses is to design and develop modules with peer feedback possibility that provide them with pleasant opportunities for learning. Despite the fact that scientific literature highlights the importance of feedback for learning (see Bayerlein et al., 2014), there remains a challenge for students to construct good quality feedback in collaborative settings (see Noroozi & Weinberger et al., 2012, 2013). As a result, the feedback may remain at the surface level and lack solid arguments for promoting deep learning. Thus, additional feedback support is needed if students are to willingly and with a high degree of motivation provide high-quality feedback in such modules. This study thus designs, implements, and evaluates a digital learning module with an intensified peer feedback support. The goal is to explore whether a digital module with guided peer feedback which encourages challenges and motivation support students' domain specific knowledge gain. In addition, the extent to which the use of such a digital learning module is appreciated by students is studied as well.

## Methods

The study took place at Wageningen University in the Netherlands with 203 BSc students who were divided into groups of three students. The topic for discussion was Genetically Modified Organisms (GMOs) with the focus on the use of "cultured meat manufacturing – insect cells". A digital module was designed with a web-enabled platform that provides students with various modes of information presentation, such as texts, exercises, graphs, diagrams, and pictures with the feedback features. The feedback features was designed in such a way as to guide the interaction style for both synchronous and asynchronous interactions – promoting reasoning, critical discussion, and justified arguments – (see Figure 1). Overall, the session took about 4 hours and consisted of four main phases.

Table 1: Features of a good reflection report and guided peer feedback embedded in the digital module

Number	Features of a good reflection report by panel of experts and teachers	Guided peer feedback embedded in the digital module using input text boxes and sentence openers
1	The intuitive opinion on the topic.	To what extent your learning partner present his/her intuitive opinion on the topic? Is that clear? Why or why not? (30 to 50 words).
2	The arguments in favour of the topic (pros).	To what extent your learning partner provide arguments in favour of the topic? To what extent your learning partner reflect the opinion of the advocates on the topic? (30 to 50 words).

3	The scientific facts in favour of the topic (pros).	To what extent your learning partner provide arguments against the topic? To what extent your learning partner reflect the opinion of the opponents on the topic? (30 to 50 words).
4	The arguments against the topic (cons).	To what extent your learning partner provide scientific facts in favour of the topic? (30 to 50 words).
5	The scientific facts against the topic (cons).	To what extent your learning partner provide scientific facts against the topic? (30 to 50 words).
6	The opinion on the topic taking into account various pros and cons.	To what extent your learning partner integrate various pros and cons of the topic? (30 to 50 words).
7	The arguments and scientific facts (evidence, examples, figures, facts etc.) to support opinion.	Does your learning partner come to a conclusion based on his/her arguments? What do you think about his/her conclusion? (30 to 50 words).
8	The final conclusion and statement on the topic.	What are your suggestions for improving the quality of the reflection report of your learning partner? (30 to 50 words).

A pre-test post-test questionnaire was used to measure students' domain-specific knowledge gain. This questionnaire consisted of 17 multiple-choice questions. A questionnaire was used to assess students' motivation and satisfaction with the learning experiences. This questionnaire consisted of four main sections and 36 items in total on a five-point Likert scale ranging from "almost never true", "rarely true", "occasionally true", "often true" through to "almost always true".

## Findings

Repeated measurement for ANOVA test showed that the domain-specific knowledge of students improved significantly from pre-test to post-test. This indicates the positive effects of the digital learning module on the domain-specific knowledge gain of students. Students' motivation and satisfaction with the learning experiences appeared to be sufficiently high (around four on a five-point Likert scale) for all students.

## Conclusions and implications

This study used a digital learning module that also supported peer feedback process to engage students in an intensified processes of learning and writing about a controversial topic. The module was designed in such a way as to provoke students for exchanging and directing diverse and multiple conflicting opinions towards deeper reasoning. The use of peer feedback support guided the students in appropriate ways to analyse learning partners arguments about the topic, express agreements/disagreements and when possible integrate various points of views in their own reflection report. This digital learning module provided a safe and respectful learning environment for students to also practice their argumentation and exercise critical discussion and reasoning skills without recourse to, or fear of, personal statements, enhancing their awareness of the topic. Exchanging diverse and multiple conflicting opinions, analysing one another arguments, and expressing agreements/disagreements supported with scientific facts, arguments, logical evidence and examples were then reflected in the attitudinal change of students towards the controversial topic of the GMOs from pre-test to post-test.

## References

- Bayerlein, L. (2014). Students' feedback preferences: How do students react to timely and automatically generated assessment feedback? *Assessment & Evaluation in Higher Education*, 39(8), 916-931.
- Noroozi, O., Busstra, M.C., Mulder, M., Biemans, H.J.A., Tobi, H., Geelen, M.M.E.E., van't Veer, P., & Chizari, M. (2012). Online discussion compensates for suboptimal timing of supportive information presentation in a digitally supported learning environment. *Educational Technology Research and Development*, 60(2), 193-221.
- Noroozi, O., Weinberger, A., Biemans, H.J.A., Mulder, M., & Chizari, M. (2012). Argumentation-based computer supported collaborative learning (ABCSCCL). A systematic review and synthesis of fifteen years of research. *Educational Research Review*, 7(2), 79-106.
- Noroozi, O., Weinberger, A., Biemans, H.J.A., Mulder, M., & Chizari, M. (2013). Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. *Computers and Education*, 61(2), 59-76.

# StandUp: Engaging Professionals to Coach Design Projects

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**Abstract:** To investigate how we might expand learning environments to include professionals to coach students enacting disciplinary practices, we created StandUp, a socially-shared regulation of learning (SSRL) system. We implemented StandUp in an undergraduate design program with 3 student teams and 5 volunteer professionals. We captured 12 online coaching interactions that significantly changed project trajectories. This suggests SSRL designs can encourage online coaching that influences project trajectories.

## Introduction

Educational researchers have long imagined how learning environments might better connect to disciplinary practice, such as engaging volunteer professionals with disciplinary expertise in classrooms (Brown & Campione, 1994). Online systems might connect students and professionals who can only rarely meet face-to-face. We implement *StandUp*, a system created to connect student design teams with professional designers who coach the teams off- and online. Design education uses project-based learning in which students work in teams to create products or services in response to a problem experienced by real-world stakeholders. Specifically, we examine if online coaching supports student design project trajectories.

Prior work shows it is unlikely professionals and students will sustain online coaching interactions independently (Rees Lewis et al., 2015): (a) students do not communicate their thinking clearly online (communication barrier), (b) students are not motivated to communicate with professionals because they did not see communicating online as immediately useful to their project (motivation barrier), and consequently (c) professionals do not have enough information about team activities and thinking to coach (awareness barrier).

The design argument for StandUp draws on SSRL (Järvelä & Hadwin, 2013). To encourage online coaching from professionals we propose SSRL systems (Järvelä & Hadwin, 2013) should include (a) a regular SSRL script in which students make daily and weekly project goals, report project progress, and surface obstacles; (b) questions prompts and textboxes to help teams to surface and record goals, progress, and obstacles on a feed (figure 1a); and (c) automated emails prompting coaches to leave online comments on the feed (Rees Lewis et al., 2017). In previous work we showed StandUp could increase both student communication to coaches online, and subsequent online coaching (Rees Lewis et al., 2017). However, research has not explored whether these online coaching interactions influenced student project trajectories. So, we ask *can coaching through online SSRL systems impact student design team project trajectories?*

## Methods

We implemented *StandUp* in a 6-week full-time (40hrs/week) extra-curricular (no credit/grades) US university design program. Each of the 3 teams of 4 undergraduates were paired with 1-2 unpaid design professionals who coached the team. Professionals had 2 hour face-to-face meetings with the teams a week, and also agreed to communicate online for 2-hours/week. Teams worked with clients and other stakeholders on improving: access to healthy food, newly diagnosed diabetics lifestyle adjustments, or refugee transitions. Participants were 12 US undergraduates, and 5 professionals with between 5-34 years of relevant professional experience.

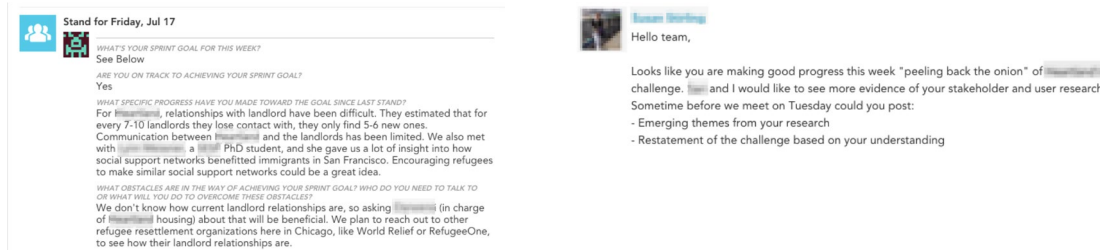
We interviewed students and professionals, collecting log data of StandUp use, and in-person field observations. We conducted 18 semi-structured interviews with students (20-36 minutes) and 6 semi-structured interviews with professionals (20-75 minutes), in which we asked questions about the project, and use of StandUp. We collected the log-data in the form of student and coach posts. In total there were 63 online coaching comments. We also collected field notes from 30-60 minutes of classroom observations each day.

To see if online coaching impacted team project trajectories, we first conducted inductive coding (Miles, Huberman, & Saldaña, 2013) to identify each section in student transcripts to find references of online coaching informing team trajectories. We defined project trajectories as changes in (a) project goals, (b) ways to achieve a goals, and (c) teamwork processes (e.g. meetings). Once we found a reference to changes in project trajectory in student interviews, we would then locate the online coaching comment students referenced, and checked if the professionals coaching the team also referenced this change. Finally, we would check if there were any references in the field notes to this change in trajectory. That is, we would only count an instance of a change in trajectory if we could find evidence in interviews with students, professionals, and in field notes.

## Findings

Our analysis found 12 changes in project trajectories from online coaching comments across the 3 teams. We found 4 instances of teams changing their goals about what to investigate or build, 5 instances of changing how to enact a plan for a given goal, and 3 changes in work processes. This is an increase over the previous year in which teams did not use StandUp, online coaching did not occur, and thus had no impact on project trajectories.

The following example illustrates a team changing goals in response to an online coaching comment. The team was working on supporting the transition of newly arrived refugees. The team posted on a Friday about learning about their client's relationship with landlords of refugees, an interview with a refugee case worker, and an idea about designing "social support networks" for refugees (figure 1a). Two hours later, the professional posted suggesting carrying out more synthesis of user interviews with refugees (Figure 1b).



**Figure 1a** (left). StandUp report from a student design team that elicited online coaching.

**Figure 1b** (right). The online coaching in turn lead to a team changing their goals.

In an interview the professionals explained that she wrote the comment (figure 1b) because she was concerned the team was focusing on the wrong user (landlords) and solutions for an unnamed problem (social support networks), without understanding the needs of their primary user (refugees) ("Nobody paused to say what are the deeper insights for the stakeholders [refugees]"). In interviews, three students noted that upon reading the comment (figure 1b) they shifted to synthesizing existing refugee interviews. Field notes showed on the four days after the coaching comment the team worked on listing the findings from refugee interviews.

The other 3 instances of teams changing goals also saw changes in team activity across multiple days. Other instances involved (1) another example of conducting synthesis to focus on primary user needs, (2) changing the type of users and goals during user testing, and (3) conducting testing rather than user research. There were also 5 instances of professionals' comments changing how students enacted their plans to complete their goals. There were (1) 2 instances involving changing how to conduct solution testing, (2) 1 instance of changing how to brainstorm, and (3) 2 instances involving taking up specific methods of synthesizing user research. Finally, there were three instances of professionals' comments on work processes leading to changes in teamwork. These were (1) regularly timing how long activities took to monitor efficiency, (2) changing their work patterns, and (3) conducting group reflection meetings to improve teamwork practices.

This work shows that SSRL tools (Järvelä & Hadwin, 2013) can influence project trajectories; StandUp supported professionals' influence on student practices, despite barriers to volunteer professionals coaching teams (Rees Lewis et al., 2015). This work suggests that if we want to encourage online coaching comments from volunteer professional that supports students project trajectories, we should use: SSRL technologies (Järvelä & Hadwin, 2013) that support students to discuss and summarize their goals, activities, and obstacles into a written report which is emailed to the professional. This work contributes to our knowledge of how to engage professionals online to supporting students enacting disciplinary practices (Brown & Campione, 1994).

## References

- Brown, A. L., & Campione, J. C. (1994). *Guided discovery in a community of learners*. Boston, MA: MIT.
- Järvelä, S., & Hadwin, A. F. (2013). New frontiers: Regulating learning in CSCL. *Educational Psychologist*, 48(1), 25-39.
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2013). *Qualitative data analysis: A methods sourcebook*. Thousand Oakes, CA: SAGE Publications
- Rees Lewis, D. G., Easterday, M. W., Harburg, E., Gerber, E. M., & Riesbeck, C. K. (2018). Overcoming barriers between volunteer professionals advising project-based learning teams with regulation tools. *British Journal of Educational Technology*, 49(3), 354-369.
- Rees Lewis, D., Harburg, E., Gerber, E., & Easterday, M. (2015). Building support tools to connect novice designers with professional coaches. In *Proceedings of the 2015 ACM Conference on C&C* (pp. 43-52).

# Scaling Dialogic Peer Feedback via Learning Analytics and Scripts

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**Abstract:** Dialogic peer feedback is a challenge to design and implement when learning takes place at scale. For proper implementation of dialogic feedback among large learning cohorts, peers' interactions and learning activities need to be framed and systematized within a solid theoretical perspective. This paper presents a theoretical model of dialogic peer feedback, consisting of three interconnected phases. This model incorporates learning analytics and scripts to support individual and collaborative regulatory processes involved in each phase.

## Introduction

Peer review has been a common approach to scale feedback among large learning cohorts. However, the way it is practiced offers limited potential for learning. Students often receive peers' feedback after they move to a different task (Carless, 2006), and the feedback process lacks follow-up interactions, which are crucial to understanding the feedback (Stahl, Koschmann, & Suthers, 2006). In the last years, the dialogic view on feedback has been favoured (Yang & Carless, 2013). When conceptualized as a dialogic process, peer feedback is conceived as a collaborative learning activity during which students reflect on the feedback received, construct and negotiate meaning with peers, and reach joint conclusions (Filius et al., 2018). Although literature notes significant learning gains when dialogue is part of feedback process, dialogic peer feedback is a challenge to design and implement when learning takes place at scale. This paper presents a theoretical model of dialogic peer feedback. This model identifies regulatory learning processes that students should undertake (collectively and individually) and recognizes the affordances of learning analytics and scripts to support these processes and to create scalable feedback practices.

## Background

Dialogue can elevate the power of feedback (Carless, 2016). However, most feedback practices in the literature consider instructors' active engagement in dialogue, which is unlikely in large contexts. Initiating and continuing dialogue with every student and addressing their distinct learning needs is infeasible for instructors who teach large enrolment classes. One approach to mitigate this issue is to involve peers in dialogic feedback. Indeed, large learning settings of higher education offer desirable conditions for dialogic peer feedback. Large learning cohorts, who are considered a barrier to scaling (instructor-centred) dialogic feedback (Nicol & Macfarlane-Dick, 2006), indeed are the necessary source to leverage for initiating dialogic interactions.

For dialogic feedback to function effectively among large learning cohorts, peers' interactions and learning activities need to be framed and systematized within a solid theoretical perspective. The literature is limited primarily to a very basic conceptualization of dialogic feedback as talking with peers to understand their feedback. To the best of our knowledge, there are no theoretical models that conceptualizes dialogic peer feedback in a way that can scale to large learning cohorts in today's higher education context. In the following section, we present a model of dialogic peer feedback to help formulate scalable feedback practices.

## A model of dialogic peer feedback

We present a model of dialogic peer feedback in Figure 1, targeting large scale online or blended learning environments. Three interconnected phases are suggested in the model. First phase involves negotiation and coordination of feedback provision, during which peers providing feedback work together to plan and coordinate their activities. The second phase refers literally to the dialogue component of the dialogic feedback, which has been the main focus of the literature (Zhu & Carless, 2018). In this phase, based on their shared plan, peers provide feedback and engage in dialogue with the student to support the uptake of the feedback. The third phase refers to the translation of the feedback into task progress by the recipient student. In particular, the student engages in the task based on the plan derived from peer feedback and progress toward the learning goals set.

Each of these phases involves different levels of regulated learning. The first phase involves the peers' socially shared regulation of learning (SSRL) to negotiate the feedback activities (Hadwin, Järvelä, & Miller, 2011); the second phase involves co-regulation of learning (CoRL) as peers intend to guide students' regulation of learning (Hadwin, Oshige, Gress, & Winne, 2010); and, the last phase involves students' self-regulation of their learning (SRL) (Winne & Hadwin, 1998). Scripting support is integrated to guide students' SSRL (in the

first phase) and CoRL (in the second phase) activities and to shape their interactions with each other. Learning analytics support is integrated to assist students in monitoring and evaluating their individual and collective progress based on certain standards. Based on their evaluations, students can make adaptations in their task perceptions, goals, and strategies.

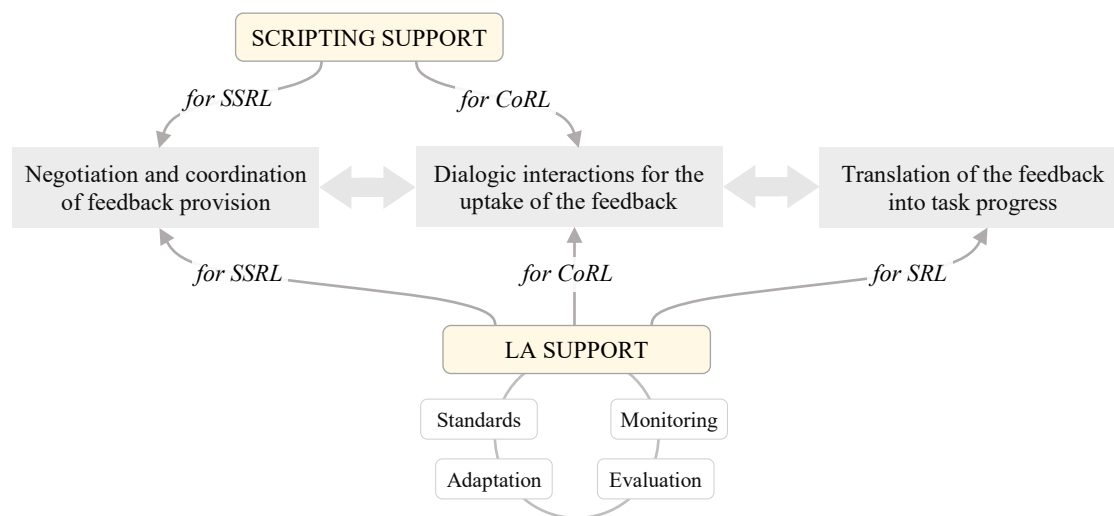


Figure 1. A model of dialogic peer feedback.

## References

- Carless, D. (2006). Differing perceptions in the feedback process. *Studies in Higher Education*, 31(2), 219–233.
- Carless, D. (2016). Feedback as dialogue. In M. Peters (Ed.), *Encyclopedia of Educational Philosophy and Theory* (pp. 1–6). Singapore: Springer. <https://doi.org/10.1007/978-981-287-532-7>
- Filius, R. M., de Kleijn, R. A. M., Uijl, S. G., Prins, F. J., van Rijen, H. V. M., & Grobbee, D. E. (2018). Strengthening dialogic peer feedback aiming for deep learning in SPOCs. *Computers & Education*, 125, 86–100. <https://doi.org/10.1016/j.compedu.2018.06.004>
- Hadwin, A. F., Järvelä, S., & Miller, M. (2011). Self-Regulated, Co-Regulated, and Socially Shared Regulation of Learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of Self-Regulation of Learning and Performance* (pp. 65–84). <https://doi.org/10.4324/9780203839010.ch5>
- Hadwin, A. F., Oshige, M., Gress, C. L. Z., & Winne, P. H. (2010). Innovative ways for using gStudy to orchestrate and research social aspects of self-regulated learning. *Computers in Human Behavior*, 26(5), 794–805. <https://doi.org/10.1016/j.chb.2007.06.007>
- Nicol, D., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, 31(2), 199–218.
- Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge, UK: Cambridge University Press.
- Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesse (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Hillsdale, NJ: Erlbaum.
- Yang, M., & Carless, D. (2013). The feedback triangle and the enhancement of dialogic feedback processes. *Teaching in Higher Education*, 18(3), 285–297.
- Zhu, Q., & Carless, D. (2018). Dialogue within peer feedback processes: Clarification and negotiation of meaning. *Higher Education Research & Development*, 37(4), 883–897.

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# A Case Study on the Development of Pre-Service Teachers' Design Thinking

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**Abstract:** This study aimed to understand the learning effect of design thinking activities of college students in an undergraduate class. The results showed that after experiencing the design thinking activities, the participants successfully created their course product (i.e., online learning courses in the prototype form) through online discussion, reflection and peer feedback under the guidance of knowledge-building pedagogy. It is also found that students had a slightly improved gain in terms of technological pedagogical content knowledge & technology-integrated design knowledge and their design belief of teachers.

## Introduction

Design thinking, a praxis model of learning by doing, has recently been recognized as an effective teaching and learning strategy. In the present study, design-thinking activities under the guidance of knowledge building pedagogy was found to facilitate students' design of a course project/product, i.e., an online course in the form of a prototype (Toshiaki, 2013) and to help them develop creativity in an integrated, cross-disciplinary manner (Goldman, Estrada, 2016). Not only were the learners able to collaboratively build new knowledge by addressing a challenging, ill-structured design problem together in the knowledge building community, but they were also benefited from improving their integration ability that is required as a part of their pre-service teacher preparation and training program (IDEO, 2017).

Online learning has been an important part of the K12 landscape in Taiwan, but the field still has some issues to be further researched. For instant, most of the online learning content in Taiwan are decontextualized; as such, what is learned online can easily become inert knowledge. To address this issue, teachers can strengthen their design knowledge and design thinking capacity to guide students to use learning material and content more authentically and meaningfully to solve some real-life tasks. Previous research has claimed that learning together as a community, effective use of discussion, group reflection, and peer feedback can greatly help improve learning outcomes (Jim, 2010). By incorporating and implementing these activities together into a design cycle, this research is trying to examine the effect of design thinking activities, as guided by knowledge building pedagogy, on students' TPACK and design beliefs.

## Method and data

This case study adopted a design research method with two design iterations. The experiment was carried out in an authentic environment without a specific control group. The participants were 38 teacher-education students who took a course in a Taiwan's university concerning the use of educational media for education. Students were randomly divided into 10 groups (each group containing two to five persons). They were then asked to work collaboratively to develop an online learning course which should at least contain three class time periods, and should include contextualized learning content for their target users/learners to learn independently online without teacher aid. In the entire semester, design thinking activities, with the guidance of knowledge building pedagogy, were adopted as the main instructional activities in the course. There was also a mid-term and a final-term presentation for students to test their designed online course as a prototype and to give feedback to one another so as to improve one another's prototype design. For data analysis, students' online interactions and the process of their design thinking were analyzed using coding schemes progressively emerged from data (open coding) with the help of the software NVivo 12. Then, a descriptive statistic was calculated within each of the groups. Moreover, two seven-point Likert-scaled questionnaires (i.e., Technological Pedagogical Content Knowledge, & Technology-Integrated Design Knowledge and Design Belief of Teacher; both Cronbach alpha >.90) were employed before and after the course and then a t-test was performed.

## Results

The implementation of this research was based on a course that required class students to design an online learning course in a prototype form. As such, the participants need to work in teams and discuss their design project in an

online forum called Knowledge Forum (KF). The KF can auto-record the entire process of all online activities. To analyze the online logs, firstly, it was found that the participants' action of the note-reading ( $M=505$ ,  $SD=241.15$ ), note-revising ( $M=133.3$ ,  $SD=114.37$ ), note-creating ( $M=39.3$ ,  $SD=11.91$ ) showed a good design pattern that supports user-centered learning after repeated modification via within-group revision and between-group idea-exchange. Secondly, the results concerning the groups' design thinking activities showed progress at each of the activity stages (see Fig.1, left), including empathy ( $M=5.06$ ,  $SD=0.90$ ), define ( $M=8.53$ ,  $SD=2.19$ ), ideate ( $M=13.13$ ,  $SD=1.69$ ), prototype ( $M=13.47$ ,  $SD=1.19$ ), test ( $M=9.81$ ,  $SD=1.72$ ) and feedback ( $M=10.86$ ,  $SD=1.08$ ) stages. After the first design iteration, a screenshot of a mid-term presentation was captured (Fig.1, mid), and the final design result showed a better and completed final design interface (Fig.1, right). Thirdly, regarding the two questionnaires, including TPACK & T-IDK ( $M=-5.60$ ,  $SD=1.36$ ,  $t=-13.02$ ) and DBT ( $M=4.30$ ,  $SD=1.45$ ,  $t=-9.37$ ) they both showed improvement from pre-test to post-test.



**Figure 1.** Design thinking process (left); a screenshot of the mid-term report on the interface design presented by one group (mid); a few screenshots of the final-term design interface presented by the same group (right).

## Discussion and conclusion

With the rapid development of technology, various walks of life have changed their approach to dealing with issues with digitalization. In particular, the educational field has tried to keep up with the times in supplying different teaching methods for current digital native learners. Accordingly, for teachers to learn and design new learning sources before they enter the teaching workplace, they should change their fixed mindset about “learning” and “knowledge acquisition” by developing a growth mindset that highlights design and knowledge creation. By engaging students in design thinking activities as guided by knowledge building pedagogy in this course, it was found that their TPACK knowledge was enhanced. The results also showed that they could come up with interesting design ideas and translate them into actions to improve their final projects—online learning courses. More importantly, it is also clear that the knowledge building environment employed in this study allowed students to generate and advance their ideas that served as an indispensable part of their learning to support their design thinking.

In addition, during students' design thinking process, it was found that their discussion, reflection, and feedback-giving activities have great influence on the finally designed online product/project. In particular, the “feedback” activity have helped students to perform better in the “ideate” and “prototype” stages. Moreover, as students were engaged in actual hands-on learning experience of product design, they were able to actually solve many different practical, ill-structured, and contextualized real-life related problems. Such active-inquiry activities not only give the participants learning opportunities to integrate their design knowledge and TPACK knowledge (in particular, technology-related TPACK knowledge), but they also help them to adapt their traditional teaching views to accepting more diversified ways of thinking about teaching. For further research, we will try to analyze in-depth the participants' behavior sequence in order to strengthen the evidence.

## References

- Goldman, S., & Estrada, L. R. C. (2016). A praxis model for design thinking: Catalysing life readiness. In *Taking Design Thinking to School*, 55-68. New York: Routledge.
- IDEO (2017). Design thinking for educators. Retrieved from <https://designthinkingforeducators.com/>
- New Zealand Centre for Political Research (2017). Singapore's education system: Some key success factor. Retrieved from <https://www.nzcp.com/singaporeseducation-system-some-key-success-factors/>
- Toshiaki, K. (2013). Design thinking education at universities and graduate schools. *Quarterly Review on Sciences & Technology Trends*, 46, 50-63.
- Wong, Y. L (2010). Design thinking for the 21st Century. Retrieved from <http://singteach.nie.edu.sg/issue31-teachered/>

# Rural Students' Cultural Assets During Science Argumentation

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**Abstract:** Rural students have lower academic achievement in science. Recent research has suggested that contextualizing science instruction in rural life can help rural students learn science. This study uses discourse analysis to show how collaborative argumentative science discussions that give students interpretive authority can help students access cultural resources. Early results indicate the potential benefits of integrating collaborative argumentation in science teaching and learning among rural students.

## Objectives

Compared to urban students, students in rural regions of the United States have lagged in terms of achievement in science. They have lower test scores in science, take less advanced science classes, and enter science careers at lower rates than students from urban regions (Abrams & Middleton, 2017). This is not surprising given that rural students experience higher rates of poverty, have less technological resources or opportunities for extra curricular activities, and have less qualified teachers (National Student Clearinghouse Research Center).

Much research on rural education has been focused on changes that fix the problems of rural youth (Harmon, Henderson, & Royster, 2003). This effort is laudable; however, recent research has tried to look at rural education through a positive perspective. This includes looking at the cultural assets of rural children (Barnhardt, 2005). Aikenhead (2002) has theorized that some of the achievement gap in science education between rural and urban students can be reduced by contextualizing science in the lives of rural children. In other words, educators can improve science education by taking advantage of the strengths of rural children.

This study is trying to extend this line of research by examining rural children's discourses during collaborative science discussions. The authors examined how rural children used their linguistic and cultural assets to collectively understand science. While rural children are a diverse group, they all have rich linguistic and cultural backgrounds that are often neglected by teachers because they do not mirror the language and context of standard science curricula. This study seeks to serve as a demonstration of how these cultural assets can be harnessed through an approach to discussion called Collaborative Reasoning (Reznitskaya et al., 2009). This approach allows students to have interpretive authority and control over the flow of discussion, and enables them to explore their own prior knowledge beyond the traditional bounds of the standard science curricula.

## Perspective(s) or theoretical framework

This work is conducted using a sociocultural framework. In this framework, cognitive processes are first developed as discourse between participants. Then, these cognitive processes are internalized as the collective voice is appropriated by each student to make their own conclusions (Wertch & Bevins, 1992). Reznitskaya et al. (2009) combined the idea of internalization with schema theory (Anderson & Pearson, 1984) to describe how broad argumentation skills are developed through the internalization of many small argumentative devices such as placing the speaker in the position of a character in a story or asking the group to find evidence in the text.

## Methods, techniques, or modes of inquiry

The data was analyzed using discourse analysis. The method uses a careful analysis of language with the understanding that patterns and structures of language communicate social identities and cultural understandings in addition to factual information.

## Data sources, evidence, objects, or materials

The participants are 34 fourth-grade students from three fourth-grade classrooms. They are enrolled in a public school in a rural school district, with the majority of them are Caucasian students. The children met in six discussion groups, each group had two CR discussions on topics relating to counterintuitive scientific phenomena that children of their age would be familiar with. All of their discussions were video taped and transcribed. While there were a total of twelve CR discussions, we included analysis on six discussions about the story "Deep Water" for this paper. In this story, three boys are fishing on a boat. The boys want to take the boat into the deep water, but they are unsure about how the depth of the water will change how well the boat floats. The participants discussed if they thought the children should take the boat into the deep water.

## Early results and/or substantiated conclusions

We found that the cultural experiences of students living in a rural area did in fact help students to understand the scientific concepts. The argumentative structure allowed the students to explore some interesting topics, and required minimum teachers' input to direct the students to the underlying scientific concepts illustrated by their examples. This is demonstrated in the following excerpt:

- Laura: I think that it would--I think because it would--I think it would've already sunk if it was gonna sink, so...
- Ms. Mason: Why would it have already sunk?
- Laura: Like, if it has a lot of stuff in it, um, it's probably gonna, um, sink when you put it in the water but since it--it's just, like, all the way out, I bet it's probably just gonna stay 'cause//
- Eric: //Cause you're not--like I said earlier, you're not adding something every time.
- Mary: Eric, I **challenge** your thinking. Technically they are adding, every time they catch a fish they put it in the boat.
- Eric: But, uh, it said that for a long time they didn't catch any fish, so they only have like three fish and they said they were small fish like they said they were really small fish.
- Justin: And those are like half a pound.
- Mary: But if they go into the deep end and they do catch their catfish, wouldn't it make the boat sink if it was heavy enough?
- Eric: Umm, it could, but, I don't--like, boats are made to float, like, boats are made to hold a lot of

In this excerpt, the teacher only speaks once. The role of the teacher is to encourage the students to use evidence. She does not try to take interpretive authority back from the students. For this reason, they are able to follow a line of reasoning that verges from the story. The story considers only the depth of the water. Here the students are able to use their detailed knowledge of fishing to shift the topic to considering the weight of the boat and the relationship between weight and floating. A teacher-controlled approach to science teaching would depend on the teacher to inject these connections into the class. With the Collaborative Reasoning approach in which students have interpretive authority, the contextualization of science instruction is achieved naturally.

## Scientific or scholarly significance of the study or work

The method of engaging rural children in argumentative discussion allows them to take advantage of their local and unique resources. From a broader perspective, this research is another example of how rural students bring many strengths and resources to their education. While they face increasing challenges in a globalized society, teachers can take some encouragement from examples such as the ones in this paper.

## References

- Abrams, E., & Middleton, M. (2017). Towards multidimensional approaches to research on rural science education. *Cultural Studies of Science Education, 12*, 167-176.
- Aikenhead, G. S. (2002). Whose scientific knowledge? The colonizer and the colonized. In W.-M. Roth & J. De´sauteles (Eds.), *Science education as/for sociopolitical action* (pp. 39-52). New York: Peter Lang.
- Anderson, R. C., & Pearson, P. D. (1984). A schema-theoretic view of basic processes in reading comprehension. In Pearson, P. D. , Barr, R. , Kamil, M. L. , & Mosenthal, P. (Eds.), *Handbook of reading research* (pp. 255-291). New York: Longman.
- Barnhardt, R. (2005). Indigenous knowledge systems and Alaska native ways of knowing. *Anthropology & Education Quarterly, 36*, 8-23. doi:10.1525/aeq.2005.36.1.008.
- Harmon, H. L., Henderson, S. A., & Royster, W. C. (2003). A research agenda for improving science and mathematics education in rural schools. *Journal of Research in Rural Education, 18*, 52-58.
- Reznitskaya, A., Kuo, L.-J., Clark, A.-M., Miller, B. W., Jadallah, M., Anderson, R. C., & Nguyen-Jahiel, K. (2009). Collaborative reasoning: A dialogic approach to group discussions. *Cambridge Journal of Education, 39*(1), 29-48.

# Assessing Iterative Planning for Real-world Design Teams

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**Abstract:** Design disciplines require iteratively defining the problem, and building and testing solutions—consequently design requires regularly planning. However, we do not have frameworks to assess design planning. We propose Team Planning Trajectories (TPT)—a technology assisted formative assessment framework for planning in design classrooms.

## Introduction

Learning environments for real-world design help students learn to tackle highly ill-structured design problems while working closely with stakeholders to create solutions to stakeholder problems (Jonassen, 2000)—solutions such as products, services, or policy. For example, in our research in an instructional design class, one team worked with multiple stakeholders to create a software voting system to generate plans for how a university department could better support underserved students.

One core and under-taught practice in real-world design is planning. Planning in real-world design is vital because design problems are so highly ill-structured—design problems have no initially obvious solution, and no clear steps for solving the problem (Jonassen, 2000). Consequently, design teams must continually plan (Cross, 2011). Unlike experienced designers, student designers tend to plan in a way that reduces their chances of meeting stakeholder needs. Students struggle to plan: (a) in a way that is aligned with the needs of the project, (b) in an efficient way that maximizes learning what solutions might work, and (c) an appropriate workload given their time and experience (Adams et al., 2003; Rees Lewis et al., 2018; Cross, 2011). Assessing planning in real-world design is challenging because teachers do not know the right solution or solution path. Despite the importance of planning, we have not developed formative assessments for design planning.

## The Team Planning Trajectories Assessment Framework

We propose the Team Planning Trajectories (TPT; Figure 1) a technology supported assessment framework we are developing to help teachers and researchers know the extent a learning environment is supporting student team design planning. TPT is a conceptual assessment framework (Pellegrino, 2014)—an assessment blueprint that defines (a) the student performance variables to attend to (student model), (b) the student and teacher activities, and tools used (task model), and (c) how evidence is collected and analyzed (evidence model).

TPT involves organizing the class into iterative 1-2 weeks cycles. At the start of each cycle teams use a project template and a plan template to create a written record of (a) the state of their project, (b) the risks that can make the project fail, and (c) their plan to reduce these risks (Rees Lewis et al., 2018). First, student teams define the current state of their design problem and proposed solution such as user needs, and problem causes. Teams then identify risks—what aspects of their problem and proposed solution might stop them making an effective solution (Carlson, Maliakal, Rees Lewis, Gorson, Gerber, & Easterday, 2018). For example, it is risky if teams have limited evidence of their assumed user need. Teams then plan to reduce their most severe risks.

We propose three variables for assessing student plans drawn from research on design practice and student struggles in design planning (Adams et al., 2003; Rees Lewis et al., 2018; Cross, 2011): (a) Alignment—the extent a plan is aligned with the project. An aligned plan is logically consistent with what the team understands about the problem and solution (e.g. user needs, why existing solutions fail), and most severe risks (e.g. users are 60+ years old, so might not want proposed software solution). (b) Efficiency—the extent the plan achieves the goals efficiently. If the team’s goal is to understand if a solution is desirable, are they planning to spend 3 hours building a prototype, or 3 weeks building a complete working software? (c) Appropriateness of workload—the extent the plan outlines work that the team can achieve given their time and expertise.

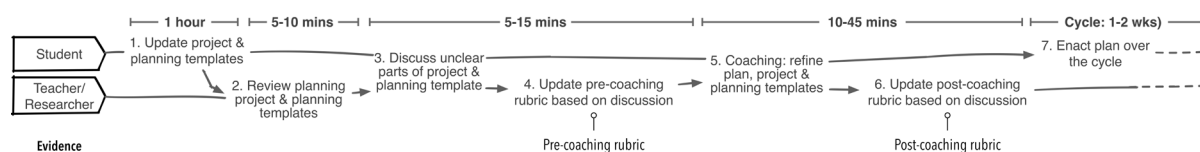


Figure 1. Team Planning Trajectories technology supported assessment framework involves student design teams planning iterative cycles of work and teachers or researchers creating a pre- and post-coaching rubric.

Each cycle, TPT involves the following student and teacher activities, tools, and technology (Figure 1): (1) At the start of a cycle, the teams fill out a project and plan templates, which involves defining the state of the project, risks, and planning to reduce those risks. The plan stipulates the goal(s) of the cycle and activities to meet the goal. (2) The teacher then reviews the teams' templates, and uses an online rubric to create a pre-coaching record of the plan's alignment, efficiency, and appropriateness of workload. (3) The teacher and team then discuss any parts of the templates the teacher found unclear. (4) The teacher updates the online rubric based on this discussion. (5) The teacher and students then engage in coaching, revising the templates. (6) The teacher then creates a post-coaching record of the plan using the same online rubric. (7) The team then enacts the plan.

We created TPT to collect and assess teams' plans within and across cycles for real-world design projects. Each cycle, the teacher or researcher captures rubric scores of the plans pre- and post-coaching. At its most simple, the TPT captures yes/no/unclear for plan alignment, efficiency, and appropriateness of workload, displayed on a dashboard (Table 1). TPT helps answer two questions: (1) how are teams producing design plans outside of coaching? This is measured by the change in the quality of the pre-coaching plan scores across cycles—that is, what is each team's pre-coaching score in cycle 1 compared to cycle 2 etc.; (2) How are teams planning with coaching? This is measured by the difference between the pre- and post-coaching scores within each cycle. A learning environment created to help student design team planning would aim to: increase the pre-coaching scores over time (across cycles), increase in pre-coaching scores and post-coaching scores in the same cycle, and decrease difference between the pre-coaching scores and the post-coaching scores over time.

We now illustrate TPT in an ongoing design-based research initiative (data display Table 1). We focus on a team in cycle 3 of an instructional design class working with their client, a university department's diversity committee. Their client experienced the challenge of drawing on diverse community perspectives to create action plans for better supporting underserved students. The team had proposed a software voting system to gather data that can generate action plans. The team noted a risk: they did not know what data the client needed from the community to generate and justify action plans. The team planned to create a prototype of the voting system using off-the-shelf technology, gather data from 20+ stakeholders, and then present the data to the client to test if it met their needs. The teacher rated this pre-coaching plan as (a) aligned, as the activities sought to reduce a risk by testing something with the goal of solving stakeholder problems, (b) not efficient, as the team had already collected data from 30 stakeholders, and didn't need to collect new data, and (c) an inappropriate workload, as the proposed workload is more than undergraduates can typically undertake in 2 weeks. During coaching, the team and teacher refined the plan to be more efficient with a more appropriate workload.

Table 1. A technology data display of the planning rubric scores of one team in a 10-week class

Team 3	Cycle 1:		Cycle 2:		Cycle 3:		Cycle 4:	
	Pre-coaching	Post-coaching	Pre-coaching	Post-coaching	Pre-coaching	Post-coaching	Pre-coaching	Post-coaching
Alignment	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Efficiency	No	No	No	Yes	No	Yes	Yes	Yes
App. Work	No	No	No	No	No	Yes	No	Yes

## Conclusion

We presented TPT, a novel approach for teachers and researchers to regularly formatively assess design planning. TPT allows us to (a) regularly track changes in performance, (b) assess both independent and coach supported planning, and (c) avoid letting students flounder by only assessing planning without support. TPT uses technology to allow us to better assess and create learning environments for students learning design.

## References

- Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: The role of reflective practice. *Design Studies*, 24(3), 275–294.
- Carlson, S.E., Maliakal, L.V., Rees Lewis, D.G., Gorson, J., Gerber, E.M., & Easterday, M.W., (2018). Defining and assessing risk analysis: The key to strategic iteration in real-world problem solving. *In proceedings of the International Conference of the Learning Sciences (ICLS)*. London, UK: ICLS.
- Cross, N. (2011). *Design thinking: Understanding how designers think and work*. London, UK: Bloomsbury.
- Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development*, 48(4), 63–85.
- Pellegrino, J. W. (2014). A learning sciences perspective on the design and use of assessment in education. *In The Cambridge handbook of the learning sciences* (pp. 233–252).
- Rees Lewis, D.G., Gorson, J., Maliakal, L.V., Carlson, S.E., Riesbeck, C.K., Gerber, E.M., & Easterday, M.W. (2018). Planning to Iterate: Supporting iterative practices for real-world ill-structured problem-solving. *In proceedings of the International Conference of the Learning Sciences (ICLS)*. London, UK: ICLS.

# Perceptions of Online Professional Development: Do Newer and Experienced Teachers Differ?

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**Abstract:** In this exploratory study, a small number of biology teachers participated in an online professional development (PD) course delivered in an asynchronous format. To understand the unique perceptions of newer and experienced teachers when delivering PD through an online platform, we conducted post-experience interviews, coded the transcripts, and analyzed the connections between the codes using epistemic network analysis. Findings revealed significant differences in how teachers perceive PD delivery format; experienced teachers had positive perceptions of face-to-face PD while newer teachers had positive perceptions of online PD. In terms of the online discussion, there were no significant differences; both groups articulated positive perceptions. Implications for evolving the design of online PD approaches are discussed.

## Introduction

A well-trained teacher is a critical factor in a child's educational success. When teachers receive sustained, intensive professional development (PD), it can lead to gains in student achievement; unfortunately, most teachers participate in short-term PD (Darling-Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009). One scalable, affordable way to provide sustained, interaction possibilities is through online PD, a method that holds promise yet has little research-based evidence (National Academies of Sciences, Engineering, & Medicine, 2015). Since teachers generally prefer face-to-face PD (McConnell, Parker, Eberhardt, Koehler, & Lundeberg, 2013), online PD may receive mixed reviews. In particular, research has shown that newer teachers and experienced teachers respond differently to PD (Fox, Muccio, White, & Tian, 2015). In order to assess the extent to which negative and positive perceptions of high school biology teachers are connected with different aspects of online PD, we used epistemic network analysis (ENA). ENA enables researchers to understand not only how qualitative codes are connected but also how those connections vary between different people (Shaffer, 2017). Specifically, these questions guided the investigation: 1. How do experienced teachers differ from newer teachers in their perceptions of the PD delivery format? 2. How do experienced teachers differ from newer teachers in their perceptions of asynchronous discussion during online PD?

## Theoretical considerations

Teachers find interacting with their colleagues extremely useful, yet collaborative PD elements tend to be weak (Darling-Hammond et al., 2009). Face-to-face collaboration is the preferred method by teachers, but research shows that when teachers participate in face-to-face PD and online PD they encounter similar social interactions (McConnell et al., 2013). Recently, researchers confirmed that teachers find participating in an online course to be an efficient form of PD; teachers believed that the collaborative features and sharing of ideas helped them learn better (Koukis & Jimoyiannis, 2018). In order to take advantage of the collaborative potential of an online platform, we designed a 6-week online PD course. To promote social interactions, the fully asynchronous discussions were seeded with discussion prompts created by facilitators. By fostering socio-cultural learning, we intended for all teachers to have a high-quality experience, yet the learning patterns of newer teachers may be different than those of experienced teachers (Vermunt & Endedijk, 2011). The collaborative elements of online PD may afford newer and experienced biology teachers the necessary support they need to learn, but we need to better understand the perceived value that they place on different elements of PD by using novel analytical methods.

## Methodology

Eight high school biology teachers participated in our online course; seven teachers were female; one was male. Teaching experience ranged from 0 to 20 years with an average of 8.4 years of experience. Post-interviews were conducted. The questions were constructed to probe differences in their experiences between face-to-face PD and online PD, and to probe their perceptions of the asynchronous interactions. Transcriptions were qualitatively mined. A coding scheme was developed. For each code, utterances were assigned a positive or negative perception value. To examine connections between the coded data, we used ENA. ENA is a novel method for analyzing coded data and representing the connections as dynamic network models (Shaffer, 2017). Network models can be created that reveal a teacher's value structure, in fact, we can create one model that represents the value structures of multiple teachers. ENA can compare the two summarized network models and determine if they are statistically different.

## Results

The first research question investigated how teacher perceptions of PD delivery format differed between new teachers (6 years or less) and experienced teachers (10 years or more). The model for NEW teachers (n=5) had the strongest connection between positive perceptions of online PD and positive perceptions of colleagues. The model for EXP teachers (n=3) revealed strong connections to positive perceptions of face-to-face PD. To determine statistical difference, we compared the centroids. At the  $\alpha=0.05$  level, the t-test ( $t(4.22)=4.13$ ;  $p=.01$ ) revealed a significant difference between NEW teachers ( $M=-0.74$ ,  $SD=1.06$ ,  $N=5$ ) and EXP teachers ( $M=1.24$ ,  $SD=0.14$ ,  $N=3$ ). NEW teachers reflected a positive perception of online PD—this was intertwined with a positive perception of their colleagues. EXP teachers had negative perceptions of the online PD and positive perceptions of face-to-face PD.

The second research question examined how perceptions of asynchronous discussion differed between NEW and EXP teachers. The network models for each group were similar. In reviewing the transcripts, we found that NEW and EXP teachers had similar reflections about the online discussions. An EXP teacher stated that “they were useful especially when I got confused that I could look and see that there were other people that had the same questions.” Similarly, a NEW teacher said, “I also found reading other people's responses helpful.”

## Discussion and conclusion

Our findings revealed significant differences in how teachers perceive PD delivery format; experienced teachers had more positive perceptions of face-to-face PD while newer teachers had more positive perceptions of online PD. As we scale-up online PD, we need to be mindful of these perceptions. In this study, both new and experienced teachers had positive perceptions of the discussion prompts. It seems online discussions satisfy the unique learning needs of both groups; new teachers can acquire the support that they need, while experienced teachers can provide suggestions.

## References

- Darling-Hammond, L., Chung Wei, R., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Dallas, TX: National Staff Development Council.
- Fox, R., Muccio, L., White, C., & Tian, J. (2015). Investigating advanced professional learning of early career and experienced teachers through program portfolios. *European Journal of Teacher Education*, 38(2), 154-179.
- Koukis, N., & Jimoyiannis, A. (2018). MOOCs and teacher professional development: A case study on teachers' views and perceptions. In M.B. Nunes & P. Isaias (Eds.), *Proceedings of the International Conference e-Learning 2018* (pp. 19-26), Madrid: Intl Association for Development of the Information Society.
- McConnell, T. J., Parker, J. M., Eberhardt, J., Koehler, M. J., & Lundeborg, M. A. (2013). Virtual professional learning communities: Teachers' perceptions of virtual versus face-to-face professional development. *Journal of Science Education and Technology*, 22(3), 267-277.
- National Academies of Sciences, Engineering, and Medicine. (2015). *Science teachers learning: Enhancing opportunities, creating supportive contexts*. Washington, DC: The National Academies Press.
- Shaffer, D. W. (2017) *Quantitative Ethnography*. Madison, Wisconsin: Cathcart Press.
- Vermunt, J. D., & Endedijk, M. D. (2011). Patterns in teacher learning in different phases of the professional career. *Learning and Individual Differences*, 21(3), 294-302.

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# Leveraging the Power of Collaborative Reflection to Promote Learning Through Clinical Practice

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**Abstract:** Clinical fieldwork is increasingly central to teacher education programs. This poster reports on the development of a new teacher education program, in which collaborative structures are being incorporated to support teacher candidates' reflection on and learning from their clinical experiences. Preliminary findings from the first two iterations of the program suggest that collaborative reflection is fostering more connections between theory and practice as well as the development of new understandings about problems of practice.

## Introduction

For the past decade, there has been a movement to center teacher education on clinical practice (i.e. work in authentic educational settings; Zeichner, 2010). While teacher candidates are spending more time than ever in K-12 classrooms, this should not be equated with improved preparation. Reflection in and on clinical experiences is necessary for teacher candidates to recognize competent practice, self-assess, and figure out a path towards increased competence (Schön, 1987). However, effective reflective practice is unlikely when teacher candidates are isolated in their clinical settings, separated from peers, and paired with mentor teachers who have limited time to engage in reflective discourse. Without the benefit of multiple perspectives, teacher candidates are likely to rationalize problematic practices rather than reflecting critically (Loughran, 2002). This poster reports on the development of a clinical program in a new teacher education program, in which collaborative structures are being designed to foster peer-to-peer reflection, ultimately leading to individual and collaborative learning.

## Theory and design of clinical program structures

We view collaborative reflection as a form of knowledge building discourse (Scardamalia & Bereiter, 2014). As a group discusses a situation, group members offer multiple perspectives, leading to a deeper understanding of the situation and ultimately the development of new knowledge about how to respond. In the development of our clinical program, we are intentionally seeking to embed ongoing opportunities for teacher candidates to reflect collaboratively with peers and teacher educators about the situations that they encounter in their clinical experiences. In this poster, we describe the development of two structures that are designed to work synergistically to promote cycles of collaborative reflection and enactment, as depicted in Figure 1. First, collaborative reflection begins in the clinical setting through paired clinical placements, in which two teacher candidates are placed in the same secondary classroom. Clinical partners have daily opportunities to frame their shared experience dialogically as they seek to make meaning and decide on future actions. Second, several teacher candidates and a teacher educator reflect collaboratively outside of the clinical setting during weekly clinical debriefs. These group reflective sessions offer the potential for radical reframing of clinical experiences. Ultimately, the clinical debrief feeds back into clinical practice, as teacher candidates return to the field with collaboratively constructed new knowledge and plans.

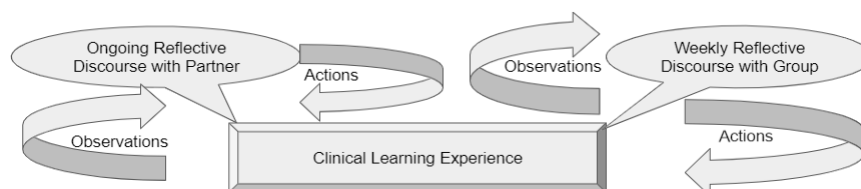


Figure 1. Structures for collaborative reflection in the clinical program.

## Methodology

We are developing the clinical program through a design-based research approach (Barab & Squire, 2004) that employs iterative cycles of design, implementation, and evaluation. Designed by teacher educators in

collaboration with veteran teachers and teacher candidates, and informed by a review of teacher education literature, the clinical program is currently in its second iteration. The first iteration involved ten teacher candidates who attended clinical placements in schools weekly on Tuesdays and in afterschool programs on Wednesdays from October 2017 through June 2018. Surveys and interviews with teacher candidates were used to understand how the clinical program was supporting their learning and to identify areas for improvement. Initial findings were incorporated into the second iteration, which is scheduled to run from September 2018 through June 2019 with 20 teacher candidates. We are collecting data including teacher candidates' written reflections, records from clinical debrief conversations, interviews, and focus groups to enable evaluation of the collaborative structures and inform further iterations.

## Preliminary findings

Preliminary findings from the first iteration of the clinical program suggest that both structures for collaborative reflection fostered teacher candidate learning. The paired clinical placement model enhanced teacher candidate learning in two main ways. First, shared knowledge of both the teacher education program context and the secondary classroom fostered teacher candidates' ability to bridge theory and practice as they engaged in activities including collaborative planning, observations of practice, and feedback conversations. Second, partners were able to develop a fuller picture of problems that they encountered in their clinical settings through reflective discussions in which they pooled their observations. Our initial findings suggest that although clinical partners were able to learn together, these novices needed more support to process their feelings. To scaffold daily reflection during the second iteration, we developed a phone-based reflection tool called CatBot (Clinical After Thought Bot), which sends a reminder to reflect and generates reflection prompts based on a teacher candidate's self-reported emotions.

Clinical debrief also fostered a deeper understanding of problems of practice, through the use of conversational protocols designed for unpacking the context of a problem. While this structure helped teacher candidates to see problems in new ways, some expressed a desire for more action-oriented conversations. Therefore, clinical debrief was redesigned in the second iteration to help the group move from reflection to action. Debrief conversations now use a protocol based on the innovator's compass (Ben-Ur, 2016), to understand a problem from the perspective of the person/group at the center of the problem and ultimately design an experiment that the teacher candidate who brought the problem can try out. We expect that these changes will foster more effective reflection, and will share results from the second iteration at the poster session.

## References

- Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1-14.
- Ben-Ur, E. (2016). Developing Powerful, Portable Design Thinking: The Innovators' Compass. In S. Goldman, & Z. Kabayadondo (Eds.), *Taking design thinking to school* (pp. 239-247). London, England: Routledge.
- Loughran, J. J. (2002). Effective reflective practice: In search of meaning in learning about teaching. *Journal of Teacher Education, 53*(1), 33-43.
- Schön, D. A. (1987). *Educating the reflective practitioner*. San Francisco: Jossey-Bass.
- Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (2<sup>nd</sup> ed., pp. 397-417). New York, NY: Cambridge University Press.
- Zeichner, K. (2010). Rethinking the connections between campus courses and field experiences in college-and university-based teacher education. *Journal of Teacher Education, 61*(1-2), 89-99.

# Development of Girls' Interest and Identities in Computer Sciences Within an CSCL Environment

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**Abstract:** *SciGirls Code* is a two-year project (2016-2018) supporting 16 STEM outreach programs in providing elementary/middle school girls with computational thinking (CT) in an extended learning environment setting. In this proposal, case analyses of six girls are presented to examine their interests in and identities toward computer sciences (CS). Findings reveal increased confidence and interest in CS activities, new appreciation for coding, the importance of teamwork and girls' understanding of gendered identities in CS careers.

## Introduction

SciGirls Code is a project with 16 STEM outreach programs to provide 160+ girls and their educators with computational thinking (CT) and coding skills within informal education spaces. As part of the curriculum, programs completed 3 curricular strands (Mobile Apps, Robotics, E-Textiles) between September 2017 - May 2018. With an emphasis in supportive connections with others, we apply the Connected Learning (CL) model (Ito et al., 2013) to understand how girls expanded their interest within production-focused CS activities and how they were empowered in their learning through a gender-equitable, peer-supported environment.

## CSCL context

This poster explores how girls' interests were affected by the collaborative participation of creating with technology, and how this learning impacts the development of girls' CS identity from two programs (Team Leo and Team Pictor). Both teams recruited 10 girls, ages 10 to 12. Each strand contained hours of activities that provided exposure to computer sciences such as creating an app using Thinkable, building robots with Hummingbird kits, and designing e-textiles using Lilypad. Following each strand's activities, girls created a group project during a 'makeathon'.

## Method, data sources, and analysis

We conducted a qualitative case study (Merriam, 2009) of six girls from Team Leo and Team Pictor to understand girls' development of identities and interest in CS activities. Three girls from each team (Nina, Sophie, Emily, Chloe, Sandy, Karen) were selected for analysis based on the following criteria: participant completed (a) the pre and post open-ended surveys and (b) three semi-structured interviews reflecting on each strand. Data sources were (a) the pre/post surveys, (b) interview responses, and (c) learning artifacts. Content analysis and deductive qualitative analysis (DQA) was conducted using Brennan and Resnick's computational thinking (CT) framework (e.g., computing concepts, practices, perspectives) and the Connected Learning model (Ito et al., 2013) (e.g., interest-powered, peer-supported) as coding schemes to review participants' responses.

## Results

### Interest and confidence increased yet career aspirations varied

To understand girls' changes over time, we examined Emily and Chloe's development through their reflections after each CS strand.

#### Emily (Team Leo)

Emily's CS practices were encouraged by a positive hands-on coding experience using Thinkable. In her first interview, she showed interest in learning how to code beyond block languages, but hesitated to consider a career in CS. During her robotic project, in addition to her increased capacity in explaining CT concepts more precisely, she demonstrated the most growth in computing practices such as debugging and remixing the code to make the robot work. Although she expressed that working with robots was "challenging and exciting," she showed low interest in working further with robotics. In her final interview, she showed a strong understanding of CT concepts, practices, and perspectives by problem-solving her design. Additionally, she demonstrated passion during her e-textile creation and articulated an identity as a designer by saying, "I'm designing an app. I'm designing this robot with the mermaid and making her body...I have more impact at being a designer."

### Chloe (Team Pictor)

Chloe began the program with lower confidence in programming compared to her peers. While she never indicated that she was considering a CS career, she gained confidence in her abilities by expressing an interest in doing more CS activities. She had difficulty explaining concepts precisely and used phrases like, “put the sensor thing in (robot)...and then we tested it.” She demonstrated an increased confidence in CS when she assisted others to code in another class. Chloe’s original motivation was to make an app to take home to work on, but her CS interests shifted to robotics in her final interview. She identified as a coder because of the capacity to “actually make stuff” with a clear direction, such as continuing to collect materials to build a robot.

### **Teamwork and gendered identities impacted perspectives**

Based on participants’ responses from surveys and interviews, we identified two sub-groups amongst the six girls. 3 girls (Karen, Emily, Sandy), who we will refer to as group A, consistently demonstrated interest in doing more CS as well as able to see it as a career. In contrast, 3 girls (Nina, Sophie, and Chloe), who we will refer as group B, gained confidence and interest in doing more CS activities but did not develop a career interest in computing.

#### Group A: Teamwork and gender identities

Two similarities among group A’s learning trajectories were: (1) the recognition of the value of teamwork and (2) the awareness of gender identities. All of them mention the importance of “agreement” during teamwork. Karen recalled group decisions and incorporating all voices in the design process as integral to her robotics project. Emily also shared a story of how finding common ground created a productive environment. Sandy connected the value of teamwork in SciGirls to her future career: “When I’m older and I get a job..., there’s teamwork in working...you’ll work together to do whatever you can.” Strong gender identities in CS (e.g., the importance to get women involved in coding) were also revealed during their interview. Overall, group A situated females learning code as empowering and as a route for women to positively impact the world around them.

#### Group B: Transferring coding experiences into more CS activities

Group B shared a strong desire to apply the skills and knowledge gained from their SciGirls coding experiences into designing robots. Sophie expressed computation as a medium of creation and reusing and remixing as part of the process. Both Sophie and Nina identified themselves as designers and were inclined to do more robot creation at home. Nina reflected that her new skills in coding allowed her to create hands-on designs using the computer. Similarly, Chloe identified herself as a coder, but showed a strong interest in developing more ideas for robotics.

### **Discussion**

Since girls valued coding and its processes as a medium of creation, this appreciation influenced each girl to develop a personal identity as a coder or as a designer. In addition to encouraging girls’ interest through experiences with coding, we found that those who developed a CS career interest appreciated teamwork and demonstrated awareness of the role of gender in CS identities. A new perspective on cognition considers not only an individual body, but also recognizes the role and influence of interactions, elements, and aspects within environments (Newen, Bruin & Gallagher, 2018). Future work will examine how the environment and its resulting impact on learners’ autonomy, sociality, and personal identity.

### **References**

- Brennan, K., & Resnick, M. (2012). Using artifact-based interviews to study the development of computational thinking in interactive media design. Paper presented at the annual American Educational Research Association meeting, Vancouver, BC, Canada.
- Ito, M., Gutierrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., Schor, J., Sefton-Green, J., Watkins, S.C. (2013). Connected learning: An agenda for research and design. Irvine, CA: Digital Media and Learning Research Hub.
- Merriam, S. B. (2009). Qualitative research: A guide to design and implementation. San Francisco, CA: Jossey-Bass.
- Newen, A., De Bruin, L., & Gallagher, S. (Eds.). (2018). The Oxford handbook of 4E cognition. Oxford, UK: Oxford University Press.

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# Using Participatory Design to Facilitate In-service Teacher Learning of Computational Thinking

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**Abstract:** Teaching computational thinking (CT) in K-12 curricula requires supporting teachers in developing relevant knowledge and skills. In this paper, we present a participatory design approach for in-service teachers' professional development which takes a *distributed expertise* stance in engaging teachers as co-designers of their learning. Our qualitative analysis revealed that teachers valued the learning community that emerged, their evolved perceptions regarding integrating CT in subject matter, and their *transformative agency* in reimagining teaching CT.

## Introduction

Integration of Computational Thinking (CT) practices is changing the nature of many disciplines and is increasingly making its way into K12 education (Weintrop et al., 2016). For the purposes of this paper, we define CT as thinking pertaining to the use of modern computational tools and practices in the context of various disciplines. Integrating CT in a subject matter as opposed to a separate course or in extra- or co-curricular programs, has the benefits in 1) providing meaningful contexts to learn CT; 2) making complex concepts in the subject matter more accessible to students; and 3) reaching a wider audience, mainly women and minorities (Weintrop et al., 2016). Most existing professional development (PD) programs use a one-size-fits-all content as it is not feasible to differentiate the PDs on all diverse teacher context and background (Jacob & McGovern, 2015). They do not support teachers to develop ownership and agency over the newly introduced curricular material (Voogt et al., 2015).

In this exploratory paper, we present the initial evidence of the potential impact of using a participatory design approach to facilitate PD for in-service teachers' learning of CT. By "participatory," we mean that the facilitators (CT experts) and teachers are all participants in this learning community with a shared goal of co-constructing the ideas to integrate CT in teachers' current practices in their local context. First, we explicitly take a *distributed expertise* stance in which all participants (teachers and facilitators) bring in distinct expertise and value (Kyza & Nicolaidou, 2017). In-service teachers bring the expertise of their pedagogical content and classroom context through experience. The facilitators, with their technological expertise in CT, contribute to advance teachers' technological content knowledge to explicitly support students' learning in CT. Second, we support teachers in developing *transformative agency* to break from the current forms of CT activities and reimagine CT practices that are appropriately designed for their classrooms (Severance et al., 2016). Compared to past work in participatory co-design, the collective object of our design efforts shifts from the creation of tools to teacher learning of the technological content. Third, our PD design has explicit efforts to foster *researcher-practitioner collaboration* (Gomez et al., 2018). While facilitators who are also the researchers in an effective CT PD would bring in ideas that are theory-driven, teachers would contribute with their pragmatic views about adapting those in their practice.

Our research question in this paper is: *In what ways has the participatory design supported teachers' learning in integrating CT practices in their subject matter?*

## Methods

EXACT is an intensive 30-week, continuing credit teacher CT PD program offered by the school of education in the University of Pennsylvania. At the time of this paper submission, the program was at its 25<sup>th</sup> week. From open advertisement, we recruited six teachers (four female and two male) who teach grades three through eleven from four northeast and two southern United States schools and have, on an average, twenty-one years of teaching experience. They teach a range subject matter including physical science, biology, chemistry, and technology and come from a diverse set of schools ranging from 99% ethnic/racial minority to almost entirely white. School-level percentage of low-income students ranges from 7% to 100%.

45-minute semi-structured *teacher interviews* were conducted on the 18<sup>th</sup> week that probed their opinions on their experience participating in the program so far. Since this is the first research on using a participatory approach to a formal teacher PD in CT, we wanted our analysis to be qualitatively rich and grounded in the data.

An extensive analysis of all the data sources is forthcoming.

## Results and discussion

At the heart of participatory design is the community of all participants (facilitators and teachers) with a *distributed expertise*, actively working towards a shared goal in an authentic setting. Our analysis revealed that teachers viewed learning together with other participants as an important aspect of their experience. They expressed a sense of belonging - as Emily (pseudonym) says, “We are on the same boat; we are learners, we have similar challenges.” We identified three key design features of the program that the teachers thought promoted the community building. First, weekly video-based synchronous sessions provided a platform for teachers and facilitators to participate in a real-time co-construction of CT technological knowledge that was the most relevant to teacher needs. Second, self-paced exploration of the technological content outside the synchronous session was strengthened by the non-synchronous discussions on an online forum. Third, facilitators’ active efforts for inclusion of teachers as co-designers of the curricular materials as well as their learning experiences created a genuine co-design experience for all the participants.

Throughout the course, there was a shift in teachers’ perceptions about the relevance and utility of CT in their practice and on their students’ learning of CT. As Blanca puts it, “[We] tend to overlook the use of data to problem solve in subject areas other than math or science. Made me more aware as an educator to this use.” We identified three subcategories in this. First, teachers had increased belief in their ability to use CT within their existing curricula. Second, teachers’ participation in the program as co-designers and their constructivist explorations of the CT content with the hands-on technological material such as CT assignments, in-class coding, and data project resulted in a shift in their perception of their students. Third, since some of the teachers were teaching their regular classes while taking this course, this parallel enactment provided them with an opportunity to experiment their newly learned ideas in their classes.

Integration of CT in their classroom requires teachers to reimagine their role in terms of their own agency in changing the classroom activities that involve incorporation of new CT practices. This quote from Linda’s interview provides a great example of how we saw teachers thinking of their *transformative agency*. “We do so many things in a school district. This course made me step back and think. What is the end goal? What should my students need to learn?...What is in the curriculum? Is there a path they can take?” Our analysis revealed that they were taking agency in shaping their own learning in this program. We identified several instances of teachers making explicit connections between these new CT practices and their prior knowledge, and identifying ways to advance their knowledge to change their classroom practice.

In conclusion, the participatory design approach helped us build a community of CT learners with a *distributed expertise* and a shared goal of supporting teachers’ learning in integrating CT practices in their subject matter. It supported teachers’ evolving perceptions on classroom integration of CT and led teachers to develop *transformative agency* in advancing their prior CT practices with a vision to reimagine new forms of teaching CT in their local context. Research on effective CT PD practices particularly for in-service teachers is limited. Given the need for large-scale integration of CT in K12 curricula, there is an immediate need for this. From the analysis of this *researcher-practitioner collaboration*, we contribute towards building a framework for effective in-service teacher CT PD. We believe that to produce enhanced CT knowledge and practice, a CT PD needs to involve the collective participation of the teachers in co-designing opportunities for them to develop an in-depth CT technological knowledge. This program was intensive and had a small number of participants. To scale up such programs by appropriately modifying the design features will require further research.

## Reference

- Gomez, K., Kyza, E. A., & Mancevice, N. (2018). Participatory Design and the Learning Sciences. In *International Handbook of the Learning Sciences* (pp. 401-409). Routledge.
- Kyza, E. A., & Nicolaidou, I. (2017). Co-designing reform-based online inquiry learning environments as a situated approach to teachers’ professional development. *CoDesign*, 13(4), 261-286.
- Jacob, A., & McGovern, K. (2015). The Mirage: Confronting the Hard Truth about Our Quest for Teacher Development. *TNTP*.
- Severance, S., Penuel, W. R., Sumner, T., & Leary, H. (2016). Organizing for teacher agency in curricular co-design. *Journal of the Learning Sciences*, 25(4), 531-564.
- Voogt, J., Laferrière, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional science*, 43(2), 259-282.
- Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, 25(1), 127-147.

# A Review of the Evolving Definition of Orchestration: Implications for Research and Design

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**Abstract:** The term *orchestration* describes how teachers manage learning in the classroom. However, interpretations of the term have influenced the application of the definition in research. In this paper, we discuss a review of orchestration technology and analyze the definitions of orchestration with respect to the research conducted and the design of orchestration tools to support teachers. We then discuss implications for the *design* of orchestration tools.

## Introduction

The term *orchestration* has been used in various ways over the past few decades to describe how teachers manage learning in the classroom and how technology can support them in doing so (Dillenbourg, Prieto, & Olsen, 2018). However, there is considerable variability in how the term is defined and conveyed in research (Prieto, Dlab, Gutiérrez, Abdulwahed, & Balid, 2011). The term orchestration has been adopted by the Learning Sciences community, specifically Computer Supported Collaborative Learning (Dillenbourg, Jarvela, & Fischer, 2009) and emphasized as a “*grand research challenge*” (p. 3) in the field of Technology Enhanced Learning (Gillet, Scott, & Sutherland, 2009). Since this work, the definition of *orchestration* has become subject to criticism, and, the way it has been framed, we believe has influenced how researchers conduct studies in these areas.

Another area that has shaped the research in the field of the Learning Sciences was the call for interdisciplinary work with Human Computer Interaction (HCI) (Rick, Horn, & Martinez-Maldonado, 2013). While collaborations between the Learning Sciences and HCI have become more common, a significant gap in the Learning Sciences is the lack of interdisciplinary reliance on design experts. Design has become a term that is overused and often undefined in research. In this review of the orchestration literature we specifically analyze how design is discussed and portrayed in the literature.

The issues of conflicting definitions pose an important question: how have different definitions of orchestration influenced the research conducted on teacher supportive orchestration tools? We are especially interested in studying the influence of those conflicting definitions on how researchers approach and evaluate the design of orchestration tools. To address this question, we compiled empirical articles that describe orchestration tools for teachers, identified what citations the authors assumed to define orchestration, and analyzed the definition’s implications on their research especially bearing in mind the design of the tool. This paper specifically addresses the design

## Methods

We conducted a search on the ERIC database for articles with orchestration in the title ( $N = 25$  articles) or abstract ( $N = 99$  articles) from 2009 to 2018. Of the 124 found articles, 101 articles were excluded by analyzing the titles and abstracts for relevancy, i.e. they were either not a research study, not from an education context, involved online learning (e.g., MOOCs, social media topics), did not include some form of technology to support teachers, were dissertations or thesis papers, or were conducted before 2009. The remaining 23 articles were coded for their definition of orchestration based on the research they cited, the focus of their research questions, methods, participants, setting, and the authors’ descriptions of the teachers’ experience. Due to the scope of this poster paper, we only discuss analysis from the definition of orchestration and the focus of the research questions.

## Results

Of the 23 articles coded, 17 articles referenced at least one of five different papers written by Dillenbourg and colleagues to define orchestration (Dillenbourg, 2013; Dillenbourg et al., 2011, 2009; Dillenbourg & Jermann, 2010; Fischer & Dillenbourg, 2006). Three articles referenced Trouche (2004), four articles referenced Prieto et al. (2011), and two articles referenced Roschelle, Dimitriadis, & Hoppe (2013). Eight remaining articles were only referenced once. Regarding research questions, across all articles, the majority of questions focused on the teachers (15 articles) and students (10 articles). Five articles asked questions related to the design of the technology and six articles asked questions regarding methods to assess orchestration tools.

## Discussion

Of all the definitions identified in this body of literature, there is no trend in definition use across years, other than the majority use of Dillenbourg and colleagues' citations to describe orchestration. However, it seems there is some consensus in the use of Dillenbourg's definitions of orchestration as it is applied across all categories of research questions, methods, and study contexts. While all of the articles that used Dillenbourg to define orchestration are positioned around the same general definition, the sequence of these papers is something to grapple with when considering the implications on the researchers that cited them.

Of the 23 articles in this review, only five articles addressed questions about design. There are a vast number of questions that can be asked about the design of orchestration in terms of representation, inclusion, interaction, implementation, process, equity, and more. Questions within design need to be addressed to help the field build more impactful tools, learn about their uses in the classroom, and understand more about design assessment. Of these five articles, only one explicitly addressed issues of the process to design the orchestration tool. While we understand that authors can be implicitly study the design of orchestration tools we hope to see this more prominently discussed in future papers.

## Implications

The process to build and assess the use of orchestration technology from a design perspective is something that needs more consideration in the orchestration research. A recent review indicated that outcomes of orchestration technology are typically user perceptions or learning outcomes (Bodily et al., 2018). User perceptions are a valuable step in the design *process*, but researchers claim usability evaluations are not enough to *assess* a design (Rick et al., 2013). This research and the present review indicate a need for more rigorous methods to evaluate the design of a tool in the context it is built for, as well as through the goals of the design and the desired learning parameters.

## References

- Bodily, R., Kay, J., Aleven, V., Jivet, I., Davis, D., Xhakaj, F., & Verbert, K. (2018). Open learner models and learning analytics dashboards. *Proceedings of the 8th International Conference on Learning Analytics and Knowledge - LAK '18*, 41–50. <https://doi.org/10.1145/3170358.3170409>
- Dillenbourg, P. (2013). Design for classroom orchestration. *Computers and Education*, 69, 485–492.
- Dillenbourg, P., Jarvela, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In N. Balacheff, T. de Jong, S. Barnes, S. Ludvigsen, & A. Lazonder (Eds.), *Technology-Enhanced Learning: Principles and Products* (pp. 26–42). Springer. <https://doi.org/10.1007/978-1-4020-9827-7>
- Dillenbourg, P., & Jermann, P. (2010). Technology for classroom orchestration. *New Science of Learning: Cognition, Computers and Collaboration in Education*, (February), 525–552. <https://doi.org/10.1007/978-1-4419-5716-0>
- Dillenbourg, P., Prieto, L. P., & Olsen, J. K. (2018). Classroom orchestration. In *International Handbook of the Learning Sciences* (pp. 180–190).
- Dillenbourg, P., Zufferey, G., Alavi, H., Jermann, P., Do-lenh, S., & Bonnard, Q. (2011). Classroom orchestration: The third circle of usability - Why is paper highly usable in classrooms? *CSCL 2011 Proceeding, I*(January), 510–517.
- Gillet, D., Scott, P., & Sutherland, R. (2009). STELLAR European Research Network of Excellence in Technology Enhanced Learning. In *Intl Conference on Engineering Education & Research* (pp. 1–8).
- Prieto, L. P., Dlab, M. H., Gutiérrez, I., Abdulwahed, M., & Balid, W. (2011). Orchestrating technology enhanced learning: A literature review and a conceptual framework. *International Journal of Technology Enhanced Learning*, 3(6).
- Rick, J., Horn, M., & Martinez-Maldonado, R. (2013). Human-computer interaction and the learning sciences. In *International Society of the Learning Sciences* (Vol. 2, pp. 451–455).
- Roschelle, J., Dimitriadis, Y., & Hoppe, U. (2013). Classroom orchestration: Synthesis. *Computers and Education*, 69, 523–526. <https://doi.org/10.1016/j.compedu.2013.04.010>
- Trouche, L. (2004). The complex process of converting tools into mathematical instruments: The case of calculators. *International Journal of Computers for Mathematical Learning*, 9, 281–307.

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# Conceptualizing and Analyzing the Instructor-Student Collaboration

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**Abstract:** This concept paper conceptualizes the instructor-student collaboration as a continuum, ranging from a lower level of aggregates of individual participation, to a higher level of turn-taking process through which participants form mutual interactions, develop sustained communications, and take joint actions to achieve a shared goal. This paper then proposes an analytical framework including *participation frequency*, *turn-taking discourse*, and *participant perception* dimensions, to analyze instructor-student collaboration in authentic teaching and learning practices.

## Introduction

Collaboration is a coordinated, joint activity among people to achieve a shared goal (Roschelle & Teasley, 1995). In education, collaboration provides an opportunity for learners, instructors and other stakeholders to together create knowledge objects, design materially embodied prototypes, or embody ideas in progressively advanced discussions. Current educational practices foster a more equal, symmetrical relationship between instructors and students, through which they together contribute to varied aspects of education, including learning and inquiry, subject-based research, scholarship of teaching and learning, and curriculum design and development (Healey, Flint, & Harrington, 2014).

## A conceptualization of instructor-student collaboration

Although similar concepts, e.g., student-faculty partnership (Cook-Sather, 2014) have been discussed, there is no one explicit definition of instructor-student collaboration in current literature. In this concept paper, I argue that the instructor-student collaboration is a complex phenomenon, that takes varied forms and occurs at different levels. The instructor-student collaboration can be viewed as a continuum, ranging from a lower level of aggregates of individual participation, to a higher level of turn-taking process through which participants form mutual interactions, develop sustained communications, and take joint actions to achieve a shared goal (Dillenbourg, 1999; Goodyear, Jones, & Thomson, 2014; Jeong, Cress, Moskaliuk, & Kimmerle, 2017).

First, an effective collaboration cannot take place without active participations from instructors and students. For example, to build a community of inquiry, the instructor designs collaborative inquiry, facilitates or directs students' learning and inquiry, and fosters socially supported environments; students actively engage in collaborative learning inquiry activities and learning environment building processes (e.g., Garrison, Anderson, & Archer, 2000). Participants' active, participatory behavior is a prerequisite for developing collaborative meaning-making in a community of inquiry. Overall, no collaboration can take place with a low-level participation; in other words, active participations build working conditions for a more synergistic collaboration (Zhao, Sullivan, & Mellenius, 2014).

However, mere participations from instructors and students do not always lead to effective collaborations; in a higher-level, synergistic collaboration, the instructor and students must take turns to contribute to teaching and learning behaviors or discourses. Through these turn-taking behaviors or discourses, the instructor and students form mutual interactions, develop sustained communications, and take joint actions to complete collective tasks or achieve shared goals. For example, during science inquiry, students and their teacher, working as equal partners, took turns to construct meanings (e.g., Tabak & Baumgartner, 2004). In pedagogical development, students provided their instructor with information about learning experiences with newly introduced pedagogical approach; and the instructor made pedagogical changes accordingly (Nel, 2017). During these turn-taking behaviors, a more equal, symmetrical partnership was built between the instructor and students and a higher level, synergistic form of instructor-student collaboration took place. Overall, in a higher-level, synergistic collaboration, responsibilities are largely shared between the instructor and students, and turn-taking behaviors are carried out by instructors and students.

More importantly, a lower-level, participatory form of and a higher-level, synergistic form of collaboration are not mutually exclusive; rather, they build on each other and shift over time, serving a purpose to advance design, learning and instruction. Active participation is a prerequisite for an advanced, synergistic form of collaboration; grounded upon active participations, a synergistic collaboration is more likely to take place during turn-taking discourses (Zhao et al., 2014). Considering its optimal form, the instructor-student

collaboration is a shared, negotiated work between students and their instructor to construct design, learning, and instruction together (Cook-Sather, 2014; Crawford, Horsley, Hagyard, & Derricot, 2015; Healey et al., 2014).

## A proposed analytical framework of instructor-student collaboration

Due to the complexity of instructor-student collaboration, it is not easy to empirically investigate different forms of instructor-student collaborations in real settings (Jeong & Hmelo-Silver, 2016). Grounded upon the abovementioned conceptualization, I propose an analytical framework, including *participation frequency*, *turn-taking discourse*, and *participant perception* dimensions, to analyze instructor-student collaboration in authentic teaching and learning practices. Here I take the investigation of the instructor-student collaboration in a community of inquiry as an example (Ouyang et al., under review). A community of inquiry (CoI) encompasses three dimensions (cognitive, teaching and social) and 12 categories (four categories under each dimension) (Garrison et al., 2000). First, to analyze participation frequency, quantitative content analysis can be used to code and count participants' cognitive, teaching, and social participations according to the CoI framework. Particularly, to better reflect the symmetric partner structure between the instructor and students, the CoI framework should be used in a less dualistic fashion; that is, all dimensions and categories should be applied to *both* the instructor and students. Second, qualitative discourse analysis can be used to analyze how cognitive, teaching and social contributions moved back and forth between the instructor and students in order to build collaboration. Third, *participant perception* about their collaboration during teaching and learning can support or disconfirm results from the previous two analysis methods. Together, this proposed analytical framework demonstrates the instructor-student collaboration from quantitative, qualitative, and perceived perspectives namely *participation frequency*, *turn-taking discourse*, and *participant perception*. Overall, this paper advances theory and analysis of the instructor-student collaboration. It is critical for researchers to further strengthen the alignment between theoretical or conceptual grounding with actual collaboration practices during design, learning, and instruction.

## References

- Cook-Sather, A. (2014). Multiplying perspectives and improving practice: what can happen when undergraduate students collaborate with college faculty to explore teaching and learning. *Instructional Science*, 42(1), 31-46.
- Crawford, K., Horsley, R., Hagyard, A., & Derricot, D. (2015). *Pedagogies of partnership: What works?* York: HE Academy.
- Dillenbourg, P. (1999). What do you mean by "collaborative learning"? In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches (Vol. 1)* (pp. 1-15). Oxford, UK: Elsevier.
- Healey, M., Flint, A., & Harrington, K. (2014). *Engagement through partnership: Students as partners in learning and teaching in higher education*. York: Higher Education Academy.
- Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, 2(2), 87-105.
- Goodyear, P., Jones, C., & Thomson, K. (2014). Computer-supported collaborative learning: instructional approaches, group processes and educational designs. In J. M. Spector, M. D. Merrill, J. Elen & M. J. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 439-451). Springer.
- Jeong, H., Cress, U., Moskaliuk, J., & Kimmerle, J. (2017). Joint interactions in large online knowledge communities: The A3C framework. *International Journal of Computer-Supported Collaborative Learning*, 12, 133-151.
- Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help? *Educational Psychologist*, 51, 247-265.
- Nel, L. (2017). Students as collaborators in creating meaningful learning experiences in technology-enhanced classrooms: An engaged scholarship approach. *British Jrnal of Educational Technology*, 48(5), 1131-1142.
- Ouyang et al. (under review). Did the instructor and students build collaboration during online asynchronous discussions? *Computers & Education*.
- Roschelle, J. & Teasley S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. E. O'Malley (Ed), *Computer-Supported Collaborative Learning* (pp. 69-197). Berlin: Springer-Verlag.
- Tabak, I., & Baumgartner, E. (2004). The teacher as partner: Exploring participant structures, symmetry, and identity work in scaffolding. *Cognition and Instruction*, 22(4), 393-429.
- Zhao, H., Sullivan, K. P., & Mellenius, I. (2014). Participation, interaction and social presence: An exploratory study of collaboration in online peer review groups. *British Journal of Educational Technology*, 45(5), 807-819.

# Conflicts and Collaboration: A Study of Upper Elementary Students Solving Computer Science Problems

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**Abstract:** Collaborative learning holds great value for young learners. However, these learners often encounter conflicts that may arise based on the learning task itself or on external factors. Little is known about the nature and evolution of conflicts that occur when elementary learners work together. To investigate this phenomenon, we analyzed videos of six pairs of students completing a programming activity. We identified four stages of conflict: *initiation*, *escalation*, *de-escalation*, and *conclusion*. Our analysis showed that the conflicts typically began around disagreements about code, who should have control of the keyboard and mouse, and other interpersonal events. Also, we found that some pairs of students resolved their conflicts through self-explanation and listening while others did not take advantage of those constructive strategies. This research reveals some ways in which conflicts evolve between elementary learners, and how we may be able to support them in conflict resolution while solving problems.

## Introduction

Collaborative learning is a complex process that involves co-constructing knowledge and maintaining shared ideas (Roscelle & Teasley, 1995, p. 70). Within computer science (CS), pair programming is a widely used collaborative learning paradigm in which two learners work on one computer, taking turns with the control. The learner controlling the computer is the *driver* and the other, the *navigator*, plans ahead and looks for mistakes. Many empirical studies have shown the benefits of pair programming for college-aged learners, including the promotion of desirable practices such as pre-planning (Porter & Simon, 2013). In light of these benefits, pair programming has recently been used when supporting younger CS learners. However, emerging observations suggest that young learners need additional support to benefit from this collaborative paradigm (Shah, Lewis, & Caires, 2014). Since most research on CSCL with young learners has focused on non-CS topics (e.g., Olsen, Rummel, & Alevén, 2017), collaborative programming with young learners is an emerging area of research.

We have recently begun to implement pair programming with students at the 4th and 5th grade level. Our observations of multiple elementary CS classrooms led us to believe that conflicts between the students are unlike those we had observed in our extensive studies of older CS students (Rodríguez, Price, & Boyer, 2017) and studying conflicts is a crucial open area for research. Therefore, we investigated the following research question: *How do conflicts arise and evolve when elementary learners engage in pair programming?* We analyzed pair programming dialogue of elementary students and categorized video excerpts of the students into stages of conflict based on previous work (Jeong, 2008; Rubin, Pruitt, & Kim, 1994), which may not all be present in each conflict: initiation, escalation, de-escalation, and conclusion. In addition, some conflicts had a resolution. Our findings highlight the importance of better understanding how elementary students collaborate while learning CS.

## Study context and participants

We collected data from a pair programming study conducted at two U.S. elementary schools. A total of 40 4th and 5th grade students (typically 8 to 11 years old) participated and provided parental consent and student assent, 20 in each school. We collected webcam video and screen capture data from each pair of students over a period of 5 weeks. The curriculum was designed by the authors and covered CS topics appropriate for 4th and 5th grade students using a block-based programming language where users write code by dragging, dropping, and connecting programming blocks.

## Results and discussion

Every conflict episode had a clear start and a conclusion but not all of them moved through a full cycle of escalation, de-escalation, or resolution. We identified 38 total conflict episodes (simply ‘conflicts’ for short)

from six programming videos in our analysis, with an average of 6.4 conflicts per 45-minute video. We found that the majority of conflicts between the students (71%) went unresolved. Additionally, many pairs engaged in more escalation than de-escalations. This suggests that the increase of intensity in their conflicts were due in part to the learners having difficulty working through their problems. The descriptive statistics of the conflicts in each pair are displayed in Table 1.

**Table 1: Information about each pair, including descriptive statistics of the conflicts**

Evans	1	7	18s	6s	40s	57%	43%	29%
	2	8	18s	8s	39s	63%	63%	0%
	3	5	53s	8s	3m 4s	40%	40%	40%
Adams	4	4	17s	4s	39s	75%	50%	0%
	5	9	35s	9s	1m 32s	89%	89%	44%
	6	5	12s	8s	22s	20%	20%	60%

While analyzing the conflicts, we noticed that they were often triggered by one of three issues: disagreements about changes in the code, disputes over who should drive, and non-CS problems (e.g. camera position, personality/social disagreements). As the conflicts unfolded, the disagreements sometimes evolved into verbal arguments and physical incidents over control of the equipment, or with each other.

Young learners do not naturally have collaborative strategies (Gillies & Ashman, 1996). This is illustrated by four pairs of learners who argued with each other frequently and often repeated suggestions but did not offer justifications or explanations. In our data, we found cases in which students were focused on the task at hand but encountered difficulty resolving their conflicts. In both cases, the navigator gave a suggestion which was rejected or ignored by the driver and the conflict escalated but did not get resolved. In the cases where pairs appeared to successfully resolve their conflicts, the navigators were engaged and contributed to the process. Through the use of collaborative dialogue strategies such as self-explanation the students resolved their conflicts. This is consistent with prior research that suggested that groups of young learners who accept suggestions or enter into discussions about them collaborate more successfully than those that reject suggestions (Barron, 2003).

## Conclusion

While collaboration has been shown to be beneficial in many situations, including CS learning, supporting younger learners in collaborative CS learning brings new challenges that we must be cognizant of, including the students' level of socio-emotional development. The results described in this paper illustrated three patterns of collaborative behavior: conflicts arising as a result of distractions, conflicts arising due to a lack of collaborative strategies, and conflicts being resolved using collaborative strategies, including listening and self-explanation. Since a lack of resolution may indicate a lack of positive change in the learners' relationships, researchers should develop interventions to support learners in resolving conflicts and developing overall healthier working relationships. Our video analysis points to the need for careful design and study of collaborative scaffolding for students of this age. Future work should continue to investigate aspects of collaboration in CS, including conflicts and how to teach collaboration skills to elementary students. This work can support future research on the design of adaptive support mechanisms to mitigate conflicts between younger learners during collaborative problem-solving, or to prevent them before they arise.

## References

- Barron, B. (2003). When Smart Groups Fail. *The Journal of the Learning Sciences*, 12(3), 307-359
- Gillies, R. M., & Ashman, A. F. (1996). Teaching Collaborative Skills to Primary School Children in Classroom-Based Work Groups. *Learning and Instruction*, 6(3), 187-200.
- Jeong, H. W. (2008). *Understanding Conflict and Conflict Analysis*. Sage.
- Olsen, J. K., Rummel, N., & Aleven, V. (2017). Learning Alone or Together? A Combination can be Best!. *Proceedings of the 12th Intl Conference on Computer Supported Collaborative Learning*, 95-102.
- Porter, L., & Simon, B. (2013). Retaining Nearly One-Third More Majors with a Trio of Instructional Best Practices in CS1. *Proceedings of the 44th SIGCSE*, 165-170.
- Rodríguez, F. J., Price, K. M., & Boyer, K. E. (2017). Expressing and addressing Uncertainty: A study of collaborative Problem-solving dialogues. *Proceedings of the 12th International Conference on Computer Supported Collaborative Learning*, 207-214.
- Rubin, J. Z., Pruitt, D. G., & Kim, S. H. (1994). *Social conflict: Escalation, stalemate, and settlement*. Mcgraw-Hill Book Company.
- Shah, N., Lewis, C., & Caires, R. (2014). Analyzing Equity in Collaborative Learning Situations: A Comparative Case Study in Elementary Computer Science. *Proceedings of the 10th ICLS*, 495-502.

# Social Media and Personal Histories: Practices, Identities, and Algorithms in the Age of Digital Nostalgia

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**Abstract:** Many of today's young adults have Facebook histories reaching back to their middle school years. These users are often prompted to engage with their past content through features that capitalize on "digital nostalgia," like Facebook's On This Day (now Memories). The present study investigates how young adults interact with this content, its effects on personal memories and identities, and the perceived role of non-human factors (like algorithms) in mediating these interactions.

**Keywords:** Social media, identity, literacies

## Key areas of discussion

This poster presents the initial findings from a qualitative study examining the way young adults (18-24) engage with and think about their interactions with past social media content, particularly on Facebook. Poster-based conversations will focus on discussion around two questions: (1) What patterns of practices do participants engage in, and how do those relate to processes of remembering/personal memory and constructing identities? (2) How do users theorize about the ways that non-human factors are involved in these processes (if at all), and what are the consequences of these theories?

## Issues addressed

Social media has become an important mediator of identity processes as young people are "growing up" with these tools (Lincoln & Robards, 2017; Robards, 2014). For some young adults, these platforms store years of content, sometimes stretching back to their middle school days.

Features of social media tools, including non-human actors like algorithms, play a key role in identity processes. One way that users engage with algorithms is by being re-presented with content they had posted previously. Tools like Facebook's On This Day, now part of an expanded Memories feature, and apps like Timehop use algorithms to sift through past content and re-present users with "memories." To further understand the role of these features in the lives of young adults, we address three research questions:

- How do young adults (18-24) engage with their past social media content?
- How do young adults relate their Facebook content to their life stories, and (how) does past content play a role in shaping the way they think about their past, present, and future identities?
- How do young adults describe and understand the role of algorithms in relation to their social media content, and past content in particular?

## Theoretical framework

The current study draws on work in New Literacies (Leu et al., 2017), sociocultural conceptions of social practices, tools, life stories, and identities (e.g., Holland, et al., 1998), and work on the role of algorithms in mediating human behavior. This study approaches social media use as a key "new literacy" (Leu et al., 2017); the internet has changed what it means to be literate, and social media use is a type of new literacy that requires complex critical skills. We approach identity as fluid and intertwined with social media practices, drawing on Holland et al.'s (1998) conceptualization of identity as part of a self in practice, which is ever-changing and socially constructed as people act in figured worlds. We also draw on Jones (2017) to think about how people understand algorithms as agent, authority, adversary, communicative resource, audience, and oracle.

## Methods

Two researchers conducted semi-structured interviews with 14 undergraduate and graduate students (4 male, 10 female; 12 White, 2 Indian-American) from U.S. universities, ages 18-24, with several years of Facebook history. The interviews followed a two-part interview protocol, with an audio-recorded portion, where participants described their current and past uses of social media, and a video-recorded portion, where participants showed researchers their Facebook feeds and timelines. The interviews were then transcribed and coded in NVivo in three stages (open, axial, and selective) according to grounded theory (Strauss & Corbin, 1990).

## Findings

Participants sometimes intentionally sought out their past content, and sometimes were presented with it upon opening Facebook. Regardless of how they came to view their past content, participants' active engagement with the content served an important function in the practice of negotiating past, present, and future identities. For example, several participants reckoned with feeling, looking, or acting different than their past (e.g., younger teen) selves as presented in their past content, and they would decide to share, delete, or disregard this content. This practice of *curating or editing Facebook content* served as a potent site of identity mediation, as participants considered deeply the stories they wanted to tell about themselves—to themselves and/or others—via Facebook. Participants also made *critical assessments* of their life stories as seen on Facebook, as well as on other platforms, and indicated that their life story is not captured in one place. Participants frequently made *comparisons* of past and present selves, and their own life to friends' lives. They reflected on changing friendships, personal growth, the felt passage of time, changes in life trajectory, and changed physical appearance.

Participants generated many theories about how Facebook algorithms operated to present them with content, similar to Jones' (2017) "folk beliefs" about algorithms. Some of these theories included: "relevancy" based on others in your network engaging with the content, number of likes, amount of engagement with a friend, or randomly. Participants also expressed concern about (the rise in) accurately *targeted ads and irrelevant content* in some types of "memories" and on their feeds. Participant language suggested connections to Jones' six metaphors for algorithms, particularly as they ascribed them a great deal of authority and agency, and sometimes saw them as magical and/or unknowable (Jones' "oracle").

## Conclusions and implications

Telling a life story in the figured world of social networking, similar to Holland et al.'s (1998) exploration of stories in Alcoholics Anonymous, draws upon a system of semiotic resources, other people, memories, and institutional rules. Introducing the element of the Facebook platform, years of easily accessible historical content, and the algorithms that propel them (in often opaque ways) calls for special consideration of technology in young peoples' identity practices. As users generate, respond to, and curate their own social media life stories, understanding how people relate to this content will be crucial to understanding personal histories, and critical engagement with the technology that mediates these relationships is a new literacy meriting further investigation.

## References

- Holland, D., Lachicotte, W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.
- Jones, R. H. (2017, July). *The text is reading you: Teaching language in the age of the algorithm*. Paper presented at the 18th World Congress of Applied Linguistics, Rio de Janeiro, Brazil.
- Leu, D., Kinzer, C., Coiro, J., Castek, J., & Henry, L. (2017). New literacies: A dual-level theory of the changing nature of literacy, instruction, and assessment. *Journal of Education*, 197(2), 1150–1181.
- Lincoln, S., & Robards, B. (2017). Editing the project of the self: Sustained facebook use and growing up online. *Journal of Youth Studies*, 20(4), 518–531.
- Robards, B. (2014). Mediating experiences of "growing up" on Facebook's Timeline: Privacy, ephemerality and the reflexive project of self. In A. Bennett & B. Robards (Eds.), *Mediated youth cultures* (pp. 26-57). London: Palgrave Macmillan.
- Strauss, A.L. & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.

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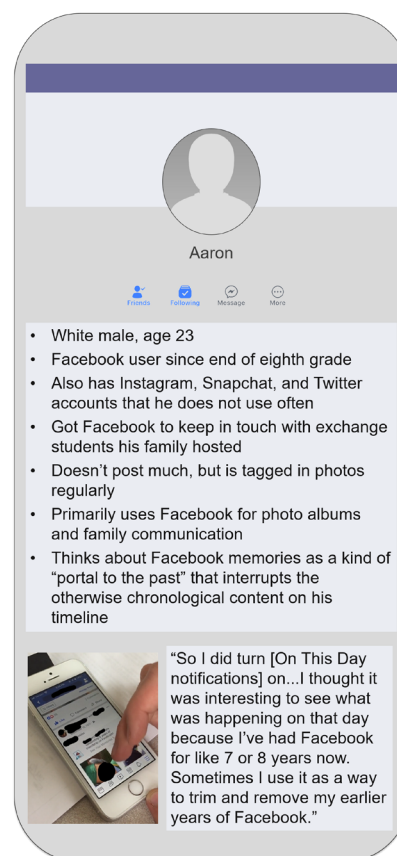


Figure 1. Aaron, one of our case studies, shows a five-year "friendiversary" post.

# Initial Knowledge and the Intensity of Online Discussion

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**Abstract:** The effect of pre-service physics teachers' prior knowledge of the subject on their roles and intensity in the online discussions is studied. Network analysis of initial knowledge and social network analysis of discussion reveal that both have characteristic structural features which are typical for each student. These features, however, are not correlated. Results show conclusively that structure and extension of student's initial knowledge cannot explain activity and role in online discussions.

## Introduction

This explorative study asks if students' background knowledge affects the structure of online discussions they conduct. Consequently, we introduce here methods to monitor and analyze the structure of content knowledge and structure of online dialogue, to correlate the structural features of both. Motivation of our research is to find the best practices for blended university course. Structure of online dialogue has been extensively discussed in many research reports addressing computer supported collaborative learning (CSCL) but dialogical structure has not been related to students' background knowledge. While several studies show that more active groups also achieve better learning outcomes (e.g. Schellens & Valcke, 2005; Järvelä, Malmberg & Koivuniemi, 2016), it is still an open question if background knowledge affects the dialogical activity. On the other hand, it has been shown that argumentation in CSCL environment might not increase domain-specific knowledge (Wecker & Fischer, 2014). Therefore, it could be possible that motivated students are more active and have higher knowledge before and after online discussions.

## Method

Data for this study was collected from a history of physics course for pre-service physics teachers. Students ( $n=10$ ) made associative semantic chains with 12 individual concepts and four associations for each six time periods that constituted a time span of about 350 years of history of science from 1572 to 1928. In addition, short explanations of associations were requested. These exercises were done to help them contextualize and temporalize historical knowledge for face-to-face discussion before studying article which was connected to themes relevant for the period under exploration. After reading the article, students conducted asynchronous online discussions. The discussion was pre-structured by guiding questions about the topic of the article.

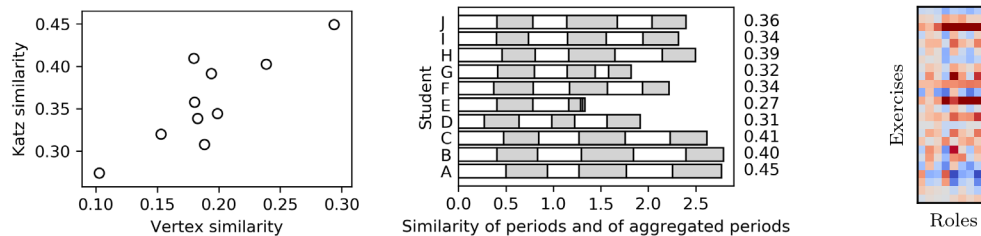
The structure of students' initial knowledge was analyzed in form of networks, which were generated from students' pairwise term and word association chains for each student individually and for each period. In addition, one aggregated networks containing all pairwise associations were constructed for each period, and one network also covering all periods. On average aggregated networks consisted of 260 nodes and 330 links. Each students' contribution for the aggregated networks were evaluated using Jaccard similarity coefficient calculated on basis of the Degree and Katz centrality; the higher the similarity of a given student's network to the aggregated network, the higher the student's contribution to the overall body of knowledge.

All in all, there were 24 online discussions with total of 984 messages with average of 41 per discussion. The discussions were reduced to networks consisting messages as nodes and edges representing responses i.e. who answered to whom. Social network analysis (SNA) was then used to detect patterns in discussions, in form of triadic census. More specifically the number of nine functional roles based on triadic patterns as presented by McDonnell et.al (2014) were computed for each student in each discussion. The average for each role in the episodes were also calculated. Intensity as a number of each of the nine roles for each student was represented as a diverging heatmap around the average to detect which students and on which roles were represented more than the averages.

Now we have the measures which allow us to correlate the structural measure (Katz similarity) characterizing the content of students' initial knowledge with the structural measure (role intensity) characterizing the participation in discussions. The Correlations analysis is based on Kendall-tau ranking correlation as well as on Pearson correlation.

## Results

The similarity of students' network to aggregated network are shown in Figures 1a and 1b. Figure 1a shows that both the Degree and Katz centrality indicates equal similarities, ranging from 27% similarity to 45% similarity. Figure 1b shows the Katz similarities for each student per timeperiod and how the similarity to aggregated network accumulates when periods are accumulated. One of the ten heatmaps representing roles in discussions are shown as an example in figure 1c.



**Figure 1.** Correlation of similarities (a), similarity for each student (b) and one heatmap (c) as example, where blues and red represent roles which are below or over the average, respectively.

Heatmaps were used to deduce each student's participation on discussions and to resolve the roles the student took in discussions. Discussion patterns stay somewhat constant across all the discussions. Of the ten students who completed the course, only half participated for each of the discussions. One (A) of the five had all the roles clearly under the average and the rest four had mainly over. The other five students who participated to only some discussion had roles mainly under the average, but with some also over. Additionally, student A had highest similarity for aggregated network and high similarities overall, but the student had lowest roles in the discussions. Student E has rather small similarities after third period, but the student also didn't participate in the later discussions. Other students did not have any type of correlation between discussion activity or patterns and similarities. The correlation analysis reveals total absence of any statistically significant correlations between the role intensities and initial knowledge. The plausible hypothesis that intensity or role in discussion could be determined by the initial knowledge is thus untenable. Reasons for distinct roles the different students have in discussions must be sought then elsewhere than from structure and extend of initial knowledge.

## Discussion

Results show that variation in similarities seems rather insignificant between students across all periods. This seems to indicate that the roles, and the quality, of the discussions are not affected by the prior understanding of the context. This constancy implies some student related factor which determines the role, although on basis of results presented here it is not likely to be the initial knowledge of the student. Small similarities with missing discussion for student E is probably explainable with lack of participation with the exercises that might arise from motivation or scheduling problems. Student A's high similarity and low role intensity could be explained by assuming that who knows don't really need collaboration and therefore the participation is superficial and shallow; student who knows, don't really benefit from discussions and does not invest effort in it. Interestingly, though, in feedback all students expressed satisfaction on online discussions and evaluated them mainly positively and valuable. On basis of this explorative study we conclude that student's initial knowledge is not a likely factor deciding the participation in discussions. A next question we need to answer is that if the final knowledge is affected by participation on discussions and whether changes between initial and final knowledge states can be correlated with discussion intensity and roles within it. The present study demonstrates that for such a correlative and more extensive study we now have suitable tools and methods.

## References

- Järvelä, S., Malmberg, J., & Koivuniemi, M. (2016). Recognizing socially shared regulation by using the temporal sequences of online chat and logs in cscl. *Learning and Instruction*, 42, 1-11.
- McDonnell, M. D., Yaveroğlu, Ö. N., Schmerl, B. A., Iannella, N., & Ward, L. M. (2014). Motif-role-fingerprints: The building-blocks of motifs, clustering-coefficients and transivities in directed networks. *PLoS ONE*, 9(12).
- Schellens, T., & Valcke, M. (2005). Collaborative learning in asynchronous discussion groups: What about the impact on cognitive processing? *Computers in Human Behavior* 21 (2005) 957-975, 21, 957-975.
- Wecker, C., & Fischer, F. (2014). Where is the evidence? A meta-analysis on the role of argumentation for the acquisition of domain-specific knowledge in computer-supported collaborative learning. *Computers and Education*, 75, 218-228.



# An Innovative Social-Cognitive Engagement Network Representation

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**Abstract:** Collaborative learning stresses an intertwined relationship between social interaction and cognitive engagement. To support collaboration, emerging social network representations strive to demonstrate not only social interactional relations, but also cognitive-related information. In this poster, we proposed an innovative social-cognitive network representation to track learners' social interactions and cognitive engagements, in order to better understand the relationships between them.

## Introduction and literature review

Grounded upon socio-cognitive constructivism theories (Liu & Matthews, 2005), collaborative learning stresses an intertwined relationship between social interaction and cognitive engagement. To support learners' collaboration, e.g., building knowledge-based epistemic objects and materially-embodied prototypes, it is beneficial to provide learners with both social (e.g., who interacted with whom) and cognitive (e.g., what information is exchanged) information.

Social network analysis (SNA) is a research method and visualization approach in the computer-supported collaborative learning (CSCL) field to examine relations between learners, characteristics of the relations, and temporality of interactions during collaboration (Cohen, Manion, & Morrison, 2013). In SNA representation, a social network is represented in graphics with entities as *nodes*, and the connections between two entities as *ties*. A node is any entity in CSCL: human (e.g., instructors, students, groups) and non-human (e.g., epistemic objects, materially-embodied prototypes). A tie is the link between two entities in a network, which has its own weights and directions.

Recently, emerging innovative SNA visualizations strive to demonstrate not only social interactional relation, but also cognitive-related information. Literature review revealed three main approaches. Taking epistemic concepts or ideas as network entities, the first approach visualizes the relations between cognitive entities through network representations (e.g., Shaffer, Collier, & Ruis, 2016). This approach can be used to demonstrate co-occurrence of concepts, keywords, or ideas within given texts. The second approach demonstrates the relations between learners and cognitive-related entities, such as who contributes to what concepts, keywords, or ideas (e.g., Oshima, Oshima, & Matsuzawa, 2012). Third, both social information (e.g., peer interaction) and cognitive information (e.g., discussion topics) in a network graph to aid students' collaborative argumentation (e.g., Dado & Bodemer, 2018). Therefore, it is beneficial to demonstrate both social and cognitive information in order to facilitate collaboration by using SNA visualization tools or representations. Therefore, it is beneficial to demonstrate both social and cognitive information in order to facilitate collaboration by using SNA visualization tools or representations. In this poster, we proposed and applied an innovative social-cognitive network representation to show learners' social and cognitive engagement.

## Research methodology

This proposed social-cognitive engagement network representation demonstrated both social interactions (e.g., participatory role, network position, interaction frequency) and cognitive engagements (e.g., knowledge inquiry, knowledge construction). We defined six social participatory roles to capture interaction patterns, i.e., *leader*, *starter*, *influencer*, *mediator*, *regular*, and *peripheral*, in terms of the levels of participation (reflected by outdegree and outcloseness), influence (reflected by indegree and incloseness) and mediation (reflected by betweenness) (Marcos-García, Martínez-Monés, & Dimitriadis, 2015). We defined six cognitive engagement levels including superficial-, medium- and deep-level "knowledge inquiry" (individual cognitive inquiry), and superficial-, medium- and deep-level "knowledge construction" (group knowledge advancement) (see Ouyang & Chang, 2018 for more details). In the social-cognitive network, node size represents a student's knowledge inquiry score in the individual level; edge width between two students represents knowledge construction score during peer interactions in the group level; node color represents a student's social participatory role. We empirically applied this network representation to show students' social and cognitive engagement in three online discussions from a graduate-level online course.

## Visual representation results

The social-cognitive networks revealed students' social participatory roles, cognitive engagement levels and the relationship between them. (see Figure 1). First, active students (e.g., *leader* R) consistently played active roles throughout discussions and had medium/high cognitive engagement. Inactive students (e.g., *peripheral* P) demonstrated inactive roles and had low/medium cognitive engagement. Second, some *leader* students made no contribution to knowledge inquiry within initial comments (e.g., R and C in discussion 3), while a couple of *peripheral* students made high-level knowledge inquiry (e.g., T in discussion 3). Third, there were very few mediator students, serving as bridges between sub-groups; they made medium level contributions to knowledge inquiry and knowledge construction (see Figure 1).

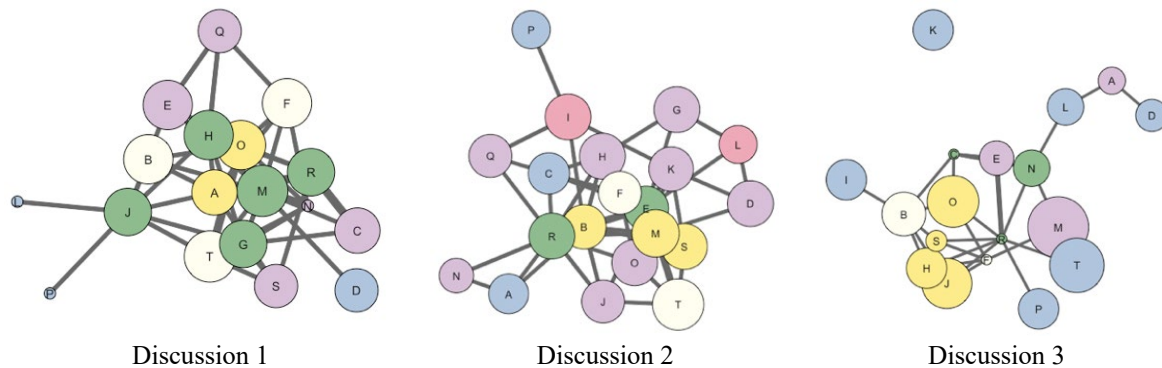


Figure 1. Social-cognitive networks.

Note. Green - leader, yellow - influencer, ivory - starter, coral - mediator, purple - regular, and blue - peripheral.

## Practical implications

To support learners' collaboration, e.g., building knowledge-based epistemic objects and materially-embodied prototypes, collaborative learning tools or representations should strive to provide both social and cognitive information. The lack of cognitive-related information may impede learner agency development. For example, some *peripheral* students did post deep-level knowledge inquiry but did not get enough peer responses to further build up knowledge construction. When these students were only provided with low-level social interaction information, their motivation for taking actions on further social-cognitive engagement may be discouraged. If students were provided with both social and cognitive information, they would develop a better self-awareness of their learning processes, which is a first step toward further knowledge construction in the groups. Therefore, it is necessary to provide students with social- and cognitive-related information through social-cognitive engagement network representations.

## References

- Cohen, L., Manion, L., & Morrison, K. (2013). *Research methods in education*. New York, NY: Routledge.
- Dado, M & Bodemer, D. (2018). Social and cognitive group awareness to aid argumentation about socially acute questions on social media. In J., Kay, and R. Luckin (Eds.) *Rethinking Learning in the Digital Age: Making the Learning Sciences Count, 13th International Conference of the Learning Sciences (ICLS) 2018, Volume 1*. (pp. 456-463). London, UK: International Society of the Learning Sciences.
- Liu, C. H., & Matthews, R. (2005). Vygotsky's Philosophy: Constructivism and its criticisms examined. *International Education Journal*, 6(3), 386-399.
- Marcos-García, J. A., Martínez-Monés, A., & Dimitriadis, Y. (2015). DESPRO: A method based on roles to provide collaboration analysis support adapted to the participants in CSCL situations. *Computers & Education*, 82, 335-353.
- Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse. *Educational technology research and development*, 60(5), 903-921.
- Ouyang, F. & Chang, Y. H. (2018). The relationship between social participatory role and cognitive engagement level in online discussions. *British Journal of Educational Technology*. [online version].
- Shaffer, D. W., Collier, W., & Ruis, A. R. (2016). A tutorial on epistemic network analysis: Analyzing the structure of connections in cognitive, social, and interaction data. *Journal of Learning Analytics*, 3(3), 9-45.

# Reinforce Context Awareness in Augmented Reality-based Learning Design

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**Abstract:** This paper provides a systematic review of Augmented Reality (AR) in education, by focusing on exploring how and why AR technology can be used to promote learning effectively. Through discussing the learning theories and pedagogies adopted in existing empirical studies, this study underlines the necessity of context-aware design in the use of AR. On that basis, we put forward two suggestions for future educational AR design in collaborative settings.

## Introduction

The major distinction between traditional instructional design and constructivism is that the former focused on designing instruction that has predictable outcomes, while the latter focuses on learning environment and experience design (Jonassen, 1994). The use of Augmented Reality (AR) in education can be considered as one of the natural evolutions because it combines virtual and real objects in a real setting, that provides a bi-directional interactive learning environment. A large and growing body of literature has reported affordances and effectiveness of the use of AR in different scenarios and a series of studies has demonstrated that cognitive and affective effects of AR on learning (e.g., Liu, 2009; Yoon et al., 2017). However, after analysing 32 studies published in 6 indexed journals between 2003 and 2013, Bacca et al., (2014) pointed out that the major learning effectiveness was reported by focusing on learning gains in terms of pre-and post-test results or learning motivations. Instead of merely providing novel and interesting approaches to convey information, the real value of AR-based learning should be uncovered through investigating how and why AR should be used to promote learning effectively. To find out these how and why questions, we conducted a systematic review study, paying attention to those studies in which theoretical foundations of learning and AR-based learning processes were discussed. The review concentrates on these two questions: (1) what are the learning theories that are used to inform the design and to predict learning effectiveness in an AR environment; and (2) what pedagogies are integrated with AR to improve learning in existing empirical studies?

## Review methods

We selected scientific articles on the educational uses of AR, published in journals that indexed in the SSCI database. We used two well-known online research databases related to education and technology (ERIC and ACM Digital Library), searching with the query string: (“AR” OR “mixed reality”) AND (education), and then obtained a total of 356 journal papers. We eliminated studies that did not involve a concrete intervention (e.g., technical development papers or literature reviews) and the papers from similar authors discussing the same application in similar settings and excluded the studies that only provided users’ perceptions towards the system use without a discussion about learning effect. In this process, we also added 8 more relevant papers via scanning references cited in the previously selected papers. As a result, 57 papers were identified as eligible articles for further analysis.

## Findings and suggestions

The results showed that of the 57 papers that we identified and analyzed, only 11 provided an explicit theoretical framework. These theories and frameworks, and the referenced studies were presented below. These referenced studies were further categorized into **context-independent** and **context-aware** design. Taking into account the education levels and the subject contents, the main fields of studies in which AR are applied to were classified into seven categories (see Table 1).

Findings from this review showed that those context-independent AR applications focused more on conveying content information in an alternative approach but paid less attention to the pedagogical design. The context-aware AR applications, however, underlying the learning theories, such as situated learning and distributed cognition, tended to have more holistic learning environment designs by integrating diverse pedagogical approaches and strategies. Moreover, the majority of the context-aware AR applications worked on taking use of AR to increase collaboration and knowledge transfer in the different scenarios, beyond multimodal or multimedia content presentations.

Table 1: The pedagogical approaches or strategies used

Fields	No.	Context-independent	Context-aware
Kindergarten	3		<b>Dramatic play</b> (Han et al., 2015)
K12_Math	6		
K12_Science	23	<b>Game-based learning</b> (Lu & Liu, 2015)	<b>Digital storytelling</b> (Laine et al., 2016) <b>Inquiry-based learning</b> (Bressler & Bodzin, 2013; Chiang et al., 2014; Kamarainen et al., 2016) <b>Game-based learning</b> (Hwang et al., 2016; Squire & Klopfer, 2007) <b>Collaborative problem-based learning</b> (Tolentino et al., 2009; Liu et al., 2009)
K12_Language learning & other social studies	5	<b>Game-based learning</b> (Tobar-Muñoz et al., 2017)	<b>Digital storytelling</b> (Sugimoto, 2011) <b>Inquiry-based learning</b> (e.g., Chang et al., 2013) <b>Game-based learning</b> (Dunleavy et al., 2009) <b>Task-based collaborative learning</b> (Liu, 2009)
University	12		<b>Historical reasoning through inquiry</b> (Harley et al., 2016); <b>Experiential learning</b> (Yin et al., 2013)
Workplace	5		<b>Peer assessment</b> (Chao et al., 2016)
Special education	1		
<b>Total</b>	<b>57</b>	<b>33</b>	<b>24</b>

The findings suggest further studies of AR applications in teaching and learning are needed to study context-aware learning designs. Two concrete suggestions are pinpointed and summarized. They are:

- **Foregrounding design of human-context interactions:** It has been noted that AR not only provides each individual with a new interactive approach to realize human and computer interaction but also integrates human-computer-context interactions. Hence, in addition to providing rich content via 3D models or environments, future studies should pay more attention to enhancing the interactions between learners and the contextual information through pedagogical content design. The link between virtual information and authentic environments should be emphasized. As Klopfer and Squire (2007) pointed out in their early study, successful AR applications require learners to solve complex problems in which they have to use a combination of real collected evidence and virtual information. One mechanism for achieving this is to design context-aware applications on mobile devices. Meanwhile, the integration of pedagogical designs (such as collaborative problem solving or task-based inquiry learning) with AR also can help to create authentic learning contexts where participants need to solve problems or complete tasks together.
- **Designing immersive learning experience to achieve collaborative distributed cognition:** One of the most significant affordances of AR is providing an immersive hybrid learning environment that combines virtual and physical objects. Nevertheless, the purpose of using AR in education is not to replicate or replace real-world interactions with highly immersive environments. As Lindgren and Johnson-Glenberg (2013) stated that AR environments may be particularly well aligned with collaborative activity as social interactions typically involve the physical interplay between participants, and the structure of AR can facilitate and enhance these interactions. AR designers can focus on the use of AR to enable learners to build up common ground for shared understanding.

## References

- Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented reality trends in education: A Systematic review of research and applications. *Educational Technology & Society*, 17(4), 133-149.
- Jonassen, D. H. (1994). Toward a Constructivist Design Model. *Educational Technology*, 34-37.
- Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment six precepts for research on embodied learning and mixed reality. *Educational researcher*, 42(8), 445-452.
- Liu, T. Y. (2009). A context-aware ubiquitous learning environment for language listening and speaking. *Journal of Computer Assisted Learning*, 25(6), 515-527.
- Squire, K. D., & Jan, M. (2007). Mad city mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology*, 16(1), 5-29.
- Yoon, S., Anderson, E., Lin, J., & Elinich, K. (2017). How augmented reality enables conceptual understanding of challenging science content. *Educational Technology and Society*, 20(1), 156-168.

# Citizen Science in Schools: Supporting Implementation of Innovative Learning Environments Using Design-Centric Research-Practice Partnerships

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**Abstract:** Citizen Science can be used in schools to enhance science learning, bringing people from distinct cultural communities to a joint endeavor. This research examines how this unique setting can be turned into a mutually-beneficial learning ecology. To do so, a Design-Centric Research-Practice Partnership (DC-RPP) approach was applied in an elementary school, while examining what mechanisms of intervention can serve to support the development of the learning ecology.

## Introduction

Citizen Science (CS) projects, in which non-scientists (citizens) take part in various stages of the scientific process (Shirk et al., 2012), aim for advancement of science, along with other goals such as outreach, public engagement and policy-making. Engaging in CS may promote different aspects of scientific literacy (Bonney, Phillips, Enck, Shirk, & Trautmann, 2015) as participants take part in authentic inquiry. Thus, CS has the potential to become a unique learning environment for school-based science education (National Academies of Sciences, Engineering, and Medicine, 2018).

CS-based learning environments bring together multiple forms and levels of expertise, including students, scientists, school educational staff and educational researchers. This joint endeavor can provide context for potential learning for each of the participants. Such an environment can be perceived as a learning ecology (Barron, 2006), as illustrated in Figure 1a. Nonetheless, fostering mutual learning in such a diverse setting, comprised of distinct cultural communities, can be challenging (Penuel, Allen, Coburn, & Farrell, 2015). We believe that Design-Centric Research-Practice Partnerships (DC-RPPs: Kali, Eylon, McKenney, & Kidron, 2018) can address this challenge. DC-RPPs are long-term partnerships that aim to co-design and implement innovative solutions to practical challenges in schools in a mutually beneficial way. Two theoretical lenses can serve in establishing productive DC-RPPs: (1) Boundary Crossing - a sociocultural theory that describes how boundaries can facilitate learning between communities (Akkerman & Bakker, 2011; Akkerman & Bruining, 2016) and (2) Organizational Learning - a theory that concerns with becoming a learning organization (Senge, 1990), as detailed in Figure 1b. We contend that using mechanisms of intervention based on these theories can promote learning in a CS-based learning ecology. Hence, this research aims to explore: (1) What type of learning outcomes can be achieved in such a unique ecology for each of the participants, and (2) What mechanisms of intervention can serve to support its development, particularly in relation to the interaction between the school educational staff and educational researchers.

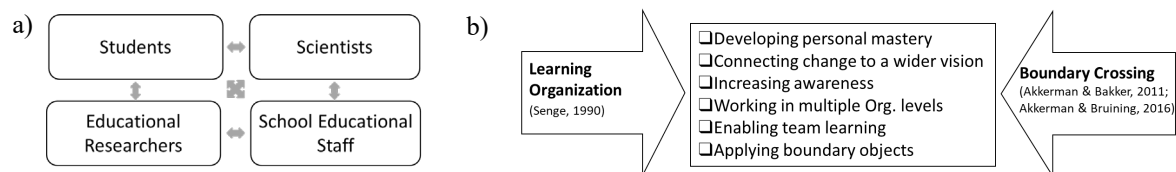


Figure 1. A CS-based learning ecology in school, and mechanisms of intervention to foster its development.

## Intervention and methods

A CS-based learning ecology was established in an elementary school around a CS project that aims to collect the public's observations of jellyfish. The ecology included students from the 4th and 5th grades, marine ecologists, school educational staff, and educational researchers (present authors). A 3-year intervention program was designed based on mechanisms of intervention detailed in Figure 1b. Here we report initial findings from the first two years of the intervention. Data was collected from 20 students (out of 60), two scientists, nine educational practitioners (the principal and eight teachers), and three educational researchers. At

the end of each year, interviews and focus groups were conducted with the research participants. Students and teachers each filled their own questionnaire regarding learning experiences. In addition, ongoing correspondence between participants, reflections and researchers' journals were used as data sources. Initial content analysis was conducted to address both research questions using our theoretical frameworks.

## Preliminary results

Regarding types of learning outcomes in the CS-based ecology, findings show that some progress was made for all participants, but learning was more prominent for particular groups. Examples are highlighted in Table 1.

Table 1: Examples of types of learning outcomes in the CS-based learning ecology examined in this research

Participant Group	Examples for Types of Learning Outcomes (Initial Findings)	Sample Quote
School Educational Staff	Expansion of assumptions about learning and teaching	"I realized that scientific research is feasible also for elementary school kids, not just for MA students."
Educational Researchers	Adoption of new attitudes and practices to meet school's needs	"It was a great learning experience, an unexpected path with recalculations as needed...."
Students	Realizing how science works	"I used to think these things aren't getting verified."
Scientists	Insights on communicating science to children	"To pass on a message to younger children, we are missing an understanding of how they see things."

To reveal the mechanisms of intervention that supported learning, we focus on the DC-RPP between the educational researchers and school educational staff. Findings show commonalities as well as differences in how various functionaries perceived which mechanisms contributed to learning. An example of a repeated mechanism is the added value of a "broker" role (individuals that bridge between communities), consistent with Akkerman and Bruining's conceptualization (2016). An example of a differing one is the perceived contribution of on-going communication. While the teachers gave little attention to this mechanism, the researchers felt that lack of communication impaired the partnership. In addition, we observed an interesting development of mechanisms along the course of the partnership. For example, using confrontation as a direct mechanism to promote learning, was feasible only towards the middle of the second year, probably thanks to maturation in the relationships between the communities. In addition, we observed how maturation in the relationships between the communities allowed the employment of different mechanisms along the course of intervention. For example, utilizing confrontation between the researchers and school principal to promote learning, was feasible only towards the middle of the second year.

## Conclusions

The described research demonstrates how DC-RPP can be highly instrumental in successfully promoting mutually-beneficial learning ecologies of CS in schools.

## References

- Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81*(2), 132-169.
- Akkerman, S. F., & Bruining, T. (2016). Multi-level boundary crossing in a professional development school partnership. *Journal of the Learning Sciences, 25*(2), 240-284.
- Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development, 49*(4), 193-224.
- Bonney, R., Phillips, T. B., Enck, J., Shirk, J. L., & Trautmann, N. (2015). Citizen science and youth education. *National Research Council Committee on Out-of-School Time STEM*. Washington, DC.
- Kali Y., Eylon BS., McKenney S., Kidron A. (2018) Design-centric research-practice partnerships: Three key lenses for building productive bridges between theory and practice. In: Spector M., Lockee B., Childress M. (Eds.) *Learning, Design, and Technology*. Location: Springer.
- National Academies of Sciences, Engineering, and Medicine. 2018. *Learning Through Citizen Science: Enhancing Opportunities by Design*. Washington, DC: The National Academies Press.
- Penuel, W. R., Allen, A. R., Coburn, C. E., & Farrell, C. (2015). Conceptualizing research-practice partnerships as joint work at boundaries. *Journal of Education for Students Placed at Risk, 20*(1-2), 182-197.
- Senge, P. (1990). *The Fifth Discipline: The Art and Practice of the Learning Organization*. NY: Doubleday.
- Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, ... Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. *Ecology and Society, 17*(2), 29.

# Designing for ESM-Mediated Collaborative Science Learning

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**Abstract:** Emergent Systems Microworlds (ESM) are learning environments that combine agent-based approach of modeling complex emergent phenomena and constructionist design principles. In an ESM-based curriculum implementation, students worked in groups to explore and investigate computer-based ESMs. They shared their findings and participated in teacher-guided reflections to collaboratively construct scientific knowledge. We present an analysis of a shift in students' perceptions regarding their agency, as passive recipients or active creators of knowledge, in a science classroom.

## Introduction

The goal of science education should not be limited to 'knowing about science', rather it should include 'learning to use science practices and tools to make sense of the world' (Schwarz, Passmore & Reiser, 2017). In order to support such learning in classrooms, researchers and educators are increasingly designing newer technology-enhanced collaborative learning environments and curricula that are authentic to contemporary scientific inquiry practices and provide epistemic and conceptual scaffolds for learning those practices (Quintana et al., 2009). We contribute to this work of designing for computer-based collaborative science learning by combining two powerful design approaches in learning sciences: agent-based modeling of complex systems and constructionism (Wilensky & Resnick, 1999; Jacobson & Wilensky, 2006). We call this design approach Emergent Systems Microworlds (ESM) (Dabholkar, Anton & Wilensky, 2018). In this article, we first describe design of an ESM and a pedagogical practice of using ESM-based curricula in a classroom setting. We then present an analysis of student pre- and post- interviews regarding their perceptions about learning of science and process of constructing knowledge using scientific inquiry practices. Our research question is as follows: *How do students' perceptions of their agency in the process of scientific knowledge construction get transformed after their participation in an ESM-based curriculum?*

## ESM-mediated learning of genetics and evolution

ESMs are agent-based models of emergent systems that are designed as microworlds to support students' learning through explorations and investigations of those models. Agent-based modeling of emergent Systems is one of the central design features of an ESM. This approach allows students to observe behaviors of agents, and reason about emergent patterns at the system level by reducing cognitive and perceptual limitations (Goldstone & Wilensky, 2008). Learners manipulate objects and execute specific operations instantiated in a microworld. Such manipulations would result in observable changes in the microworld. As learners observe those changes, they receive feedback through representations linked with the objects about their behaviors and changes in the system. Learners use this feedback to induce or discover properties and functioning of the system as a whole.

In an ESM-based curriculum, students explore and learn about scientific phenomena using ESMs. Students actively construct knowledge in a computational microworld using scientific inquiry practices similar to those scientists use to construct knowledge about the real world. The *GenEvo* curriculum incorporates a series of computational models designed using NetLogo (Dabholkar and Wilensky, 2016). In this curriculum, the emergent properties of biological systems include, genetic regulation, carrying capacity, genetic drift and natural selection. Students work in small groups of two or three. Their explorations are scaffolded by guiding them to focus on specific aspects of agent behaviors such as resource availability or DNA-proteins interactions. Students explore a model and identify its aspect that they find interesting to investigate. They are asked to state it as a research question and state their preliminary answer as a testable hypothesis. Then they design and conduct computational experiments in the ESM learning environment to test their hypotheses and present their investigations. Their findings collectively build towards ideas about the emergent properties in the context of genetic regulation and evolution.

## Methods

The data used in this paper are from an ESM-based biology course conducted in a residential summer camp in a western city in India where students from all over India participated. In this fourth iteration of the course, 12 students of age 11 to 14 participated of whom 5 were females and 7 were males. All the students were of Asian Indian origin. In addition to field notes and video recording, we conducted pre- and post- tests, and pre- and

post- interviews about students' ideas regarding science learning and what scientists do.

## Results

For the analysis in this paper, we focus on pre- and post- interview questions that were about students' perceptions regarding learning of science, especially from the perspective of understanding their agency in knowledge construction, and practices that scientists follow to construct knowledge. We identified shift in students' perceptions about their own agency after their participation in the ESM-based curriculum (Figure 1).

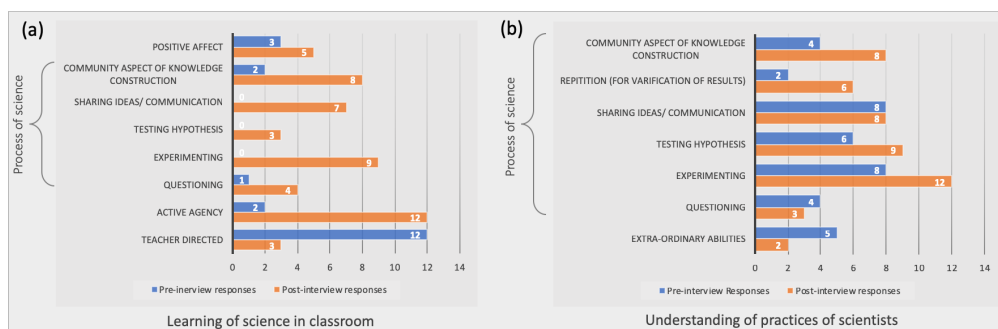


Figure 1. Students' perceptions about learning of science and practices of scientists.

Students described learning in a traditional classroom setting as a teacher directed process and they did not see active agency in learning and knowledge construction (Figure 1a). However, after participating in the ESM-mediated learning experience, all the students talked about actively constructing knowledge. The students specifically talked about process of science that they engaged in when they discussed their learning in the course. It is important to note that none of the students even mentioned about process of science when they talked about their science classroom learning prior to the course, as a response to the same question prompt. More number of students talked about learning in this course being enjoyable and fun. Students perceptions of who scientists are and what they do also showed notable shift (Figure 1b). In the post interviews, more students spoke about the scientific process of knowledge construction than mentioning scientists as people with extraordinary abilities. They talked about experimentation, testing hypotheses, repetitions to validate results and community aspects of knowledge creation being important parts of practices of scientists.

This analysis demonstrates how ESM-mediated learning in the *GenEvo* course transformed students' perceptions about their agency in knowledge construction in the context of a science classroom and changed their understanding of practices of scientists as well.

## References

- Berland, L. K., Schwarz, C. V., Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2016). Epistemologies in practice: Making scientific practices meaningful for students. *Journal of Research in Science Teaching*, 53(7), 1082-1112.
- Dabholkar, S., Anton, G., & Wilensky, U. (2018). GenEvo - An emergent systems microworld for model-based scientific inquiry in the context of genetics and evolution. *Proceedings of the International Conference for the Learning Sciences (ICLS 2018)*.
- Dabholkar, S. & Wilensky, U. (2016). GenEvo Systems Biology curriculum. <http://ccl.northwestern.edu/curriculum/genevo/>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.
- Jacobson, M. J., & Wilensky, U. (2006). Complex systems in education: Scientific and educational importance and implications for the learning sciences. *The Journal of the learning sciences*, 15(1), 11-34.
- Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., ... & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *The journal of the learning sciences*, 13(3), 337-386.
- Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). Helping students make sense of the world using next generation science and engineering practices. NSTA Press.
- Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories—an embodied modeling approach. *Cognition and instruction*, 24(2), 171-209.
- Wilensky, U., & Resnick, M. (1999). Thinking in levels: A dynamic systems approach to making sense of the world. *Journal of Science Education and technology*, 8(1), 3-19.



# Contribution to the Integration of MOOC in a Hybrid-Learning Project in the Moroccan University

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**Abstract:** This model relies mainly on the use of Massive Open Online Courses (MOOC). Several general questions have been raised around the MOOC, especially in relation to the reliability of online education and its ability to find a place on a par with traditional education. We have tried, through field studies, to answer key questions such as: Is higher education in Morocco able to produce more interesting results by adopting this new means of training?

## Introduction

Moroccan higher education is based mainly on direct face-to-face contact between students and teachers. As present, it has become possible to replace this medium of transmission of knowledge with a new pedagogical tool based on ICT (Information and Communication Technologies). The latter is not based solely on a simple reproduction of what is traditionally found in higher education, but with a new vision that highlights the positive aspects of virtual communities that allow for the emulation of experiences and knowledge. Our contribution is an attempt to advance a new model of the integration of a hybrid pedagogy based on real attendance and distance learning in relation to courses delivered at the Moroccan university.

## Significance and relevance of the topic

For a long time, the different entities of the educational triangle of Moroccan higher education, the teacher, the learner and the knowledge, have benefited very marginally from the ICT. But with the advent of training management platforms such as Moodle (Modular Object-Oriented Dynamic Learning Environment), e-learning platforms such as MOOC (Cisel, M., Bruillard, E. 2012) and the emergence of new mobile devices such as smartphones and tablets, training in the Moroccan university has changed a lot and in depth.

Currently, the Moroccan state has undertaken several investment projects for the modernization of its higher education system (Ouazzani Touhami, A., Benjelloun, N., Aami, M. and Haddou, A. 2014), as in the case of the Digital Morocco 2013 project, the ICT integration project in education, the LAWHATI project and the project INJAZ, (Alj, O. and Benjelloun, N. 2016), etc. Equally, the Moroccan universities have taken the initiative of setting up MOOC platforms for the benefit of learners, such as UH2C (MH2C MOOCs), UCAM (UC@Mooc), UIZ (MOOC UIZ) and UM5R (UM5MOOC). This initiative, if followed by distance learning, can help to minimize the problem of massification within universities, to improve the level of learners as well as their motivation and involvement in the use of ICT information and communication.

In this paper, we propose a hybrid-learning model in the Moroccan university education system. This project studied the different needs and expectations of learners and teachers, based on real experimental facts (Riyami, B., Mansouri, K. and Poirier, F. 2019) with the objective of testing the degree of motivation, satisfaction, involvement and appropriation of this new pedagogical approach. It tries to consolidate the initiatives of the Moroccan universities by a better exploitation of the MOOC in higher education and to generalize this new pedagogical approach for all the university learners.

## Content

The pedagogical approach proposed is in the form of a hybridization between face-to-face and the distance learning (Nissen, E. 2006). Among its main objectives are the diversification of pedagogical content, the development of new skills and the possibility of providing learners with the benefits of face-to-face classroom work and of free and flexible work at a distance. This approach brings together the tools and resources most adapted to modern pedagogical dimensions. A first part of the training is composed of face-to-face modules (direct exchanges, lectures, documents and discussions). A second part is taught remotely in a synchronous way through virtual classes and MOOC as external resources (De Poël, V., François, J., Lecomte, and Béatrice. 2013). A third part is done at a distance and asynchronously through the institution's own e-Learning systems as internal resources (Riyami, B., Mansouri, K. and Poirier, F. 2017). Our experiments have shown that the following conspiracies have to be respected in order to ensure the success of the hybrid-learning (see Figure 1):

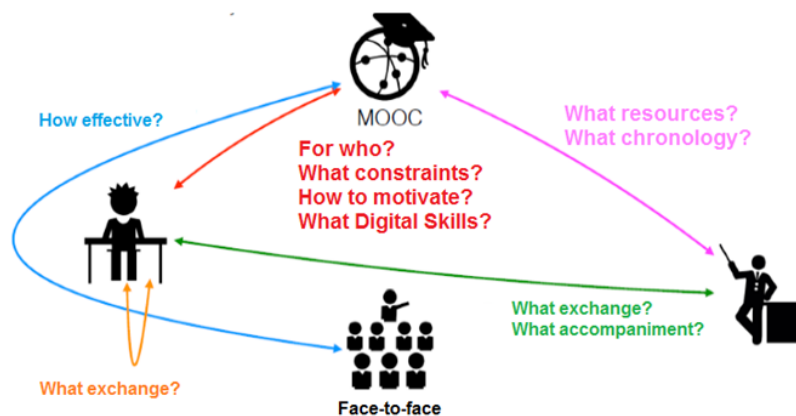


Figure 1. Questions of the success of the hybrid-learning.

- Effective and strong engagement of learners and teachers,
- Work on the prerequisites of the learners before starting the subject to be taught through the MOOC,
- Encouraging frequent Peer exchanges,
- Foster collaborative work between learners (Riyami, B., Mansouri, K. and Poirier, F. 2019),
- Effective supervision and guidance of learners,
- Good motivation of learners (Foon Hew, K., Sum Cheung, W. 2014),
- A provision of the necessary infrastructure to facilitate access to MOOC.

## Conclusion

In conclusion, we can confirm that our approach can satisfy most of the objectives targeted by the Moroccan higher education system:

- The struggle against the problem of the large number of student during the first years of university,
- The continuous updating of educational content,
- The decrease in the failure of university students,
- Facilitation of exchanges between peers and between learners and teachers.

## References

- Alj, O. and Benjelloun, N. (2016). Etude comparative de quelques recherches sur l'intégration des TIC dans l'enseignement des disciplines scientifiques au sein du programme GENIE marocain. Association EPI.
- Cisel, M., Bruillard, E. 2012. Chronique des MOOC. *Sciences et Technologies de l'Information et de la Communication pour l'Éducation et la Formation*, Vol. 19, 2012, [http://sticef.univ-lemans.fr/num/vol2012/13r-cisel/sticef\\_2012\\_cisel\\_13r.htm](http://sticef.univ-lemans.fr/num/vol2012/13r-cisel/sticef_2012_cisel_13r.htm)
- De Poël, V., François, J., Lecomte, Béatrice. 2013. MOOC, RÉVOLUTION ? BUSINESS ? OPPORTUNITÉ ? , Documents pédagogiques, Sciences sociales & comportementales, psychologie : Education & enseignement, jui-2013, <http://hdl.handle.net/2268/154729>.
- Foon Hew, K., Sum Cheung, W. (2014). Students' and instructors' use of massive open online courses (MOOCs): Motivations and challenges. *Educational Research Review*, 12 (2014) pp.45–58, [www.elsevier.com/locate/EDUREV](http://www.elsevier.com/locate/EDUREV)
- Nissen, E. (2006). Scénarios de communication en ligne dans des formations hybrides» *Le Français dans le monde. Recherches et applications, Paris : Français dans le monde, 2006, Les échanges en ligne dans l'apprentissage et la formation*, pp. 44-58. « edutice-00124819> », <https://edutice.archives-ouvertes.fr/edutice-00124819>.
- Ouazzani Touhami, A., Benjelloun, N., Aami, M. and Haddou, A. (2014). Impact of using Java Software of Geometrical Optics JSOG on the construction success of the virtual image among the first year university students. *IOSR Journal Of Research & Method in education IOSR-JRME*, Volume 4, Issue 3 Ver II, pp. 16-24

# From Face-to-Face to Online: Considerations for a Social Capital Design to Scale Science Teacher Access to High-Quality PD

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**Abstract:** This research investigates an approach to improving science teacher’s access to high-quality PD. Working with a small number of teachers, this exploratory study details how we combined social capital mechanisms with essential teacher learning and PD requirements to overcome existing challenges in the delivery of a PD course in a fully online asynchronous platform. Findings reveal comparably high satisfaction and usability of course materials as compared to previous face-to-face PD. Teachers also articulated positive experiences from the intentional social capital course design in the areas of tie quality, depth of interaction, and access to expertise. However, the development of trust among teachers was harder to construct.

## Introduction and theoretical considerations

This work was built on known characteristics of high-quality face-to-face PD for science teachers that included, teacher’s hands-on training, aligning with teaching contexts, exposure to scientific practices, and working with teachers as collaborators. Findings from our previous studies (e.g., Yoon et al., 2017) revealed high teacher satisfaction, high curricular utility, and increased student participation and learning outcomes. Strategic efforts to build teacher’s social capital in addition to building teacher’s human capital also improved their teaching. We were encouraged to consider how to scale to reach more teachers. Merritt (2016) noted that among the highest concerns articulated by teachers for improving practice is the need for more and flexible time. Peltola et al. (2017) highlight a dearth of access to professional peers. This report and others suggest that online PD has the potential to supplement local, in-person experiences. In this research, we investigated the application of an online social capital design asking: To what extent can a fully asynchronous PD course constructed through a social capital design deliver high-quality PD? There is already research that can inform us on strategies for building networked teacher communities such as making practice public (Lieberman & Mace, 2010), multiple options for knowledge sharing, the development of trust, and highlighting member expertise (Booth, 2012). This can also be collectively described as development of teacher social capital (e.g., Yoon & Baker-Doyle, 2018). As opposed to teachers’ human capital which is a focus on developing knowledge and skills within an individual, a focus on social capital develops teaching capacities that can be acquired through direct and indirect relationships in social networks. Coburn and Russell (2008) offer a useful categorization of social capital characteristics that include: tie quality, trust, depth of interaction, and access to expertise.

## Methodology

This work was funded to examine the ability to scale high-quality PD on a MOOC platform. However, in this proof-of-concept study, we worked with a small number of teachers to examine the impact of design choices that frame participation through social capital and teacher learning that could eventually support PD at larger scales. Our task in the online PD delivery mode was to replicate the high levels of satisfaction, confidence, and engagement with the StarLogo Nova modeling curricula. We developed six weekly online modules that mirrored the topics that were investigated in the face-to-face PD. With respect to designing for the characteristics of high-quality PD and teacher learning through building social capital online, Table 1 outlines details of the first category of design choices. The other three categories will be presented in the poster.

Table 1: Considerations for social capital plus PD and teacher learning that led to design choices

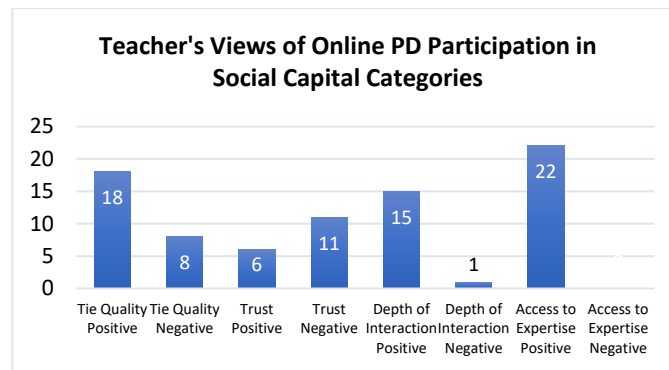
Social Capital Category	PD and Teacher Learning Characteristics	Design Choice for Online Delivery
Tie Quality	Building relationships	• Online profiles to share professional and personal information, e.g., <i>Write a post that describes your background (e.g., how long you have taught, unique skills or knowledge)</i>

		that might interest your classmates). After you have responded, use the forum to connect to a couple of other course participants by clicking "reply" to comment on their posts.
	Peer-to-peer support	• Seeding norms of support, e.g., <i>In the Discussion Forum, briefly discuss how one example impacted your thinking about systems. After you have responded, read a couple of other posts and click the heart icon for any that resonate with you.</i>

We worked with eight teachers from different geographic locations around the northeastern part of the U.S. Of the eight teachers, seven were female and one was male. Teaching experience ranged from 0 to 20 years with an average of 8.4 years of experience. We collected two data sources: PD satisfaction surveys and teacher post-course experience interviews. The survey probed experiences with the course resources in terms of course satisfaction. Results from two previous implementations of the face-to-face PD were also used for comparison. Individual post-course interviews were conducted with teachers to gather information about their participation.

## Results and discussion

Findings from the usability survey showed that the online teachers on average rated all 18 Likert-scale items between 4.5 and 5, which indicated very positive PD experiences. These scores were comparable to scores from previous face-to-face PD. The teacher interview analysis showed 26 comments related to the category of Tie Quality; 17 related to the category of Trust; 16 related to the category of Depth of Interaction; and 22 related to the category of Access to Expertise. The figure below shows the breakdown in terms of positive and negative comments in each category.



These findings provide encouragement that through a social capital and teacher learning framework, we may be able to offer high quality PD in a fully asynchronous online mode.

## References

- Booth, S. E. (2012). Cultivating knowledge sharing and trust in online communities for educators. *Journal of Educational Computing Research*, 47(1), 1-31.
- Coburn, C. E., & Russell, J. L. (2008). District policy and teachers' social networks. *Educational Evaluation and Policy Analysis*, 30(3), 203-235.
- Lieberman, A., & Mace, D. P. (2010). Making practice public: Teacher learning in the 21<sup>st</sup> Century. *Journal of Teacher Education*, 61(1-2), 77-88.
- Merritt, E. G. (2016). Time for teacher learning, planning critical for school reform: Students aren't the only ones who need more time to learn; teachers also need more and better time for learning and for planning. *Phi Delta Kappan*, 98(4), 31.
- Peltola, P., Haynes, E., Clymer, L., McMillan, A., & Williams, H. (2017). Opportunities for teacher professional development in Oklahoma rural and nonrural schools (REL 2017-273). Washington, DC: U.S.
- Yoon, S., Anderson, E., Koehler-Yom, Evans, C., Park, M., J., Sheldon, J., Schoenfeld, I., Wendel, D., Scheintaub, H., & Klopfer, E. (2017). Teaching about complex systems is no simple matter: Building effective professional development for computer-supported complex systems instruction. *Instructional Science*, 45(1), 99-121.
- Yoon, S.A., & Baker-Doyle, K. (Eds.) (2018). *Networked by design: Interventions for teachers to develop social capital*. New York, NY: Routledge Press.

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# Epistemic Frames of Idea Evaluation in Collaboration

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**Abstract:** Idea promisingness is a key to the creative work. Although studies have shown its importance, they have not yet dug into multiple meanings of promisingness. In this study, we approached the problem by examining the criteria of idea evaluation. Epistemic network analysis by successful and unsuccessful groups revealed that students in the successful groups held their epistemic frames of idea evaluation by taking the balance between being challenging and pragmatic.

## Background and research purpose

In the knowledge age, workers are expected to engage in continuously creating new ideas through collaboration with others. Such competence is not innate but should be developed in the context of learning. Chen, Scardamalia, and Bereiter (2015) examined the extent to which elementary school students could appropriately judge promisingness of their ideas to facilitate knowledge-building. Their analyses indicated that their students held their primitive sense of promisingness and could develop their competence to judge promisingness of their ideas through well-designed exercise. Chen (2017) further explored the relationship among students' competence to judge their idea promisingness, conceptual understanding of their study topic, and their epistemic beliefs. Through his design-based research in a sixth-grade classroom, Chen found that students succeeded in improving their understanding and judging promisingness through their repeated practices. Along with the development of their competence to judge promisingness, conceptual understanding and epistemic beliefs also improved throughout practice. Although the promisingness of ideas has been found a key to the collective knowledge advancement, studies so far have not dug into the criteria of idea evaluation. When students evaluate their ideas, the promisingness may have multiple meanings. Blair and Mumford (2007), for instance, asked undergraduates to evaluate ideas, and found that students highly evaluated ideas based on the criteria such as (1) whether the ideas are easy to understand, (2) whether they provide short-term benefits to many, and (3) whether they are consistent with prevailing social norms. Their undergraduate students disregard risky, time consuming, and original ideas. Original and risky ideas, however, were conditionally preferred. When evaluation criteria were not especially stringent and time pressure was high, the undergraduates selected the risky and original ideas. What studies like Blair and Mumford suggest is that people use multiple criteria to evaluate their ideas depending on conditions. In future studies, therefore, we have to examine what criteria of idea evaluation including the promisingness are used by learners in learning environments and their individual or group differences for considering further support for learners to engage in the knowledge creation practices.

The purpose of this study was to propose a new framework of analysis of learners' idea evaluation and examine group differences in their epistemic frames of idea evaluation during project-based learning. For doing so, we used Epistemic Network Analysis (ENA) as a tool for describing epistemic frames held by successful and unsuccessful groups. ENA is an algorithm that identifies and calculates connections among elements in coded data and visualizes them in dynamic network models that illustrate their structure and strength over time (Shaffer, 2017). With ENA, researchers can qualitatively and quantitatively examine cultural practices that participants engage through their discourse.

## Method

### Subject groups

We selected four groups (two successful groups and two unsuccessful groups) in a project-based learning course on creating new happiness indicators for first-year university students. Seventy students took the course for their requirement and worked in groups on their proposal of new happiness indicators with the use of open source data available on the internet. Based on their final grades, two successful and two unsuccessful groups were selected for our analysis of their epistemic frames of idea evaluation. The two successful groups were comprised of four students each, and the unsuccessful groups were comprised of three and four students.

### Collected data and coding

The course continued in fifteen weeks. Students' discussion in their groups was audio-recorded and the recordings in week 9–11 for the target groups were used for the analysis. We selected the recordings in the weeks as they were a period when students were mainly engaged in generating their new ideas. Every discourse exchange was coded on ELAN (<https://tla.mpi.nl/tools/tla-tools/elan/>) with using twelve attributes of idea evaluation by Blair and Mumford (2007).

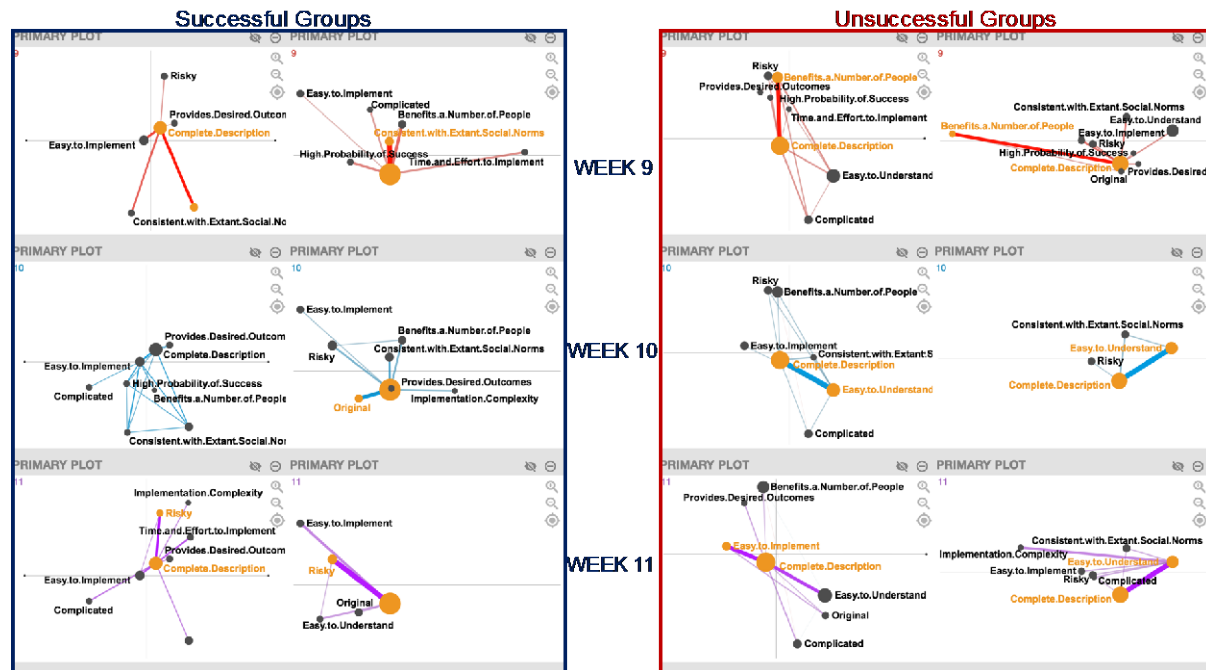


Figure 1. Temporal changes in epistemic frames of idea evaluation by successful and unsuccessful groups.

## Results and discussion

Based on the co-occurrence of attributes within units of discourse exchanges, the target groups' epistemic frames of their idea evaluation were visualized across the three weeks (Figure 1). Comparison between the successful and unsuccessful groups revealed commonalities and differences. First, both types of groups mainly discussed their ideas from the perspective of complete description (i.e., how their ideas about new happiness indicators should be described). They paid much attention to which evidence and data should be used for claiming the effectiveness and importance of their ideas. Second, although both types of groups shared the primary component in their epistemic frames, they were critically different in that different attributes were strongly connected with the complete description. In the successful groups, they were more likely to consider aspects of the risk and originality of their own ideas in later weeks in comparison with the unsuccessful groups that stayed at easiness to understand and implement. Thus, the successful groups engaged in an examination of the risks and originality of their ideas at some points of their generating ideas. How promising their ideas were crucial for both groups, but their meanings of the promisingness was not the same. For successful groups, the promisingness meant challenging enough as well as reasonable to understand and implement. The balance between the two dimensions of idea evaluation might be the key for us to support every group of students to be engaged in their creative work with ideas.

## References

- Blair, S. C. and Mumford, D. M. (2007). Errors in idea evaluation: Preference for the unoriginal? *The Journal of Creative Behavior*, 41(3), 197–222.
- Chen, B. (2017). Fostering scientific understanding and epistemic beliefs through judgments of promisingness. *Educational Technology Research and Development*, 65, 255–277.
- Chen, B., Scardamalia, M., and Bereiter, C. (2015). Advancing knowledge-building discourse through judgments of promising ideas. *International Journal of Computer-Supported Collaborative Learning*, 10, 345–366.
- Shaffer, D. W. (2017). *Quantitative ethnography*. Madison, WI: Cathcart Press.

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# Collaborative Knowledge Construction Mediated by Technology

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**Abstract:** Collaborative knowledge construction is a complex process and entails many forms of communicative and social interactions. This preliminary, qualitative case study attempts to understand collaborative knowledge construction processes when learners share both physical and virtual environments to create digital structures. The results show four techniques in which the participants engage to advance the digital creations. This study provides educators with insight of how to capitalize on opportunities to use technology and support collaboration.

**Keywords:** knowledge construction, collaboration, informal environments

## Introduction

Collaboration has been strongly emphasized as a means of helping students in educational school systems to thrive in an era of technological acceleration. Virtual environments provide unique opportunities for participation in and practice with collaborating in the creation of artifacts, solutions, and play (Gee, 2007). In considering creative knowledge work, it is essential that students have experience in building knowledge to serve two purposes: practical purposes and conceptual understanding (Scardamalia & Bereiter, 2014). Doing this, of course, results in heightened challenges for educational institutions integrating such technology into classrooms. Students in school use technology at the request of teachers to participate in a structured, supervised, directed and often perform given tasks individually. Contrarily, young people at home have developed habits and expectations of how to utilize technologies to participate in unstructured, non-supervised, and collaborative ways to pursue interests (Clark et al., 2009). If educators are to capitalize on opportunities to use technology to support collaboration in classrooms, there is a need for a more nuanced understanding of natural collaborative interactions and knowledge construction like those that take place in home environments. Three-dimensional virtual learning environments (e.g., *Minecraft*) offer rich tools and features that support collaboration and facilitate group tasks in a way that leads to rich and effective collaborative learning. To study collaborative knowledge construction, we need to consider the context in which group activity occurs. Collaborative knowledge construction takes place when team members contribute to the accretion of shared understanding through seeking and integrating information, which leads to the transformation of the shared representation within the specific context (Suthers, 2006). Hence, this study aims to explore how elementary school students incorporate ways of knowing and acting to advance knowledge construction as they use iPads to engage in collaborative digital production within *Minecraft*'s virtual environment, while at the same time sharing a physical environment.

## Methods

I conducted the study in the home of two siblings who usually invite friends over to play together. The participants engaged with *Minecraft* in two phases. In the free play phase, the participants engaged in planning, designing, and constructing the digital structures without being asked to meet specific requirements. The semi-structured play phase included ill-structured design scenarios that I had created with specific requirements to satisfy. The study lasted for nine weeks, from April to June 2018. The collected data is from three groups of elementary school students (third-, fourth-, and fifth-graders) who are siblings or friends. A variety of data sources were collected: weekly video sessions of *Minecraft* group digital constructions (a total of 24 sessions), produced artifacts, and individual interviews. For the purposes of this paper, I draw on data collected from one group (two male fifth-graders). The members in the selected group have the strongest friend relationship and more *Minecraft* experience among the other groups. To analyze the collected data, I used the analytical framework that was developed by Borge et al. (2015) as a basis to assess the quality of online collaborative discourses. Because the framework focuses on the dialogical aspect of social interaction, I expanded the framework to include other interactions like gestures, body movements, and interaction with the iPad. The group video-recording sessions were coded and analyzed at the micro level using interaction analysis. Two coders coded 20% of the total data. Inter-rater reliability was  $Kappa = 0.80$  ( $p < 0.001$ ). Upon reaching good level of agreement, I coded the rest of the data.

## Findings

The data analysis identified four techniques that the participants employed to advance the digital structures.



## Utilizing the screen's presentation with talk responses

Six primary forms of talk response emerged from the interactions: joint idea-building, questioning, justification, task management, reflection and judgment, and claiming. These techniques made for a remarkable contribution in constructing group knowledge. One example is when the participants expanded the original idea of their project, the mall, to include a beach next to it. The participants advanced their ideas and moved from the focus on the mall to the focus on the area surrounding the mall and how the mall should provide and serve as a supplemental organization for the people who visit the beach area. The generation of this thoughtful new understanding was as a result of joint idea-building and understanding and iterative judgment.

## Presenting meaning through embodied knowledge and gestures

In addition to verbal speech, gestural and body conceptualizations were essential tools for the group in displaying tacit knowledge and explaining the abstract concept. These types of expressions support the construction of shared meaning between individuals, facilitate the comprehension of abstract concepts, and bridge the gap between individual knowledge and group cognition.

## Switching the screen between public and private spaces

The participants often shared their iPad screens with each other to share content, seek help, obtain confirmation, or request clarification. The participants' frequent transitions between private and public spaces reveal four different patterns (see Fig. 1). As the participants made their iPad screens as part of their dialogue and switching between their public and private spaces, the socially constructed meaning of their ideas was affected.

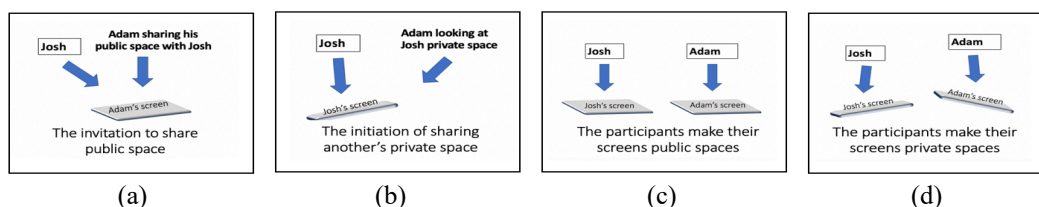


Figure 1. Four different patterns of switching iPad screens between group members.

## Workspace awareness: The presence of links between physical and virtual locations

The participants frequently employed strategies, including self-awareness and group-awareness, over the course of the projects to maintain the presence of links between their physical and virtual locations. These critical strategies help the team members navigate each other's work and provide each other with updated information about current co-constructed work, which eventually leads the team to achieve the desired objectives.

## Conclusion and implications

The study shows how learners engage in multimodal interactions to advance the creation of artifacts. To maximize the quality of collaboration, students need to know what each other is doing, keep track of the group work, and recognize what relevant features of the used materials and technology. Educators can play the role of facilitators who help students possess this required knowledge. Educators also can plan instruction to help students learn and experience the processes of constructing knowledge. Nevertheless, this study sheds light on the need for models and best practices that support the engagement in such processes.

## References

- Borge, M., Ong, Y., & Rosé, C. (2015). Activity design models to support the development of high-quality collaborative processes in online settings. *CSCCL*. In O. Lindwall, H. Päävi, K. Timothy, T. Pierre, & L. Sten (Eds.), *The Computer-Supported Collaborative Learning Conference 2015 Conference Proceedings: Volume 1* (427–434). Gothenburg, Sweden: International Society of the Learning Sciences
- Clark, W., Logan, K., Luckin, R., Mee, A., & Oliver, M. (2009). Beyond web 2.0: Mapping the technology landscapes of young learners. *Journal of Computer Assisted Learning*, 25, 56–69.
- Gee, J. (2007). *What video games have to teach us about learning and literacy*. New York: Palgrave MacMillan.
- Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge Handbook of Learning Sciences* (397–417). New York: Cambridge University Press.
- Suthers, D. (2006). A qualitative analysis of collaborative knowledge construction through shared representations. *Research and Practice in Technology Enhanced Learning*, 1(2), 1–28.



# Online Mob Programming: Bridging the 21<sup>st</sup> Century Workplace and the Classroom

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**Abstract:** We investigate how an industry-standard collaborative software development paradigm can be adapted for collaborative project-based learning in the classroom. The synchronous face-to-face collaboration paradigm, called Mob Programming, inspires Online Mob Programming (OMP), which structures groups of 3-6 students collaborating online in a rotating set of 3 roles supported by a conversational computer agent who takes on a 4<sup>th</sup> role. Results comparing OMP scaffolding with self-organization in a university computer science course shows OMP scaffolds encourage role-taking, division of labor, and conceptual reflection during work without a significant drop in group product quality.

## Introduction

With a goal of integrating learning opportunities into collaborative work, we start in the software engineering context by adapting an industry inspired paradigm for collaborative software development called Mob Programming (Zuill and Meadows, 2016) into a collaborative learning paradigm for the classroom called Online Mob Programming (OMP). By focusing on a paradigm already popular in the industry, we aim for two distinct benefits: first, allowing students to engage in an industry relevant group practice in order to prepare them for work in industry; and second, developing an empirical foundation for structuring work practices in ways that might facilitate injecting collaborative learning opportunities into the workplace of the future. Evidenced by the rise of standards such as 21<sup>st</sup> Century Skills (Burrus et al., 2013), providing workplace-relevant learning opportunities for students is an increasing concern even as the rate at which the job market is changing is rapidly increasing.

Online Mob Programming is adapted from the industrial practice of Mob Programming, where participants rotate through the following roles – **Driver**: A single participant who converts high-level instructions from the Navigator into code; **Navigator**: A single participant who makes decisions from discussing with the Mob and communicates that to the Driver to be implemented into code; **Mob**: A participant or group of participants who consider and deliberate between multiple alternative implementations ultimately informing the decision of the Navigator; **Facilitator**: A single participant who observes and intervenes when necessary, such as to indicate when roles are to switch and to keep the activity progressing. The rotation of mob roles affords participants the opportunity to experience how group processes change when leadership changes within a group. Each participant will experience all the roles throughout a single mob programming session.

We address the concern that students in project courses fall into a pattern of emphasizing productivity over learning, which leads to divide-and-conquer strategies rather than shared cognition and conceptual reflection during work. In our work, the role of the facilitator is meant to guide role taking in order to mitigate these problems. That role is performed by an intelligent conversational agent implemented using the open source Bazaar framework (Adamson et al., 2014). Our study investigates the extent to which assigning students to OMP roles and periodic rotation of the role assignments reduces the adoption of suboptimal strategies. Through the interaction afforded by the paradigm, students are exposed to different perspectives in solving problems, building solutions, experimenting, debugging and writing readable code. They are also forced to externalize their thinking, which provides the opportunity for knowledge gaps to be revealed and addressed. Finally, they have the opportunity to observe knowledge and expertise in action as they observe their team-mates.

## Experiment and results

The OMP framework discourages the allocation of tasks purely on the basis of prior expertise, thus allowing students to not only contribute in roles they are already good at, but also learn from their teammates to contribute in roles when they are not. We can hypothesize therefore, that (1) ***the OMP scaffold, if effective, will produce distinct collaborative behaviors associated with each role in mob programming.*** If we also believe that students would default to optimizing for productivity in the absence of such as a scaffold, we can hypothesize that (2) ***these distinct collaborative behaviors will not be adopted in self-organized groups, which might result in student behavior looking far more consistent throughout the activity.*** By enforcing the OMP scaffold for collaboration however, we run the risk that productivity may be harmed because students less expert at each subtask may get in

the way. Furthermore, the cognitive load from role-switching might reduce productivity on the task and putting students in roles they are not familiar with could increase discomfort and therefore negatively affect their perception of the task. We hypothesize therefore, that (3) **students from the OMP scaffold groups might feel more negatively about their experience compared to students from the self-organized groups and might perform worse on their project.** In order to test our hypotheses, we experimentally contrast the mob programming scaffold against student self-organization in a between subjects design embedded within a *completely online* software development course. A total of 120 students took the course organizing themselves into teams of 3 for a semester long course project. In the first week of the course, they were grouped randomly into teams based only on their time availability to participate in an OMP training session. The experimental manipulation took place two weeks after the OMP training session when students had acquired the prerequisites necessary to complete the programming task. We collected logs of code contributions and chat logs from the team programming activity, Grades on individual assignments and the team project prior to and post the team programming exercise help control for differences in prior knowledge among students assigned to either condition, and a Post team programming exercise survey asking about prior familiarity with teammates, how this activity helped discover teammates', how they chose to structure the activity, how their experience with the OMP training session helped structure this activity, how effective they felt their organization was, both in the training session and in this activity, and their experience with the Cloud9 interface.

**Hypothesis 1: The OMP scaffold, if effective, will produce distinct collaborative behaviors associated with each role in mob programming.** A goal of OMP is to orchestrate rotation of team members through a set of three distinct but interdependent roles. We therefore expect to see distinctive behavior patterns within the collected data streams associated with the roles. As both a manipulation check and a lens to elucidate the effect of the manipulation on collaborative processes, we conducted a quantitative discourse analysis in the form of a factor analysis over the text. We expected and indeed saw characteristic patterns between roles to be more distinctive in the OMP condition. Hypothesis 1 was thus supported.

**Hypothesis 2: The distinct collaborative behaviors associated with roles in the OMP condition will not be observed in self-organized groups, which might result in student behavior looking far more consistent throughout the activity.** We considered that it is possible that within self-organized groups that members took up roles despite not having been assigned. If this was the case, we might not see those distinctively in the analysis above since turns from all team members are taken together in the self-organized condition and thus, we would only be able to see average behavior across roles (if any). In order to test this hypothesis therefore, we had to adopt a different methodology - cluster analysis. We clustered turns using k-means clustering in order to identify cross-cutting factor profiles. One cluster contained only turns from the 3 supported roles. None of the clusters were distinguishing for the unsupported condition. Hypothesis 2 is thus supported.

**Hypothesis 3: Students from the OMP scaffolded groups might experience more discomfort as compared to students from the self-organized groups if the scaffolds are effective in countering the natural tendencies of students to gravitate towards what they are experienced doing. They may also produce lower quality work.** In the post-programming exercise survey, we asked students about their experience with the Cloud 9 environment and how prepared they were for future group projects. The evidence that students in the Mob programming condition were less comfortable was marginal. Importantly however, a linear regression model built using the mob session grade as the outcome variable, the condition as the main factor while controlling for students' prior grades and familiarity with their team members found no significant differences between the two conditions suggesting that while students provided with the scaffold experienced marginally significantly more discomfort, this did not manifest itself in actual performance differences. Hypothesis 3 is thus partly supported.

## References

- Burrus, J., Jackson, T., Xi, N., & Steinberg, J. (2013). Identifying the most important 21st century workforce competencies: An analysis of the Occupational Information Network (O\* NET). *ETS Research Report Series, 2013(2)*, i-55.
- Zuill, W., & Meadows, K. (2016). Mob Programming: A whole Team Approach. In *Agile 2014 Conference, Orlando, Florida*.
- Adamson, D., Dyke, G., Jang, H., & Rosé, C. P. (2014). Towards an agile approach to adapting dynamic collaboration support to student needs. *International Journal of Artificial Intelligence in Education, 24(1)*, 92-124.
- Buchan, J., & Pearl, M. (2018, June). Leveraging the Mob Mentality: An Experience Report on Mob

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# Moving Beyond the “Façade of Participation”: Using Choice-based Design to Enhance Online Discussions

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**Abstract:** A universal struggle in online education is encouraging authentic engagement. Nowhere is this familiar challenge more apparent than the online discussion forum, which students often treat as obligatory rather than enriching. This reaction could be due to low self-determination within the course design. Using Self-Determination Theory as its basis, this study seeks to address the question of whether a choice-based course encourages autonomy, competence, and relatedness, and if these result in enhanced engagement in forums.

## Introduction

Online course enrollment continues to grow, with over a quarter of U.S. higher education students taking at least one online course (Online Learning Consortium, 2016). However, though it is now generally accepted that learning outcomes from online courses equal those of face-to-face (f2f) courses (Means, Bakia, & Murphy, 2014), one area that still struggles to compete with the f2f environment is the asynchronous online discussion forum.

While current LMS forums include tools beyond text to help facilitate more human interaction, students often treat discussion forum assignments as requirements to check off a list, rarely engaging in sustained, meaningful conversation (LaPointe & Reisetter, 2008). What results is a formulaic “discussion,” where each student creates an initial response to the instructor’s prompt and 1–2 (if any) replies to peers. In this way, forums can feel more like reporting in than having a real conversation, what Stodel, Thompson, and MacDonald (2006) term “a façade of participation” (p. 11).

To encourage more authentic interaction, the forum needs to appeal to students’ intrinsic motivation. Choice and opportunities for self-determination enhance people’s sense of agency, which in turn tends to enhance their intrinsic motivation (Deci & Ryan, 2000). This suggests that if an instructor uses a choice-based model to encourage student autonomy, competence and relatedness should follow, ideally resulting in forum discussions that move beyond the façade of participation.

## Theoretical frameworks

Students interacting minimally in discussion forums are demonstrating “amotivation,” meaning they either do not post at all, or they post without intent, “just go[ing] through the motions” (Deci & Ryan, 2000, p. 72). These displays of amotivation are a signal that the forum is not meeting the students’ educational needs, whereas environments that appeal to innate psychological needs of autonomy, competence, and relatedness promote intrinsic motivation (Deci & Ryan, 2000). This idea forms the basis of Deci and Ryan’s (2000) Self-Determination Theory (SDT). According to SDT, amotivation manifests from one (or more) of four conditions: nonintentional, nonvaluing, incompetence, or lack of control. Unfortunately, this captures all too many online discussions: required forums (lack of control) a student does not care about (nonvaluing) or cannot adequately address (incompetence), resulting in lackluster posts (nonintentional).

One way to address amotivation is to instill in students a sense of control. If students can choose whether and how they interact in a discussion forum, this sense of choice could help promote agency. Control alone, though, will not result in a student’s feeling empowered self-determination. All three aspects of SDT—autonomy, competence, and relatedness—contribute equally to an individual’s sense of self-determination, so all elements must be present. Therefore, the autonomy gained from having choice would need to positively impact competence and relatedness as well for self-determination to be actualized.

This design-based research study (Amiel & Reeves, 2008) explores whether using a choice-based course design will positively impact all three aspects of SDT, leading to the first research question: ***RQ1: How does a choice-based course influence students’ perceptions of self-determination?***

In addition to students’ feeling enhanced autonomy in a choice-based course, it is hypothesized this approach will also lead to higher levels of both cognitive and social engagement within discussion forums, addressing SDT’s competence and relatedness. To gauge these levels, this study employs the Community of Inquiry model (Garrison, Anderson, & Archer, 2000), a framework popular for assessing online learning communities. The Community of Inquiry (CoI) model is illustrated by a Venn diagram that includes three domains: teaching presence, social presence, and cognitive presence. This current study focuses on social presence and cognitive presence from the model. Social presence (SP), which is comprised of affective, interactive, and cohesive subdivisions, is the ability for individuals to present themselves in a way that allows them to be seen as

real people in a virtual environment. Cognitive presence (CP) refers to a progressive scale of demonstrated critical thinking with four phases: a triggering event, exploration, integration, and resolution. This study will apply the CoI model's elements of SP and CP to assess students' levels of social and cognitive engagement in a course, which will be used to address the second research question: **RQ2: Is there a relationship between students' perceptions of self-determination and their levels of social and/or cognitive engagement in the discussion forums?** The researcher hypothesizes that students in a choice-based course will demonstrate higher levels of perceived self-determination than those in a non-choice-based course (RQ1), and that these students additionally will demonstrate higher social and cognitive engagement scores (RQ2).

## Context and methods

This study is being conducted on two sections of a fully online introductory liberal education course at a large public university in the Midwestern United States. Each course, housed in Canvas, is capped at 20 undergraduate students and is available to all programs of study at the university. One section is designed with the choice-based model, and one is not. The sections are taught by the same instructor but are not concurrent. The first way in which student autonomy is supported in the experimental course's design is through choice of topics covered. At the beginning of the semester, students are asked to complete a survey to determine preferred course topics, the outcome of which is used to determine content covered. The course design also offers choice in assessment. Students are offered a variety of activities at different point values, allowing them to participate in ways they find meaningful. For students uncomfortable with options, there is a default method provided.

To address SDT perceptions of autonomy, competence, and relatedness (RQ1), students will be given an end-of-course survey based on a modified version of the Basic Psychological Need Satisfaction in General (Deci & Ryan, 2000; Gagné, 2003). To assess students' levels of competence and relatedness, the CoI model (Garrison, Anderson, & Archer, 2000) will be used. Students' discussion posts will be qualitatively coded using a quasi-deductive approach based on the CoI model, with the inclusion of internal breakdowns of low, medium, and high levels for each subdivision of each presence. These will be used to create two coding sets: one with a score of 1–12 for the progressive states of cognitive presence (to assess competence), and one for a score of 1–3 for each subset of social presence (to assess relatedness). See Table 1. A correlational analysis of survey scores and SP and CP scores then will be conducted, comparing the choice-based course and the control (RQ2).

**Table 1: Two sample codes – Social Presence (Interactive)**

Score	Characteristics	Course example
Low (1)	Short response that does not elicit further interaction or demonstrate comprehension; agrees/disagrees/compliments but does not elaborate	“Great post! I really like what you had to say about rights ethics.”
High (3)	Agrees/disagrees with more in-depth explanation; adds own opinion with support; seeks to engage discussion further with questions, elaboration, challenges, etc.	“N—, Your statement regarding the relevance of cultural relativism being extremely relevant, ‘especially in 2019’ intrigues me. I wonder if your wording was intentional, meaning that the current year that we are experiencing has made cultural relativism more important to our society than it was in past years. I also wonder what your meaning is behind, ‘society is at different stages depending on where you go in the world.’ What are these stages? Is one stage a progression of the next, or are they all dependent on the society that they refer to?”

## Implications

As online courses become omnipresent, understanding how design choices impact learning is increasingly imperative. While this study is ongoing, the hope is results will suggest using a choice-based model positively impacts self-determination, ultimately helping to alleviate the “façade of participation” in discussion forums.

## Key references

- Deci, E. L., & Ryan, R. M. (2000). Self-Determination Theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), 68–78.
- Gagné, M. (2003). The role of autonomy support and autonomy orientation in prosocial behavior engagement. *Motivation and Emotion*, 27, 199–223.
- Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, 2(2–3), 87–105.

# Making the Design of CSCL Analytics Interfaces a Co-design Process: The Case of Multimodal Teamwork in Healthcare

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**Abstract:** Multimodal Learning Analytics innovations offer exciting opportunities for Computer-Supported Collaborative Learning (CSCL) practice and research, but they also make more evident the need to make the design of analytics tool into a horizontal, co-design process. The emergence of new algorithms and sensors can be a major breakthrough in the way CSCL research is conducted and automated feedback is provided. However, there still is a lack of research on how these innovations can be used by teachers and learners, as most existing systems are restricted to experimental research setups. This poster paper sheds light on the first steps that can be made towards making the design of CSCL analytics interfaces a co-design process where teachers, learners and other stakeholders become design partners.

## Introduction and related work

The emergence of new algorithms and sensors that can track activity in both physical and digital spaces are making collocated activity visible and available for computational analysis, particularly for open-ended, unrestricted tasks that are closer to the kinds of activities that learners commonly face in professional placements (Blikstein and Worsley, 2018). This can be a major breakthrough in the way Computer-Supported Collaborative Learning (CSCL) research is conducted and automated feedback is provided. Moreover, there is a recent intention within the CSCL community to consider the physical and embodied characteristics of learners, the learning environment and the interactions that occur with and within this environment (as highlighted in the CSCL 2019 conference theme). There is currently however a lack of research on how Multimodal Learning Analytics (MMLA) innovations can support reflection and decision-making (Shankar et al., 2018), as most existing systems are restricted to experimental setups (Ochoa, 2017).

## Design challenges for CSCL and Multimodal Learning Analytics

There is a small but growing interest in building a new generation of monitoring, awareness and reflection tools for f2f learning activities (see review in Rodríguez-Triana et al., 2017). A promising way to achieve this is to capture behavioural traces from co-present activities using sensors and logging capabilities of educational interfaces, analyse them, and create feedback mechanisms to support reflection and evidence-based practice (Blikstein and Worsley, 2018). In contrast to the significant effort that has been invested in automatically mining digital traces of online group experiences, where logs can be easily captured, much more needs to be done to invent ways to support f2f collaboration. However, the complexities of embedding yet another type of technology in authentic CSCL contexts may open a range of critical challenges for successful adoption.

We have identified, through our empirical work in the area of MMLA, the following challenges that motivate the need for making the design of effective CSCL interfaces a collaborative, horizontal co-design process (e.g. including teachers and learners throughout the design process, moving beyond initial consultation): 1) representations of multimodal, group data can be inherently complex (Di Mitri et al., 2018) hence the need for making the mapping from low level data to higher-order constructs explicit and transparent to stakeholders to facilitate sense-making (Martinez-Maldonado et al., 2019); 2) critical privacy issues may arise in tracking activity in a collocated setting, compared to fully online group settings, as sensing technologies may unintentionally capture more behavioural data than needed (Krontiris and Maisonneuve, 2011); 3) CSCL analytics interfaces would show data of more than one person hence the need for mechanisms to ensure privacy while endorsing visibility and accountability (Echeverria et al., 2019). Our paper contributes to address these challenges by motivating a five-step elicitation process to *design-for* effective use of CSCL visualisation systems with teachers and/or learners.

## First steps towards co-designing effective CSCL interfaces

The overarching aim of our particular MMLA research is to provide automated feedback to nursing students working around patient manikins engaged in clinical simulations. These are commonly run as laboratory sessions in clinical classrooms equipped with 5-6 basic manikins located on hospital beds which produce indicators of a patients' health, respond to actions, and can be programmed to deteriorate over time. We have equipped the

environment and learners with a number of sensors (including microphones, indoor localisation badges and physiological wristbands) to track different aspects of the activity such as determining who is speaking, where nurses are in the space, arousal states and actions performed on the manikin. Quickly we realised that for creating automated feedback mechanisms or interfaces that promote reflection in this particular CSCL setting, a deep understanding of the area of healthcare simulation was needed and close collaboration with educators, learners, professional nurses, and other stakeholders was of utmost importance to craft interfaces that could be effectively used, orchestrated and appropriated by them.

We propose a five-step elicitation process to co-design for the effective use of CSCL systems. This articulates questions for diverse stakeholders that cover orchestration aspects and particular learning analytics co-design constructs into the process steps. Table 1 presents an overview of this process

Table 1: A five-step elicitation process to design for effective use of translucent CSCL systems.

Process step	Description
STEP 1 – WHO: Understand the people who are part of the classroom ecology, by describing the different roles/stakeholders.	This step includes questions to identify the key <b>stakeholders</b> in the CSCL situation, and the different <b>roles</b> that are actually active during the (classroom) activity.
STEP 2 – INFLUENCE & POWER: Mapping the influence of all roles on interaction/activity.	This step includes questions about the relationships of power and influence among the stakeholders and roles, including: <b>influence on other people, power hierarchy, influence on the learning design and influence on the adoption</b> of the MMLA tool.
STEP 3 – QUESTIONING: Define the questions to be answered by the learning analytics solution or hypotheses/expectations that can be tested with evidence.	This step includes questions aimed at identifying the <b>classroom dynamics</b> that can be observed in regular classes and the common <b>questions or hypotheses</b> that can be confirmed or rejected based on evidence captured through the learning analytics.
STEP 4 – TRANSLUCENCE: Define the information different roles require for the classroom activity.	This step includes questions about the <b>data needs</b> and mechanisms to make data representations partly visible (translucent), by considering limitations on access and privacy issues.
STEP 5 - DESIGN FOR ORCHESTRATION: Translate the required information that lead to enhanced classroom orchestration.	This step includes questions about what different stakeholders can or cannot <b>do</b> with the information, <b>interaction aspects</b> and <b>practical orchestration aspects</b> .

## Concluding remarks

The elicitation process to design for effective use of CSCL analytics systems is work in progress. Future work in this project will provide a template for mapping the outputs of co-design techniques into data representation and system requirements. Future work will also provide guidelines for other CSCL and learning analytics researchers for adapting a more detailed version of the elicitation process outlined above into their projects.

## References

- Blikstein, P., & Worsley, M. (2018). Multimodal learning analytics and assessment of open-ended artifacts. In D. Niemi, R. D. Pea, B. Saxberg & R. E. Clark (Eds.), *Learning Analytics in Education* (pp. 89). Charlotte, USA: IAP.
- Di Mitri, D., Schneider, J., Specht, M., & Drachler, H. (2018). From signals to knowledge: A conceptual model for multimodal learning analytics. *Journal of Computer Assisted Learning*, 34(4), 338-349.
- Echeverria, V., Martinez-Maldonado, R., & Shum, S. B. (2019). Towards Collaboration Translucence: Giving Meaning to Multimodal Group Data. In *Proc. of SIGCHI Conf. on Human Factors in Computing Systems*
- Krontiris, I., & Maisonneuve, N. (2011). Participatory sensing: the tension between social translucence and privacy *Trustworthy Internet* (pp. 159-170): Springer.
- Martinez-Maldonado, R., Elliot, D., Axisa, C., Power, T., & Shum, S. B. (2019). Teachers' Perceptions on CSCL Proxy Visualisations of Multimodal Teamwork Data in Healthcare. In *Proc. of International Conference on Computer-Supported Collaborative Work (CSCL'19)* (pp. submitted).
- Ochoa, X. (2017). Multimodal Learning Analytics. In C. Lang, G. Siemens, A. F. Wise & D. Gašević (Eds.), *The Handbook of Learning Analytics* (pp. 129-141). Alberta, Canada: SOLAR.
- Rodríguez-Triana, M. J., Prieto, L. P., Vozniuk, A., Boroujeni, M. S., Schwendimann, B. A., Holzer, A., & Gillet, D. (2017). Monitoring, awareness and reflection in blended technology enhanced learning: a systematic review. *International Journal of Technology Enhanced Learning*, 9(2-3), 126-150.
- Shankar, S. K., Prieto, L. P., Rodríguez-Triana, M. J., & Ruiz-Calleja, A. (2018). A Review of Multimodal Learning Analytics Architectures. In *Proc. of IEEE 18th International Conference on Advanced Learning Technologies (ICALT'18)* (pp. 212-214).

# Examining the Role of Emotion Awareness and Sharing Emotions During Collaborative Learning

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**Abstract:** Learners' emotions have become an important area of research in computer-supported collaborative learning (CSCL). However, learners often fail to pay attention to their own or their peers' emotions during learning (Eastabrook, Flynn & Hollenstein, 2014). As the experience of some emotions (e.g., anxiety, shame, and fear) may be maladaptive to learning, it is important to raise learners' awareness of their emotions and their peers' emotions and support them in reacting timely and wisely in response to such emotions. To this end, we conducted an authentic study to identify learners' practices and preferences regarding their awareness of the types of academic emotions they experience and the extent to which they share such emotions.

## Theoretical background and research questions

Regulation of learning has three modalities: self-regulation, co-regulation and socially-shared regulation (Hadwin, Järvelä, & Miller, 2011). Self-regulation refers to regulating one's own learning, co-regulation refers to helping others regulate their learning, and socially-shared regulation refers to regulating learning together in a group setting. The current study shows the importance of considering emotions to improve shared/co-regulation of the learning tasks and identifies emotional awareness as a key step towards effective regulation of emotions and consequently, effective regulation of collaborative learning. Most emotion awareness systems have been developed to support tutors in monitoring learners' emotions (Ez-Zaouia & Lavoué, 2017). To date, only a few tools have been designed to support emotion awareness for such purposes within CSCL settings. Leveraging tools to better support students in identifying emotions felt by their peers is an important step to enriching CSCL environments. A better understanding of learners' awareness of their own and their peers' emotions could help the design of such environments. This study focuses on the reasons why students share or keep their emotions to themselves. Specifically, we investigate: (a) types of academic-related emotions learners are aware of and how they use cues to understand peers' emotions; and (b) emotions learners share or keep for themselves.

## Context and methods

11 participants (8 female, 3 male; 3 Caucasian, 8 Asian; and, average age was 24 years) undergraduate and graduate science, technology, engineering and mathematics (STEM) students from a North-American university volunteered to participate in the study. Participants were recruited through advertisements on departmental listserves. A list of nine different academic-related emotions (D'Mello et al., 2014) were created on a table during a week. Once participants completed their table they attended a face-to face interview about the table they filled out. Then they were offered a gift from the university gift store. Data used in this study comprised of the emotions students reported on the emotion table, along with the associated context in which the emotions were experienced (solo or in collaboration), as well as extracts from answers to interview questions. This study used a qualitative exploratory approach. Verbal transcripts of interview data as well as written self-report data from the emotion grids were coded using a detailed coding scheme derived by one of the authors to answer the research questions. Three author-researchers coded the data manually and obtained an agreeable interrater reliability of 89.27% using the Pearson correlation coefficient. All initial disagreements were discussed to reach final agreements.

## Results and discussions

### Academic emotions

Participants were mainly aware of their anxiety, boredom and curiosity. We observe notable differences amongst participants, as illustrated by a rather high standard deviation for all emotions. Regarding *their own emotions*, participants noticed during interviews that they were mainly aware of frustration and anxiety. Regarding *others'*

*emotions*, several participants declared that they were not able to identify others' emotions, especially if they were not friends or if that had minimal previous interactions with specific individuals.

## Indicators/cues participants use to know their and others' current emotional experiences

Participants identified general cues for remembering their own emotions. They also highlighted cues for specific negative emotions; e.g.: (a) boredom: low efficiency, engagement and concentration, (b) anxiety: physiological changes in the body such as faster heart-beats, cold body, hands shaking, perspiration and the desire to eat; (c) confusion: raised eyebrows, reading repeatedly, and change in speech; and, (d) frustration: faster heart-beats, getting easily irritated and agitated, rumination, depressions of after-exam. It is noteworthy that participants identified specific cues only for negative emotions, like anxiety, confusion and boredom. For example, cues for anxiety were reported as agitation, stronger emotional expressions, bad hairstyle, speech, impatience, blushing, and moving a pen rapidly back and forth in hands. And, regarding boredom, cues included just scrolling up and down the pages, eyes getting closed or having low engagement and curiosity in the academic material.

## Which emotions do learners share and which emotions do they not share?

Participants chose to share mainly positive emotions, like engagement, surprise, curiosity and delight. While they are willing to share boredom, even if it is a negative emotion, they are less likely to share their anxiety and frustration. Some reasons behind students choices of keeping an emotion or sharing it with peers is dependent on several factors, the most important being emotional contagion and worries of its negative effects on teamwork. Social proximity and similar emotions were other main reasons to such decisions.

## Discussions

Results showed that bodily (e.g., physiological, facial, vocal) changes as well as behavioral and cognitive cues led to an understanding of self and others' emotions. Findings also revealed that participants have less tendencies to share negative emotions such as anxiety and frustration, and reasons behind students decisions were revealed. This research also provided evidence that there are emotions learners are not aware of about their peers, there are some emotions that they want to share and there are others that they prefer to keep for themselves.

## Limitations and implications for the support of emotion awareness and sharing

The study participants were from the same curriculum (STEM) and similar university. Further research needs to examine the research questions beyond a specific curriculum and, university and across borders to extend the generalizability with larger sample sizes and different academic contexts. Our research findings contribute to a better understanding of how emotion is experienced in academic contexts and how it might influence learners' practices and needs in learning and interaction with peers. These findings have implications for the design of advanced emotional CSCL tools that support emotion awareness and sharing amongst students during collaborative learning activities. We believe that such tools should be tailored to learners' needs and context, and should not consider all types of emotions at the same way. Negative emotions could have a detrimental effect on the teamwork, especially if learners are not close to each other. Learners may be able to decide which emotions they would like to share and to make explicit what kind of reaction they expect from others in the group, either cognitive or behavioral. Such CSCL tool could support emotional socially-shared regulation.

## References

- D'Mello, S., Lehman, B., Pekrun, R., & Graesser, A. (2014). Confusion can be beneficial for learning. *Learning and Instruction, 29*, 153-170.
- Hadwin, A. F., Järvelä, S., & Miller, M. (2011). Self-regulated, co-regulated, and socially shared regulation of learning. *Handbook of self-regulation of learning and performance, 30*, 65-84.
- Isöhätälä, J., Järvenoja, H., & Järvelä, S. (2017). Socially shared regulation of learning and participation in social interaction in collaborative learning. *International Journal of Educational Research, 81*, 11-24.
- Ez-Zaouia, M., & Lavoué, E. (2017). EMODA: a tutor oriented multimodal and contextual emotional dashboard. *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (pp. 429-438).

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# Computer-based Problem Solving to Prepare for Adaptive Consolidation

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**Abstract:** During problem solving prior to instruction, students usually generate erroneous solution attempts, which can form the basis for acquiring valid concepts during subsequent instruction, if students are prompted to compare correct and incorrect examples. In a previous study, these prompts were only beneficial if the incorrect examples resembled students' own attempts. Therefore, a computer-based version that would allow for adaptation of the instruction is tested with regard to the similarity of students' products and difficulties.

## Introduction

Research on productive failure has shown beneficial effects of problem solving prior to instruction on conceptual understanding compared to instructional designs with the reverse order of the learning phases (e.g., Kapur, 2010). However, Loibl and Rummel (2014) showed that students engaging in problem solving prior to instruction outperformed their counterparts with respect to conceptual knowledge only when the instruction compared typical erroneous student solutions to the correct solution. Similarly, Loibl and Leuders (2018) showed that students who were prompted to compare solution attempts performed best at posttest. This effect was highest for students whose initial solution attempts were similar to the incorrect examples of the consolidation phase (Loibl & Leuders, 2019).

These findings call for adaptively taking students' solution attempts into account in the design of the instruction phase. This adaptivity could potentially be reached in a computer-based system. However, converting paper-based learning materials in a computer-based system may alter the learning processes and products: „Computational transposition is a process that occurs during the design and implementation of computer learning environments with the potential for significantly transforming the knowledge to be taught by these means“ (Hoyos, 2016, p. 139). As the finding regarding the importance of the fit between students' attempts and the instruction was found with paper-based materials, a first step towards an effective adaptive system requires to focus on the problem solving phase and to validate that the computer-based implementation allows the same types of products and the same categories of difficulties as the paper-based version.

We tested this assumption in a collaborative setting for two reasons: First, most research on productive failure has been implemented in collaborative settings (e.g., Kapur, 2010; Loibl & Rummel, 2014). Second, the natural verbalization of ideas and difficulties in a collaborative setting allows for in-depth analyses of the learning process.

## Research question

We investigate the question whether a collaborative computer-based implementation of the problem-solving phase, allows the same types of products and the same categories of difficulties as the paper-based version.

## Methods

### Participants

28 fifth-graders (i.e., one class) used the computer-based system in pairs. Based on their solution attempts five pairs were selected to additionally participate in an interview regarding their experiences and difficulties.

### Learning material and computer-based system

The learning unit covered comparing fractions. The present study focused on the problem-solving phase only. All students were asked to decide which team wins a scoring contest where each player attempts to score a goal once: a team of 5 girls who scored a total of 3 goals or a team of 10 boys who scored a total of 5 goals. It was clarified that each team member only had one attempt. During the problem-solving phase students worked on a computer. The computer-based system included a task description and an applet. The applet allowed students to generate fractions bars with any number of parts. The sizes of the parts had to be selected one by one, thus, allowing the typical errors of unequal parts. In addition, students could color the parts.

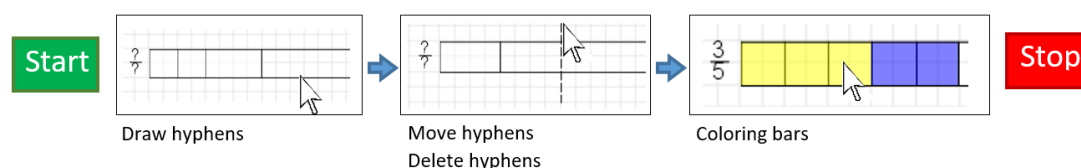


Figure 1. Possible actions in the applet.

## Coding scheme

We analyzed the screen recordings and interview data two-folds. First, we coded whether the seen or reported difficulties stemmed from the problem-solving task or from the use of the computer. Second, we coded the incorrect solution attempts based on the coding scheme from Loibl and Leuders (2018).

## Procedure

The study started with an activation of prior knowledge about fractions. Afterwards, the experimenter introduced the applet and tried to eliminate any difficulties that may result from the unfamiliar use of computers. Afterwards the problem-solving phase started with a short verbal introduction of the problem to ensure that all students understood the cover story and the question to be worked on (i.e., fair comparison on which group wins). During the problem-solving phase, students worked in pairs on one computer. Students' utterances and their screens were recorded. Based on the solution attempts, five pairs were selected for in-depth interviews. These interviews used the stimulated recall technique.

## Results

36.99% of the difficulties stemmed from the use of the computer and 63.01% difficulties related to the content or the task. All incorrect solution attempts could be assigned to one of the categories found with the paper-based version. Table 1 compares the relative frequency of categories of incorrect solution attempts between the paper-based version (cf. Tab. 5 in Loibl & Leuders, 2018) and the computer-based system.

Table 1: Differences in frequency of incorrect solution attempts

	Paper-based version	Computer-based system
Special non-generalizable strategy	7,53%	18,92%
Absolute frequency without notion of relativity	48,39%	29,73%
Argumentation with only one component	27,96%	16,22%
Unclear or non-mathematical strategy	13,98%	24,32%
Correct solution	2,15%	10,81%

## Discussion

Our results show that students generated similar products in our computer-based system as shown with the paper-based version by Loibl and Leuders (2018). Thus, a future adaptive system can build on previous results and prompt comparisons between correct and incorrect examples by selecting the examples based on students' own attempts. However, our results also show that students encountered additional difficulties that stemmed from the system. While this finding is not surprising, given that this version was a low-integrated pilot, it highlights the need to refine the system substantially to allow for a more smooth application.

## References

- Hoyos, V. (2016). Distance technologies and the teaching and learning of mathematics in the Era of MOOC. In: M. Niess, S. Driskell, & K. Hollebrands (Eds.), *Handbook of research on transforming mathematics teacher education in the digital age* (pp. 137–164). USA: IGI Global.
- Kapur, M. (2010). A further study of productive failure in mathematical problem solving: Unpacking the design components. *Instructional Science*, 39(4), 561-579.
- Loibl, K., & Leuders, T. (2018). Errors during exploration and consolidation – The effectiveness of productive failure as sequentially guided discovery learning. *Journal für Mathematik-Didaktik*, 39(1), 69-96.
- Loibl, K. & Leuders, T. (2019). *How to make failure productive: Fostering learning from errors through elaboration prompts*. Manuscript submitted for publication.
- Loibl, K., & Rummel, N. (2014). Knowing what you don't know makes failure productive. *Learning and Instruction*, 34, 74-85.

# The Relationship Between Young Students' Attitudes Toward Collaboration and Team Satisfaction in a STEAM-based Program

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**Abstract:** Project teams have gained popularity recently as many companies increase the amount of work they require project teams to complete (Robbins & Judge, 2009). In order to address this need in the workforce, the educational institutions have incorporated more project team based learning into their curriculum (Parmelee & Hudes, 2012). Students, on the other hand, have shown a lack of interest towards team projects, are not always satisfied with their teamwork, and experience challenges in the process of collaborative work (Espey, 2010). Motivated by these facts, the purpose of this study is to shed some light on the relationship between team dynamics, team acquaintance, instructor support, and team satisfaction in a STEAM Enrichment program in a middle school formal classroom setting.

## Introduction

As our society moves forward, the ability for learners to work as part of a team and coordinate team efforts is becoming more critical for the advancement of knowledge and the success in any job (Johnson & Johnson, 2005). However, it is well-documented in the literature that students typically show lack of interest towards team projects and experience challenges in the process of collaborative work (Espey, 2010; Vance et al., 2015).

The scarcity of empirical studies looking into team satisfaction for K-12 students in a STEAM-based program led the researchers to conduct the current study. Specifically, researchers in this study investigated the relationship between team satisfaction and students' attitudes toward collaboration within a K-12 STEAM-based program context in a computer-supported collaborative learning environment. Students' attitudes toward collaboration were measured through three components: team dynamics, team acquaintance, and instructor support (Ku, Tseng, & Akarasriwon, 2013).

Team dynamics measures included participation, communication, collaboration, trust, and cohesion (Ku, Tseng, & Akarasriwon, 2013). Team acquaintance refers to students' familiarity with the team members and is found to be strongly associated with students' attitudes towards collaboration by earlier studies (Stark & Bierly, 2009). Specifically, students who are familiar with each other are reported to more easily form teams and set goals more quickly than others. The final component, instructor support, is another major driver in students' collaboration. In particular, surveyed students by earlier studies emphasized the need for instructor support especially in offering timely resources and providing opportunities to view examples, among others.

With this study, the researchers aimed to close the research gap in examining the relationship between team satisfaction and students' attitudes toward collaboration. More specifically, researchers sought to answer the following research question: what is the relationship between team satisfaction and students' attitude toward collaboration in a STEAM Enrichment Program?

## Framework

In this study, students were required to follow the engineering design process summarized in NASA's BEST engineering design model (REF). The engineering design process involves six steps: a) ask, b) imagine, c) plan, d) create, e) test and f) improve. While following these steps, students were also required to communicate with each other while doing research, brainstorming ideas, and refining the solutions to the chosen problem.

## Method: Participants, data collection, and instrument

Participants included 163 students in a STEAM Enrichment Program at a private middle school in Northern Georgia. The STEAM Enrichment Program was required for all students in grades 4<sup>th</sup> through 10<sup>th</sup> and was part of the weekly school schedule and the curriculum. Upon the completion of the STEAM Enrichment Program, an online student (adapted Ku, Tseng, and Akarasriwon's survey (2013)) survey was administered to evaluate the level of collaboration and assess satisfaction during the last week of school. The survey was employed to all students participating in the program using google forms, of whom 40% were female.

## Results

The three subscales of students' attitude towards collaboration (team dynamics, acquaintance, and instructor support) were correlated with each other, but the pairwise correlation coefficients were lower than 0.5, much smaller than the recommended cut-off of the value of 0.85 for distinguishing for an additional factor model (Kenny, 2012). This means the three considered factors were somewhat similar but distinct enough to separately explain variation in students' satisfaction (See Table 1).

In addition to correlation analysis, a multiple regression analysis was carried out to investigate whether students' attitude toward collaboration (as measured by team dynamics, team acquaintance, and instructor support) could significantly predict their team satisfaction. The results of the regression indicated that the model explained 35.1% of the variance and that the model explained a significant amount of variation at students' team satisfaction,  $F(3, 153) = 27.564, p < .001$ . While team dynamics ( $\beta = .740, p < .001$ ) and team acquaintance ( $\beta = -.447, p = .030$ ) contributed significantly to the model, instructor support did not ( $\beta = -.458, p = .074$ ).

**Table 1: Correlation between Team Satisfaction and Team Dynamics, Acquaintance, and Instructor Support**

	1	2	3	4	Mean	Std.	Cronbach's $\alpha$
1.Team Dynamics	-	.487**	.302**	.549**	44.18	9.11	.84
2.Team Acquaintance	-	-	.406**	.103	14.11	3.86	.78
3.Instructor Support	-	-	-	.003	11.6	2.81	.78
4.Team Satisfaction	-	-	-	-	38.84	10.03	.95

## Implementation and conclusions

Students' negative attitude toward teamwork and project teams is frequently discussed in education literature (Vance et al., 2015). However, the scarcity of empirical studies looking into the impact subfactors of students' attitude toward collaboration such team dynamics, acquaintance, and instructor support led the researchers to conduct the current study within a STEAM program context.

The findings of this study revealed that team dynamics had a positive association with students' team satisfaction. This result aligns with the relevant past literature which showed dynamics promoted higher teamwork satisfaction (Liu, Magjuka, & Lee, 2008). In addition, the regression analysis showed that team dynamics and acquaintance contributed significantly to the explanation of teamwork satisfaction and accounted for 35% of the variance. This finding is in line with previous studies showing that students acquainted with team members built good relationships with each other, resulting in higher team satisfaction (Ku, Tseng, & Akarasriwon, 2013; Stark & Bierly, 2009).

Since "establishing team commitment" is stated as an effective strategy for team dynamics and acquaintance in the literature, future research should explore ways to establish team commitment for K-12 students in a STEAM-based context. In an extension study, the researchers will explore the effects of increased flexibility in forming teams and assess the impact of this flexibility on team acquaintance and ultimately satisfaction.

## References

- Espey, M. (2010). Valuing teams: What influences student attitudes? *NACTA Journal*, 54(1).
- Johnson, R. T., & Johnson, D. W. (2005). Cooperative learning, values, and culturally plural classrooms. In *Classroom Issues* (pp. 29-47). Routledge.
- Kenny, D. A. (2012). Multiple latent variable models: Confirmatory factor analysis. Retrieved from <http://davidakenny.net/cm/mfactor.htm>
- Ku, H. Y., Tseng, H. W., & Akarasriworn, C. (2013). Collaboration factors, teamwork satisfaction, and student attitudes toward online collaborative learning. *Computers in Human Behavior*, 29(3), 922-929.
- Liu, X., Magjuka, R. J., & Lee, S. H. (2008). An examination of the relationship among structure, trust, and conflict management styles in virtual teams. *Performance Improvement Quarterly*, 21 (1), 77-93.
- Parmelee, D., Michaelsen, L. K., Cook, S., & Hudes, P. D. (2012). Team-based learning: a practical guide: AMEE guide no. 65. *Medical teacher*, 34(5), e275-e287.
- Robbins, S.P., and Judge, T.A. (2009). *Organizational behavior*, 13th Ed., Pearson Education, Prentice Hall, NJ.
- Stark, E. M., & Bierly, P. E. (2009). An analysis of predictors of team satisfaction in product development teams with differing levels of virtualness. *R&D Management*, 39 (5), 461-472.
- Vance K., Kulturel-Konak S., Konak A. (2015). "Teamwork efficacy and attitude differences between online and face-to-face students," in *Proceedings of the IEEE Integrated STEM Education Conference (ISEC)*, Princeton, NJ, 246-251.

# Theorizing and Operationalizing Social Engagement as a Precursor to Productive Disciplinary Engagement in Collaborative Groups

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**Abstract:** An important goal of CSCL is to support social engagement within small groups. Our aim is to theorize and operationalize *social engagement (SE)*, as a group-level construct and one dimension of group productive disciplinary engagement. We conducted joint analysis of videotaped interactions, garnered from multiple projects with common disciplinary practices but task and domain variation, to operationalize SE in 3-point quality ratings. Our ratings afford examining SE as dynamic and interrelated with other engagement dimensions.

## Introduction

An important goal of CSCL is to promote intersubjective meaning making (Suthers, 2006) which requires high quality engagement. We aim to define and operationalize *social engagement (SE)* as a group-level construct, and as one dimension of *productive disciplinary engagement (PDE)*. PDE involves students making collective intellectual progress on core conceptual ideas and disciplinary activities during authentic tasks (Engle & Conant, 2002). We include SE as part of a multi-faceted and collaborative group conceptualization of PDE. We aim to extend research by (1) conceptualizing SE through joint analysis of videotaped interactions garnered from multiple projects, which have common features and disciplinary practices (i.e., modeling and argumentation) but vary in domain and task; and, subsequently, (2) operationalizing SE in 3-point quality ratings.

To theorize SE, we draw from literature on coordination and equity. Previous studies examining social processes during argumentation have identified competitive responses to different positions, in which students push for the inclusion of their own perspective while ignoring others', positioning others as less competent, and using personal attacks (Rogat & Adams-Wiggins, 2015). Previous research has identified power differentials that result from negotiation of influence over the group's task response and the conversational floor (Engle, Langer-Osuna, & McKinney de Royston, 2014). In contrast, when group members are responsive to and build upon multiple viewpoints, inclusive of and integrating diverse perspectives, and contributors are treated as mutually competent, group dynamics are coordinated and equitable.

Barron (2003) argued that to understand how quality varies in group productivity and learning, we need to account for the dual-space operating in collaborative groups, which includes both content and relational spaces. Previous research has primarily investigated cognitive processes (e.g., knowledge co-construction; argumentation), with fewer studies exploring the role of groups' social processes. Some recent research has examined social and cognitive processes, but has relied on illustrative or single cases, purposefully selecting the high or low quality examples of social engagement. Our developed rubric, grounded in theoretical review and joint analysis, contributes to this field by enabling the examination of a large number of, and/or individual, groups across time, inclusive of moderate-quality SE, with potential to critically inform our understanding of how SE interrelates with group engagement dimensions to promote PDE.

## Method

We contextualize PDE during collaborative tasks that involve modeling and argumentation in technology-rich middle school science and engineering units. We draw on a rich corpus of video data collected in four research projects where group work was central to student learning. The range in domain, disciplinary practices and curricular features (e.g., technology tools; scaffolds) enriched our theoretical development efforts. The project team, with different areas of expertise and knowledge of individual curricular contexts, conducted joint analyses of videotaped group interactions (N = 4 groups), with the goal to describe and negotiate shared understandings of observable SE (Jordan & Henderson, 1995). These analyses informed the development of a 3-point quality rubric.

## Results

We operationalize SE within disciplinary practices of modeling and argumentation, which are also inherently social. Therein, productive group activity requires (1) coordination and responsiveness of different perspectives, and (2) equal opportunity to make contributions that inform the shared product; two interpersonal processes which are central to our operationalization of SE (Table 1). High ratings indicate collective norms that promote and correspond with productive group activity, while low ratings inhibit it. Observations suggest indicators of coordination can be both implicit (seamless physical, nonverbal coordination) and explicit (coordinating a conclusion from the evidence) (examples, Table 1). Joint analyses of SE supported rich elaboration of indicators, including curriculum, task, domain and disciplinary differences. For example, in analysis of an engineering unit, high-quality SE interactions were exemplified by spatial proximity and nonverbal exchange of materials (i.e., indicators uniquely supported within this engineering unit).

Table 1: Social Engagement Quality-Ratings

1 – Low	2 – Moderate	3 - High
<p><b>Lack of coordination:</b> Conversation involves separate contributions without attempts to link, or contributions are unrelated</p> <p><b>Inequitable interactions:</b> Not all group members have access to conversational floor, materials or task, while others have heavy and consistent access.</p> <p>Dysfunctional status hierarchy may exist where groupmates are positioned as more and/or less competent; resistance to position</p> <p><b>Physicality:</b> Limited eye contact, spatial distance; turning away, physically blocking from shared product, technology resources</p>	<p><b>Intermittent Coordination:</b> A subset of high-quality indicators are present, but are inconsistent</p> <p>Quick consensus</p> <p>There are no ideas to coordinate as part of discussion</p> <p><b>Somewhat equitable:</b> Most group members have access to the conversational floor</p> <p>It is unclear who has access to the conversational floor (e.g., dominant position is not resisted against or implicit agreement on hierarchy.)</p>	<p><b>Coordinated action:</b> Conversations build and are responsive to ideas during activity</p> <p><b>Equitable interactions:</b> All group members have access to conversational floor, materials, task</p> <p>Functional hierarchy, with leadership or as a collective</p> <p><b>Physicality:</b> Eye contact; spatial closeness; nonverbal bids for participation; access to materials</p>

## Discussion and implications

Our theoretical synthesis and operationalization of SE stands to contribute to a group literature introducing quality ratings. The SE rubric and associated indicators afford the examination of SE as evolving, in socially negotiated processes that unfold over time. Specific to SE, sustained low quality ratings within and/or across group interactions may show evidence of fragmented discussion or a lack of working toward consensus. Further, we can analyze how SE interrelates with other dimensions that together constitute PDE, central to CSCL’s aim to understand interdependencies of learning processes.

## References

- Engle, R. A., & Conant, F. C. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emerging argument in a community of learners classroom. *Cognition and Instruction*, 20(4), 399-483.
- Engle, R. A., Langer-Osuna, J. M., & McKinney de Royston, M. (2014). Toward a Model of Influence in Persuasive Discussions: Negotiating Quality, Authority, Privilege, and Access Within a Student-Led Argument. *Journal of the Learning Sciences*, 23(2), 245-268. doi:10.1080/10508406.2014.883979
- Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences*, 4(1), 39-103. doi:10.1207/s15327809jls0401\_2
- Rogat, T. K., & Adams-Wiggins, K. R. (2015). Interrelation between regulatory and socioemotional processes within collaborative groups characterized by facilitative and directive other-regulation. *Computers in Human Behavior*, 52, 589-600. doi:10.1016/j.chb.2015.01.026
- Suthers, D. D. (2006). Technology affordances for intersubjective meaning making. *International Journal of Computer Supported Collaborative Learning*, 1, 315-337.

# Embedding Computational Thinking in the Elementary Classroom: An Extended Collaborative Teacher Learning Experience

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**Abstract:** We used design-based research to investigate an extended professional learning experience to prepare teachers to embed computational thinking in elementary science. Opportunities to interact synchronously in a community of practice - including through in-person engagement in embodied challenges, discussion, and resource sharing, appeared to productively support teacher preparedness to embed CT in their science teaching. However, asynchronous collaboration via an online platform was less effective. We describe planned adjustments for future iterations of the program.

## Introduction

The centrality of computing in modern science has elevated the importance of computational thinking (CT) as a critical skill for everyone (Wing, 2006). Elementary teachers have the potential to play an essential role in developing foundational CT competencies among all learners. However, there is a fundamental need for effective approaches to supporting teacher learning in this novel domain (Hestness, Ketelhut, McGinnis, & Plane, 2018). Because CT is heavily embedded with technological tools, we are particularly interested in the role of CSCL environments for facilitating teacher learning experiences. We are exploring the research question: “What computer supported design elements can help promote collaborative learning for enacting CT, a novel and potentially intimidating topic, in elementary science?” Because communities of practice (CoP; Lave & Wenger, 1991) have shown promise to support novices (i.e. teachers) enact new practices (i.e. CT-infused science pedagogies), we are seeking to cultivate a community of practice among veteran and preservice elementary teachers to support teacher learning related to CT integration in the classroom. To realize this goal, we created the CT Science Teaching Inquiry Group (STIG<sup>CT</sup>), a collaborative learning experience designed to create new knowledge of effective strategies to embed CT in the elementary science classroom.

## Methods

We adopted a design-based research (DBR) approach, entailing iterative cycles of design and analysis. For the first iteration of the STIG<sup>CT</sup>, we designed and facilitated seven 90-minute in-person professional development sessions that met monthly throughout the school year. The sessions began as primarily facilitator-directed, in which members of our team led collaborative learning activities and discussion. Midway through the year, we shifted the design of the sessions to be primarily participant-directed, in which participants worked together to create, share, and discuss learning activities to support CT integration. Between sessions, participants were invited to collaborate by sharing ideas and resources via an online platform ([piazza.com](https://piazza.com)). Participants (N=24) included practicing teachers (n=11) and preservice teachers (PSTs; n=13).

We used qualitative research methods (Miles, Huberman, & Saldana, 2014) to analyze the session plans and field notes for each STIG<sup>CT</sup> session, identifying key design elements included throughout the PD experience. Next, we analyzed data including field notes, written reflections collected at the end of each session, and focus group interviews collected at the end of the full experience. Where the focal design elements were referenced, we coded evidence of how (or whether) they appeared to promote collaborative learning toward CT integration.

## Findings

We describe how three focal design elements appeared to contribute to teacher collaborative learning related to CT integration in elementary science. A summary and examples are provided in Figure 1.

First, we found that collaborative engagement in hands-on activities, both computer-supported and not computer-supported, appeared to foster collaborative learning about CT conceptually and improve participants’ perceptions of their CT understandings. However, we did not encounter clear evidence that this design element on its own supported teachers in transferring conceptual CT understandings into their own classroom practice.

Second, incorporating intentional discussion opportunities within the sessions helped participants generate ideas about how CT concepts could relate to the teaching of elementary science curriculum topics. In addition, preservice teachers expressed a sense of empowerment when able to learn from experienced teachers about how they were applying (or considering applying) CT in their classrooms. We encouraged participants to

continue sharing their CT integration ideas with one another outside of the in-person sessions, but participants rarely made use of the online platform which was set up for this purpose.

Last, sharing resources to support CT integration helped participants design lesson plans to enact CT in their elementary science classrooms. We found that resource sharing that was both lead by facilitators and codesigned by participants appeared to promote a sense of empowerment. Participants understood and had the resources to enact strategies for applying CT in their classrooms. We noted, however, that the participant-designed lesson plans varied in the extent to which they accurately represented CT or integrated it into curricular content in science. As with the discussion design element, participants rarely made use of the online platform to share resources between sessions, which was one of its intended purposes.

Element	Activity examples	Example participant response
CT sensemaking through collaborative challenges	-Teachers manipulate an online ecosystem to learn about models -Teachers “program” a blindfolded teammate to walk a specified path, modeling problem decomposition	“[Problem decomposition was... a really big and newer topic for a lot of us... I said something out loud to the class... I was approaching being right, but I was maybe 65% right, and you were like, “Um, let me refine that.” And then I was like, “Oh, okay. Now I get it a little bit more.”
Discussing classroom applications of CT concepts	-Teachers examine standards and discuss opportunities for CT integration -Teachers encouraged to update each other asynchronously on CT integration efforts via online platform	“[At first, I wondered] how realistic is it to think that people are implementing these things in the classroom for real? ...Seeing teachers here [in the STIG] that have taught for many years kind of implementing it [CT] .... I think it just made it... seem like it was more attainable.”
Sharing resources to support CT integration in elementary science	- Teachers are invited to borrow educational robotics tools for use in their classrooms and report back - Teachers co-author and present learning activities (lesson plans) that integrate CT into elementary science	“I really liked the activity of having people create lessons and then teach it to us. Because... it gave people the opportunity to learn from different teachers, people they might not know. But also, I really liked learning how different people might take a lesson and interpret it in their own way. I thought it was really helpful.”

## Conclusions and implications

The STIG<sup>CT</sup> design elements offered affordances and limitations relevant to promoting a CoP focused on collaborative learning of how to enact CT in elementary science. Specifically, we found that hands on experiences, discussions and resource sharing were helpful in facilitating collaborative learning around CT. However, we struggled to maintain our CoP virtually, with low participation in the asynchronous, online space. We plan to modify future iterations of the STIG<sup>CT</sup> by: 1) Retaining the collaborative design of CT-infused elementary science lessons to promote participant-created resource sharing, with greater facilitator support and more consistency; 2) Encouraging participants to test participant-created resources in their classroom and to share their experiences online between in-person sessions; 3) Considering an alternate, more familiar online platform to promote participant discussion between sessions, and incorporating the online discussion into in-person sessions; and 4) Inviting teachers from the first iteration of the STIG<sup>CT</sup> to continue their participation in the second year and serve as mentors for newcomers. Through our ongoing process of design and refinement, we plan to use our learning to develop empirically-supported resources, tools, and measures to connect physical and virtual spaces in order to support teacher education around CT integration in elementary science.

## References

- Hestness, E., Ketelhut, D. J., McGinnis, J. R., & Plane, J. (2018). Professional knowledge building within an elementary teacher professional development experience on computational thinking in science education. *Journal of Technology and Teacher Education*, 26(3), 411-435.
- Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Miles, M. B., Huberman, A. M., & Saldana, J. (2013). *Qualitative data analysis*. Sage.
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35.

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# Visualizing Representations of Interaction States during CSCL

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**Abstract:** Existing methods for analyzing video data of small groups during collaborative problem-solving focus on analyzing certain aspects of students' task-related verbal interactions by coding and counting. In this paper, we present a method that was used to construct a visual representation to illustrate how the occurrence of students' task-related verbal interactions changed sequentially over the class duration as a function of other dimensions of the group activity. Possible uses of these representations are discussed.

## Introduction

One of the key features of embedding CSCL activities in real classrooms is the highly complex nature of the collaborative process, and the multiple dimensions that influence the learning of groups within the ecosystem of a classroom. There is an increasing number of research studies in CSCL face-to-face classrooms that collect video data of the groups as they solve the task (e.g. Paquette et al., 2018). We need additional methods to analyze this data and understand how the group activity, especially students' task-related verbal interactions, unfolds sequentially over the class duration and change from one class to another over time (Hmelo-Silver et al., 2011; Reimann, 2009). This information can be used to inform future analytical approaches to the data and future design iterations. In this paper, we describe a method that uses the video recordings of small groups during collaborative problem-solving classrooms to construct a visual representation of each of the group's activity sequentially over the class duration. Then, we discuss the possible uses of these representations in making inferences about factors that can influence group activity and in planning further analysis of the data.

## Collecting the video data

This method was developed as part of a multi-year design-based implementation research project that is focused on integrating collaborative problem solving in a large introductory engineering course. The project involves collecting video data, using ceiling mounted cameras and lapel, table or hanging microphones, from undergraduate engineering students and teaching assistants during discussion sessions (classes) that took place in a lab classroom. During each class, students worked in small groups to solve an authentic engineering task presented as a digital worksheet on 11-inch tablets. Tablets of students in the same group were synchronized, allowing them to see the work of their team. The duration of each class was approximately 50 minutes. Data was collected from 28 classes (4 per week, over 7 weeks).

## Coding the video data

To identify how the activity of a group unfolded over the class duration we segmented the video recording of the group during one class into consecutive 20 seconds clips. We then coded each clip using a coding scheme adapted from Paquette et al. (2018) for dimensions that define or influence the group activity in the context of a face-to-face CSCL classroom. These dimensions were *task-relatedness* (on-task or off-task), *students' verbal interactions* (present or not present), *teacher's verbal interactions* (with the whole class, with the group, or not present), *content of verbal interactions* (on-task talk, other talk, or no talk), *potential issues during students' verbal interactions* (the conversation is dominated by one group member, the conversation indicates that the group is confused, or none of the group members responded to an interaction attempt by another group member), *potential issues during group work* (the group is divided into sub-groups, or one group member is left out), and *technical issues* (present or not present).

## Constructing a Visual Representation of Group Activity Over Class Duration

After coding all number consecutive 20 seconds clips of the group, we used the codes of each clip to categorize the group activity into one of seven states that dominated the activity. These states are described in Table 1.

Table 1. The seven states of group activity

State	Task-Relatedness	Students' Verbal Interactions	Teacher's Verbal Interactions	Content of Verbal Interactions	Issues - Verbal Interactions	Issues - Group Work	Issues - Technology
Positive	On-Task	Present	Not Present	On-Task Talk	None	None	Not Present
Silent	On-Task	Not Present	Not Present	No Talk	None	None	Not Present

Other Talk	On-Task	Present	Not Present	Other Talk	None	None	Not Present
Off Task	Off-Task	N/A	N/A	N/A	N/A	N/A	N/A
Teacher-Whole Class	N/A	N/A	Present with the whole class	N/A	N/A	N/A	N/A
Teacher-Group	N/A	N/A	Present with group	N/A	N/A	N/A	N/A
Issue	On-Task	N/A	Not Present	N/A	Any code (other than none) under these three dimensions is present		

N/A: Not applicable

Using the state of the group activity in each of the consecutive 20 seconds clips, we constructed a visual representation of the group activity over the class duration. The representation illustrates how the occurrence of the positive state changed over the class duration as a function of the other six states. An example of this representation for two groups (A and B) that are in the same class is shown in Figure 1.

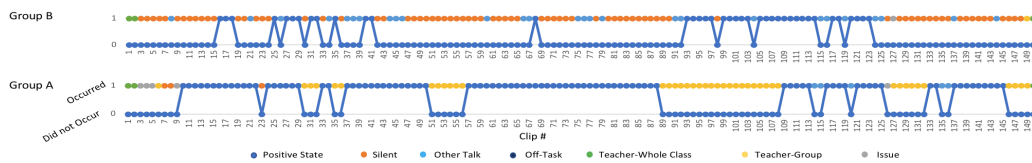


Figure 1. The Occurrence of the Positive State Over Class Duration

### Possible Uses of the Visual Representations

Comparing the visual representations of different groups in the same class provides a snap-shot of the groups’ processes and can suggest inferences about factors that may have influenced the occurrence, duration, and sequence of occurrences of the positive state in groups. For example, Figure 1 shows that Group A had longer positive state durations and less silent states than Group B. Both groups did not have many or long issues states; however, only Group A had teacher-group states that preceded the occurrence of the positive states. This suggests that these teacher-group states may have promoted students’ task-related verbal interactions. Further examination of the representations from other groups in the same class and the analysis of the transcript from Group’s A video allow us to test this, or other, hypotheses. Comparing the visual representations of different groups in the same class could provide insights about how the design of the task may have influenced the groups’ activity. For example, if the representations of all the groups of one class show that positive states did not start occurring until half way through the class, or if they show that the majority of the sequences of positive states were very short, then it is possible that the design of the task did not promote verbal interactions between students and further investigation might be warranted. In addition, comparing the visual representations of the same group across different classes can help us understand how stable collaborative behaviors are for each group, or whether variables such as the content or nature of the task or absence or change of one or more group members had an impact on the occurrence and duration of the positive state of this group. This can inform further iterations of tasks and tools, taking into account the complex ecosystem of the group within the classroom context.

### References

Hmelo-Silver, C.E., Jordan, R., Liu, L., & Chernobilsky, E. (2011). Representational tools for understanding complex computer supported collaborative learning environments. In S. Puntambekar, G. Erkens, & C.E. Hmelo-Silver (Eds.), *Analyzing interactions in CSCL* (pp. 83-106). New York, USA: Springer.

Paquette, L., Bosch, N., Mercier, E., Jung, J., Shehab, S., & Tong, Y. (2018). Matching data-driven models of group interactions to video analysis of collaborative problem solving on tablet computers. In *Proceedings of the 13<sup>th</sup> International Conference of the Learning Sciences*. London: International Society of the Learning Sciences.

Reimann, P. (2009). Time is precious: Variable-and event-centered approaches to process analysis in CSCL research. *International Journal of Computer-Supported Collaborative Learning*, 4(3), 239-257.

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# Exploration of Scaffolding in Teachers' Dialogue Analysis

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**Abstract:** This paper explored how to scaffold teachers' analysis of dialogue in order to improve their formative assessments. We implemented a half-day teacher workshop wherein the teachers were asked to collaboratively analyze a transcribed dialogue using both a manual approach and dialogue analysis tool. An analysis of the teachers' writings and dialogues in the workshop revealed that the teachers were able to identify the students' lack of understanding and consider its reasons usable in formative assessments.

## Introduction

In order to design successful collaborative learning, teachers need to conduct formative assessments. Formative assessment is often considered to be an assessment during the *learning process in a unit* in order to modify teaching to improve student attainment. However in collaborative learning situations students learn on their own, while the quality of their learning depends much on the design of the lesson. Thus teachers first should focus on the students' *learning process in a lesson* from the beginning to the end of the lesson (i.e., "What and how did the students learn or fail to learn?"). Second, regardless of whether the lesson itself goes well or not, teachers should generate hypotheses about why students learn or fail from the findings of the learning process (i.e., "What elements of the lesson affected learning and how?"). For this paper we designed a half-day workshop in which we asked teachers the above questions to tie their dialogue analyses to improvement of their formative assessments.

Why do we need dialogue analysis? Japanese "lesson study" is known to be an effective form of formative assessment in which teachers observe live classroom lessons and discuss after the observation (Lewis et al., 2006). Yet, there remains a persistent problem: many teachers lack the practice of focusing on the cognitive processes. Although the live lesson itself provides rich information about student learning, some teachers tend to focus on the superficial activities of the students or overly focus on only one student, because of their varying degree of expertise and intentions. Dialogue analysis is able to help solve this problem as tangible transcribed dialogue allows digging, surveying and revisiting from multiple perspectives. Thus, we introduced use of a dialogue analyses and support tool.

## Method

Table 1 shows the structure of the half-day teacher workshop. All 54 participants came from Japanese schools or boards of education with differences in the subjects matter and their expertise. The participants were randomly divided into 14 groups comprising three or four members. In Stage 1, we provided a hard copy of the student dialogue data of one group and presented three questions: (1) What are the issues the students are focusing on during their discussions? (2) What do students seem to understand and what don't they? (3) How do students learn? These questions compose the first question above, supporting participants to carefully comprehend the whole story of the learning process. In Stage 2, participants freely analyzed the dialogues using a technological tool named the "Conversation Analyzer" (hereafter CA: Shirouzu et al., 2018). The CA supports the visualization and analysis of student learning by presenting transcripts which are electronically searchable using keywords. By providing the CA, we aimed at supporting participants to compare detailed analysis of particular groups with an overall pattern in the class. Through the teacher workshop program, we expected that the participants would reflect on the lesson design (the second question above), while considering why students learn or fail.

The analysis targeted the dialogue data of 15-minute small group discussions in a junior high school science lesson, "The Mechanics of Exercise." The goal of the lesson was to understand the mechanics of body movement which includes three points, *the sensory nervous system*, *commands from the brain*, and *the motor portion of the nervous system*. The participants analyzed the data of three out of eight groups, because of the ease with which it would be possible to assess student learning and find problems in the lesson design. According to an analysis of the students' post-test results, none of them were able to write "complete" answers which included the three points mentioned above. Detecting this lack of understanding became a key issue in the dialogue analysis.

Table 1: Program of the teacher workshop on dialogue analysis

● Dialogue Analysis: Stage 1 (Using a hard copy/ Focusing on one group)	55 min.
● Dialogue Analysis: Stage 2 (Using the CA/ Focusing on three groups)	30 min.

## Data analysis and results

We analyzed the participants' worksheets written at the beginning and at the end of the workshop and their dialogue during the workshop from two perspectives: 1) Did the participants focus not only on the superficial activities but also on the cognitive processes? 2) Did the participants reflect on the lesson design by connecting the findings from the analysis with the lesson design? Accordingly, we analyzed the data in two steps:

Analysis 1: How many groups were able to find the specific points of the students' lack of understanding?

Analysis 2: How many groups were able to infer the reason for the lack of understanding?

We recorded the conversations of the groups during the entire workshop using IC recorders for the above analyses. The total number of teachers' utterances was about 23,508, the average of which was 1,679 per group. Figure 1 shows the results of Analysis 1. All 14 groups made a reference to some specific lack of student understanding: 10 groups identified the lack of all three targeted points of the lesson, two groups identified two points and the other two groups identified only one. It seemed more difficult to notice that the students had missed the element of "Command," indicating that not all of the groups had picked up on the complete difficulty of the lesson. However, the participants found other various points, indicating that they were able to find an unexpected insufficiency of understanding. Figure 2 shows the results of Analysis 2. Twelve out of 14 groups referred to the reason for the lack of understanding, implying that most participants considered the reason and generated hypotheses. Ten groups referred to more than two reasons. Even though each group referred to a small number of reasons, we were able to see a rich variety as a whole (see "reasons" written in the bars in Figure 2).

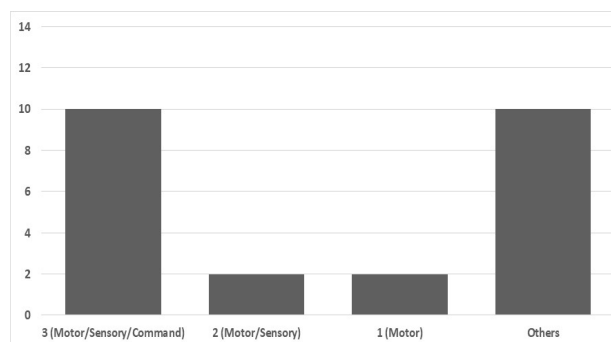


Figure 1. Lack of understanding referred (n=14)

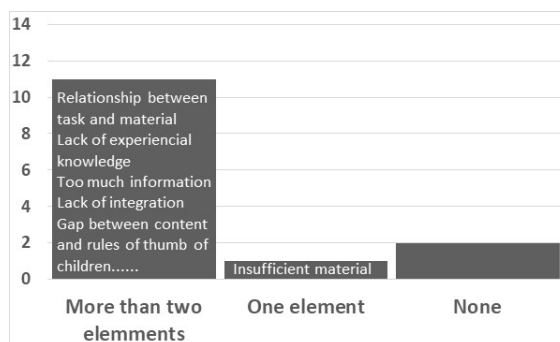


Figure 2. Reasons for lack of understanding (n=14)

## Discussion

By designing a workshop in which teachers collaboratively analyze the dialogue of students both manually and using a technological tool (CA), we demonstrated that the participants were able to uncover the students' lack of understanding and its precise points (Analysis 1), and many of them considered the reasons for that lack of understanding from various perspectives and generated hypotheses (Analysis 2). Pointing out the problems leads to generating a hypothesis about the next lesson.

On the other hand, when focusing on the qualitative aspects of the teachers' discourse, there were still some remaining issues. For example, the participants were not able to effectively use the CA. By using searchable dialogue data, some teachers had a tendency to look at trivial matters (i.e., "This student uses the wrong term.") and lost sight of the big picture of student learning processes, through which we observed that the participants' lack of sufficient understanding of the subject had a negative influence. In order to support this, we plan to design a new workshop which includes experiencing the lesson as learners before analysis.

## References

- Lewis, C., Perry, R., & Murata, A. (2006). How should research contribute to instructional improvement? The case of lesson study. *Educational Researcher*, 35(3), 3-14.
- Shirouzu, H., Saito, M., Iikubo, S., Nakayama, T., & Hori, K. (2018). Renovating assessment for the future: Design-based implementation research for a learning-in-class monitoring system based on the learning sciences. In J. Kay, & R. Luckin (Eds.). *Rethinking Learning in the Digital Age: Making the Learning Sciences Count, 13th International Conference of the Learning Sciences (ICLS) 2018, Volume 3*. London, UK: International Society of the Learning Sciences, 1807-1814.

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# How Embodied Interactions Manifest Themselves During Collaborative Learning in Classroom Settings

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**Abstract:** New physical computing toolkits offer much promise for promoting collaborative learning by engendering embodied interactions that can support collaborative discovery. To examine how these can unfold during a learning activity, we conducted a classroom study where pairs of children explored mappings between various sensors and actuators embedded in a physical-digital artifact. We found how a number of embodied interactions emerged that were effectively used to progress learning through the processes of showing, sharing and contesting.

## Introduction

A new generation of physical toolkits has emerged over the last few years, intended to teach young children about computing in fun and collaborative ways. These include the micro:bit (2018) and LittleBits (Bdeir, 2009). These toolkits offer new opportunities for learning about electronics, coding and the Internet of Things, by enabling children to connect the digital with the physical. A key property of these types of physical-digital artifacts is their visibility coupled with shareability and portability; they can be picked up, shown to others, pointed at and passed around. In this way, children can focus their attention to what is happening around them as they move, manipulate, and connect physical objects in front of them. To this end, our research is concerned with uncovering the range of embodied interactions that are engendered when interacting with handheld physical-digital artifacts. The aim of our research is to investigate how groups of children, aged 9 to 12, use embodied interaction strategies to explore and discover core physical computing concepts – namely, the physical-digital mappings between sensors and actuators – while learning together in a classroom setting. We present an analysis of how pairs and small groups of children exploit the physical properties of an interactive physical-digital artifact called the Magic Cube to learn about its functionality.

## Methodology

Groups of children in a classroom setting were asked to explore and uncover various physical-digital mappings using the Magic Cube (Lechelt et al., 2016). This is a hand-sized, electronic cube with embedded sensors and actuators, designed to teach children about computing (Figure 1, left). The goal was to determine how the form factor and the physical-digital mappings enabled by the device give rise to embodied interaction strategies, and where these would occur in the learning process. A discovery-based task was designed to enable the children to explore what happens between the sensors and actuators embedded in the cubes, in terms of what they are and how they work. Different physical actions were designed to result in different digital effects using the same cube. For the study, three sensor-actuator mappings were pre-programmed in the cubes. Specifically: 1) covering the light sensor on the cube turned on the embedded light inside the cube, 2) shaking the cube at different speeds changed the color of the embedded light and 3) blowing hot air into the temperature sensor made a ‘fire’ animation appear on the LED matrix in the cube.

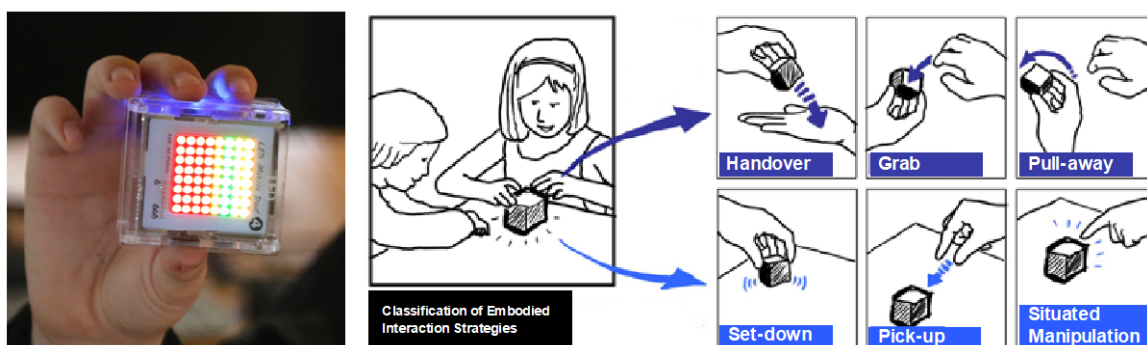


Figure 1. (left) The Magic Cube. (right) Classification of six embodied interaction strategies.

The study was conducted in computing classrooms in two primary schools in England. Participants were aged between 9-12 years. During each session, the children were asked to work in groups of two or three; one cube was provided for each group. The children were told that there were hidden mappings within the cube but not told what these were. Their challenge was to collaboratively discover what they were by testing out various physical actions (e.g., covering the cube sides with their hands, blowing into the cube, shaking the cube) to elicit the digital effects on the cube (e.g., change the color of light, make a 'fire' appear on the LED matrix). Video data was collected of the children's gestures and embodied interactions when using the cube for the specified learning activities. Based on the video data a classification was derived of the embodied interaction strategies that the children used.

## Findings

Overall, our analysis of the video data collected showed that the children used a range of embodied interaction strategies (see Figure 1, right). In particular, we found that the children alternated between handing over, grabbing the cubes and interacting with them together simultaneously, as a way of implicitly negotiating what to do next and changing their group's course of experimentation with the cubes. By analyzing the embodied interaction strategies in terms of when they occurred in the context of the task, we found how specific strategies contributed to negotiating discovery of the physical-digital mappings together. For instance, we found that when starting out with exploring the cube, the children mainly interacted with the cube individually, and then changed control of the cube by handing it over to and grabbing it from their peers. Throughout the task, there were many moments when the children uncovered a new effect. During these "moments of discovery", we found that when one child in a group discovered how a sensor-actuator mapping worked, rapid sequences of handovers and grabs ensued, in which the other(s) in the group imitated the physical movement to reach the same level of understanding. Handovers were most prevalent when the person currently holding the cube had figured out how the effect worked, while the other(s) in the group had not. In these situations, the person holding the cube handed over the cubes to the other(s) to give them the opportunity to try it. Less frequently, the children were seen to hand over the cube to group members as a prompt to "show me how it works." Setting the cube down and picking the cube up occurred most frequently during "dead ends" of interaction, when a type of physical action did not work as expected. These were observed to be implicit indicators of change of turn for control of the cube. For example, after tilting the cube in a variety of different directions to no avail when trying to figure out what was making the light turn on for one of the mappings, the current grasper in one group set the cube down on the table, where another group member immediately picked it up and began testing other physical actions.

## Conclusion

Physical-digital interfaces provide much scope for promoting collaborative learning. Our analysis of children's interactions with a hand-sized physical computing cube demonstrates how children were able to draw upon a diverse repertoire of embodied interaction strategies, that enabled them to readily change control, take control and hand over control when learning together. We also found how collaborative learning can be positively influenced by interactions that might otherwise be deemed un-collaborative (e.g., grabbing). Taken together, the results from our classroom study suggests that the extent to which new physical toolkits, aimed at teaching groups of children computing will be successful, depends on how well they 'fit' into their hands and what this then enables them to do together, by way of sharing, showing, and contesting.

## References

- BBC micro:bit. 2016. Micro:bit: get creative, get connected, get coding. Retrieved February 15, 2018 from <https://microbit.org/>
- Bdeir, A. (2009, February). Electronics as material: littleBits. In *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction* (pp. 397-400). ACM.
- Lechelt, Z., Rogers, Y., Marquardt, N., & Shum, V. (2016, May). ConnectUs: A new toolkit for teaching about the Internet of Things. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 3711-3714). ACM.

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# Enhancing Free-text Interactions in a Communication Skills Learning Environment

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**Abstract:** Learning environments frequently use gamification to enhance user interactions. Virtual characters with whom players engage in simulated conversations often employ pre-scripted dialogues; however, free user inputs enable deeper immersion and higher-order cognition. In our learning environment, experts developed a scripted scenario as a sequence of potential actions, and we explore possibilities for enhancing interactions by enabling users to type free inputs that are matched to the pre-scripted statements using Natural Language Processing techniques. In this paper, we introduce a clustering mechanism that provides recommendations for fine-tuning the pre-scripted answers in order to better match user inputs.

## Introduction

Digital learning environments are frequently used in education, in our particular case for training communication skills. Learners discuss with virtual characters, while the environment can determine whether they reached the goals established for the conversation (Jeuring et al., 2015). A communication scenario in Dutch was built for this purpose consisting of a sequence of replies between a virtual character and the learner. The script provided answer options and alternative branches corresponding to the previous choices that were made by the user. The aim of this paper is to improve users' learning experiences by enabling free-text inputs with the help of Natural Language Processing (NLP) techniques. After testing multiple NLP similarity matching methods on a dataset consisting of open input text answers annotated with matching options, clustering was performed on the students' answers and the predefined ones in order to improve the scenario.

Wang and Petrina (2013) performed discourse analysis on conversations between a student learning a new language and a digital tutor. It was observed that chatbots should reply to learners' input, but they should also provide feedback on errors. Our aim is to provide support for better matching user inputs and enhancing the feedback received from the virtual character.

## Method

Various Natural Language Processing (NLP) techniques were used in our experiment to match free text inputs provided by players in Dutch to a set of scripted options, namely: a) FuzzySet, an open source library (<https://glench.github.io/fuzzysset.js>) based on syntax; b) SpaCy (<https://spacy.io>), an advanced NLP framework integrating syntactic dependency parsing and part-of-speech tagging; c) string kernels, a method that compares texts without the need of a large training corpus (Lodhi, Saunders, Shawe-Taylor, Cristianini, & Watkins, 2002); and d) Scenario-Specific Corpus Method (SSCM) in which experts annotate emotions for each statement of the virtual character (Lala et al., 2018). The final similarity score used in follow-up analyses was calculated as the average between spaCy similarity and the average of string kernels.

However, a large number of input answers from our dataset did not match any pre-scripted statement. This shows that our scenario is incomplete in terms of pre-scripted options and influenced the accuracy of matching algorithms. An additional clustering experiment was performed on the list of input answers and predefined options put together for each stage in the scenario. Affinity Propagation (<https://scikit-learn.org/stable/modules/clustering.html#affinity-propagation>) was chosen as it relies on a distance function between points (i.e., inverse of semantic similarity between answers in our case) and there is no requirement for an a priori number of clusters. Similar answers were grouped together with the aim of fixing two common problems: 1) cases in which two predefined options were in the same cluster – one could be removed since these options are too similar compared to the variety of answers provided by students; 2) cases when multiple answers are grouped in a cluster which does not contain a predefined option – a new option related to them should be added in order to enhance the chances of adequately matching new user inputs to pre-scripted answers.

## Results

In our experiment, users were shown the available options after typing their input and they had to indicate which one was the closest to their intention, or select “No response matches” if no pre-scripted answer was adequate. The dataset consisted of 126 statements, out of which 59 (47%) had a match (Lala et al., 2018). Thus, a threshold had to be set, below which the answer was considered not to match any option. FuzzySet had a built-in threshold value. For spaCy and string kernels, a threshold was set statistically as the sum between the average and the standard deviation of all scores. For SSCM, the threshold was empirically established to .65. Table 1 provides the accuracy scores for each method. The best global accuracy was obtained by combining spaCy similarity with string kernels which was chosen as the distance function for clustering.

Table 1: Accuracy of matching methods

Method	Accuracy for matched answers (%)	Accuracy for unmatched answers (%)	Global accuracy (%)
FuzzySet	27%	82%	56%
spaCy	27%	84%	57%
String kernels	31%	<b>96%</b>	65%
SSCM (using Cosine similarity)	<b>54%</b>	48%	51%
spaCy and string kernels	37%	93%	<b>67%</b>

Allowing users to play the scenarios by writing texts in natural language lead to statements that were considerably different to the pre-scripted ones. This can emphasize an incomplete scenario, but it also has critical impact on the accuracy of NLP matching algorithms. If several similar answers are not matched to a pre-scripted answer, the scenario could be improved by adding an option similar to them. Thus, by analyzing the generated clusters, our algorithm provided improvement suggestions. These suggestions covered cases when a statement choice can be added every time a group of similar input answers do not have a matching candidate, and cases when the options were not different enough to be split across clusters and should be further adapted. As the semantic matching algorithms are far from being perfect, the clustering results and suggestions need to be analyzed by experts, who decide whether the scenario should be modified. The clustering algorithm can be applied repeatedly, thus enabling experts to visualize the effects of each modification.

## Conclusions

This paper presents an experiment of improving a communication learning environment by replacing a multiple-choice selection with free input texts that are matched using NLP techniques. A dataset of annotated Dutch statements was created, and a clustering algorithm was applied to provide suggestions for improving the learning scenario. Users engaged in innovative discussions with the chatbot, while striving for a coherent conversation following pre-scripted actions. Nevertheless, the limitations of NLP matching methods in terms of accuracy must be emphasized, together with the need of a larger training corpus.

## References

- Jeuring, J., Grosfeld, F., Heeren, B., Hulsbergen, M., IJntema, R., Jonker, V., Mastenbroek, N., van der Smagt, M., Wijmans, F., Wolters, M., & van Zeijts, H. (2015). Communicate! --- A Serious Game for Communication Skills ---. *Design for teaching and learning in a networked world*, 9307, 513-517.
- Lala, R., Jeuring, J., Heemskerk, R., van Geest, M., van Dortmont, J., Gutu-Robu, G., Ruseti, S., Dascalu, M., Alex, B., & Tobin, R. (2018). Processing Open Text Inputs in a Scripted Communication Scenario. In *SEMDIAL 2018* (pp. 211–214). Aix-en-Provence, France.
- Lodhi, H., Saunders, C., Shawe-Taylor, J., Cristianini, N., & Watkins, C. (2002). Text classification using string kernels. *Journal of Machine Learning Research*, 2(Feb), 419–444.
- Wang, Y. F., & Petrina, S. (2013). Using learning analytics to understand the design of an intelligent language tutor–Chatbot Lucy. *Editorial Preface*, 4(11), 124–131.

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# Collaboration within Mathland: What Do We become Together

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**Abstract:** Research has pushed Papert's (1980) seminal ideas of mathland and microworlds but remain focused on computational environments designed for individual work. Current group-centered activities using networked computational environments distribute mathematical objects among students and their relations and then assemble these objects in a shared public space. Within these new technological contexts, we ask how students identify with the mathematical objects distributed and maintained in socio-mathematical relations.

## Introduction and literature review

Over the last 40 years, research has pushed Papert's (1980) seminal ideas further in understanding students as epistemic agents and their material environments as fostering microworlds. Yet much of this work has remained focused on computational environments designed for individual work. A growing strand of literature has introduced group-centered activities using networked computational environments to distribute mathematical objects among students and their relations and then assemble these objects in a shared public space (Brady et al, 2013; White & Pea, 2011). Researchers have yet to broaden Papert's constructs of mathland and microworlds to these new technologies and students' collaborative interaction with them, but doing so reveals how these socio-technological *infrastructures* (cf Hegedus & Moreno-Armella, 2009) can provide rich collaborative spaces where students *identify with* mathematical objects at both the individual and collective level.

Early work in constructionism (Papert & Harel, 1991) using microworlds focused primarily on design and implementation of digital environments to support students' mathematics learning. But the microworld idea offers a framework to understand *any* designed space embodying powerful ideas (Papert, 1980) in a self-contained logical structure that students can explore and "bump up against" in order to (a) appropriate particular powerful ideas, and (b) build experiences of *what a logical structure is*, i.e. have epistemological experiences of mathland. Eisenberg (2003) broadened the notion of microworlds to extend it 'outside the computer,' exploring the material possibilities of physical or hybrid/instrumented objects to create a mathland in a child's familiar surroundings. Broadening the construct even further, we propose to analyze socially distributed activities and learning environments as microworlds on the basis of the patterns of interaction that they support. With such a frame, the social peer group can act both as infrastructure instantiating a microworld and as a social medium linking individuals with their mathematical roles. These interactional mechanisms among students, their participation structures, and the mathematical structures become essential when the nature of the computational environment leverages the peer group by aggregating distributed mathematical objects in a shared space.

Group-centered activity design with technology support has a growing base of literature establishing its unique capabilities and impact on classrooms (e.g. Kaput, Hegedus, & Lesh, 2007; Stroup, Ares & Hurford 2005). Such designs leverage technological infrastructures in classroom activities to model participation structures to mathematical structures (Brady et al. 2013; Hegedus & Penuel, 2008). For example, individual students act as points while student-pairs form a line and the collective forms a family of lines (White & Pea, 2011). Within such collaborative digital environments, the relationship between the classroom's social and mathematical structures can readily be seen as dialectic (Stroup et al. 2005), where the social influences the mathematical and the mathematical influences the social. We argue these types of environments can generate the conditions in classrooms that define microworlds as learning environments. This view highlights microworlds' interactional nature, where the social space is a medium and a representational infrastructure. In the context of a particular group-centered network activity, the preceding framing leads to the following research question: How do students identify with mathematical objects when those objects are distributed to individuals but maintained in socio-mathematical relations in a shared public space?

## Methods

To investigate the above research questions, we implemented a design-based research study of a series of activities in the 8<sup>th</sup> grade mathematics classrooms of a partner teacher at a public middle school serving a racially and economically diverse population within a large metropolitan district in a midsize southern city in the USA. Students ranged in backgrounds and relationships with mathematics from positive to negative, but the established classroom culture was overall positive and focused explicitly on a growth mindset. The two authors entered into the classroom space to assist the teacher in implementing rich mathematics tasks with technological support. All

three adults participated in supporting students' thinking during a series of weekly activities. Data for the larger project was collected broadly and is ongoing, but the current study draws on data collected from two stationary cameras and screen capture of the 'teacher' computer (which was displayed publicly via a projector), along with field notes generated during discussions of what to improve in continued activities.

To understand how students were identifying with mathematical objects in the activities, we analyzed a class discussion between two of the mathematics tasks. The previous week, the second author led the class in a group-centered activity where each student controlled a point in a shared display. By following simple verbal rules, students generated lines together; for example, "make your y-coordinate equal 4" generated the horizontal line seen in Figure 1. Together, students generated horizontal, vertical, and slanted lines by following different rules coordinating x and y coordinates. To better assess what the students recalled from this activity, the teacher prompted them to write in their journals, asking, "What do you remember from last week when [the authors] were in the room?" Students' responses to this prompt revealed how they were identifying with (or not) the mathematical objects from the previous week's task.

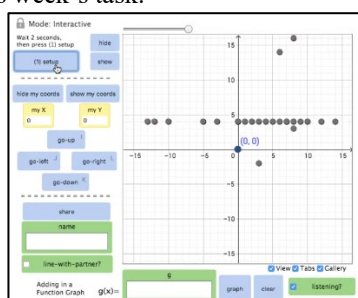


Figure 1. Collaborative group-centered activities where students control points.

## Findings

In the class discussion, students readily identified themselves with the point they controlled, using statements that blurred themselves and their point, such as "I remember chasing each other with the dots." Further, they related the technological space with the classroom space saying, "I like how we can see the whole class when we go in there." The students' use of "we" was significant, signaling a collective solidarity in the community (c.f. Hegedus & Panuel 2008). On the other hand, students did not (yet) seem to identify as strongly with the *emergent* mathematical objects (the lines), describing these as "how [second author] would give us points and stuff to go to." These descriptions hearkened back to traditional roles of teacher-as-rule-maker and student-as-rule-follower. This finding indicates further support is needed for groups of students to relate themselves with emergent mathematical objects (e.g., functions and loci of points), and our ongoing work is pushing technology designs and class discussions to explore these possibilities.

## References

- Brady, C., White, T., Davis, S., & Hegedus, S. (2013). SimCalc and the networked classroom. In *The SimCalc Vision and Contributions* (pp. 99-121). Springer, Dordrecht.
- Eisenberg, M. (2003). Mindstuff: Educational technology beyond the computer. *Convergence*, 9(2), 29-53.
- Hegedus, S. J., & Moreno-Armella, L. (2009). Intersecting representation and communication infrastructures. *ZDM*, 41(4), 399-412.
- Hegedus, S. J., & Penuel, W. R. (2008). Studying new forms of participation and identity in mathematics classrooms with integrated communication and representational infrastructures. *Educational Studies in Mathematics*, 68(2), 171-183.
- Kaput, J., Hegedus, S., & Lesh, R. (2007). Technology becoming infrastructural in mathematics education. *Foundations for the future in mathematics education*, 173-192.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc..
- Papert, S., & Harel, I. (1991). Situating constructionism. *Constructionism*, 36(2), 1-11.
- Stroup, W. M., Ares, N. M., & Hurford, A. C. (2005). A dialectic analysis of generativity: Issues of network-supported design in mathematics and science. *Mathematical Thinking and Learning*, 7(3), 181-206.
- White, T., & Pea, R. (2011). Distributed by design: On the promises and pitfalls of collaborative learning with multiple representations. *Journal of the Learning Sciences*, 20(3), 489-547.

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# Using Epistemic Network Analysis to Explore Ways of Contributing to Knowledge Building Discourse

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**Abstract:** This study explores Epistemic Network Analysis (ENA) to assess Knowledge Building discourse. Knowledge Forum notes were coded using a “ways of contributing” framework, and students were grouped based on their use of Knowledge Forum scaffolds. Findings indicate that the epistemic networks for theory, question, and source groups were significantly different from one another, yet complementary. The potential for ENA to model contribution dynamics during cycles of knowledge advancement is discussed.

## Introduction

Epistemic Network Analysis (ENA; Shaffer, 2017) is a method used for modeling the underlying structure of connections in discursive data. ENA produces weighted network visualizations by quantifying the co-occurrence of codes within discussions for each unit of analysis (e.g., individual speakers or sub-groups of speakers). These networks can then be simultaneously compared visually and statistically to further explore the similarities and differences between various speakers in a discussion. For example, when a group of students are engaged in Knowledge Building discourse to advance collective understanding (Scardamalia & Bereiter, 2017), they contribute important codes to the discussion, such as theorizing, questioning, providing evidence, and so on. Past work using statistical analyses to explore the relations between different ways of contributing to Knowledge Building discourse have revealed positive correlations between formulating questions and proposing explanations, as well as improving theories and providing evidence (Chuy, Resendes, & Scardamalia, 2010). The purpose of this study is to extend this work using ENA as a technique for modeling relationships between ways of contributing networks to better understand productive discourse moves during Knowledge Building.

## Methods and analysis

In this study, we applied Epistemic Network Analysis to Knowledge Forum data (Scardamalia, 2017) using the ENA Web Tool (Marquart et al., 2018). Based on approximately 100 notes, we created units of analysis by grouping students based on their use of Knowledge Forum scaffolds. Although the class had 21 students, the theory group had 13 students, the question group had 18 students, and the source group had 7 students. The three networks were aggregated using a binary summation to reflect the presence or absence of the co-occurrence of each pair of codes within a 4-line stanza window. More specifically, our ENA model included the following codes from the “ways of contributing” framework (Chuy, Resendes, & Scardamalia, 2010): questioning, theorizing, obtaining evidence, working with evidence, creating syntheses/analogies, and supporting discussion. The ENA model normalized the networks for all units of analysis before they were subjected to a dimensional reduction, which accounts for the fact that different units of analysis may have different amounts of coded lines in the data. For the dimensional reduction, we used a singular value decomposition, which produces orthogonal dimensions that maximize the variance explained by each dimension. Figure 1 shows the network centroids for the three groups of students along a two-dimensional space, with the x-axis accounting for 32.1% of variation and the y-axis accounting for 25.3% of variation. It can be seen that each group has a relatively unique profile, with the theory group (“My theory is”) occupying the top-left quadrant, the question group (“I need to understand/INTU”) occupying the top-right quadrant, and the source group (“New information”) occupying the bottom-left quadrant.

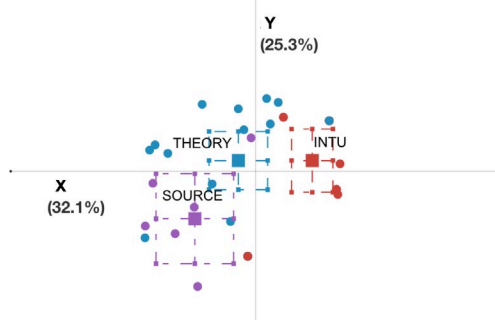
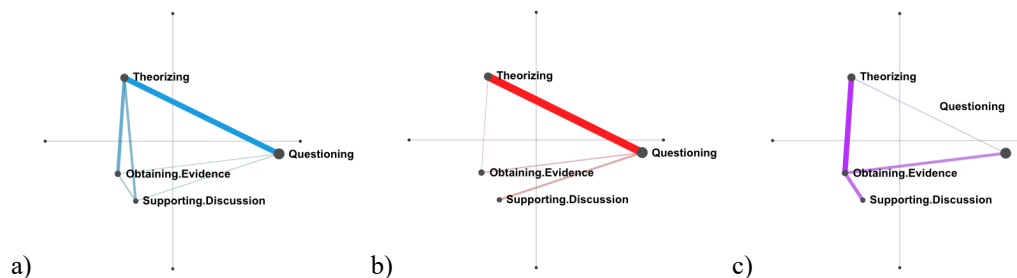


Figure 1. Network centroids for theory group (blue), question group (red), and source group (purple).

Mann-Whitney tests at the  $\alpha=0.05$  level showed that the theory group was statistically significantly different from the question group ( $U=205.50$ ,  $p=0.00$ ,  $r=-0.76$ ) along the x-axis, and the theory group was statistically significantly different from the source group ( $U=29.50$ ,  $p=0.05$ ,  $r=0.53$ ) along the y-axis.

## Findings and future directions

The epistemic networks of the three groups were visualized using network graphs where nodes correspond to the codes, and edges reflect the relative frequency of co-occurrence, or connection, between two codes. The positions of the network graph nodes are fixed, and those positions are determined by an optimization routine that minimizes the difference between the plotted points and their corresponding network centroids. Our model had co-registration correlations of 0.95 (Pearson) and 0.96 (Spearman) for the first dimension and co-registration correlations of 0.80 (Pearson) and 0.82 (Spearman) for the second dimension, suggesting a good fit among the variables of interest.



**Figure 2.** Mean networks for a) theory group, b) question group, and c) source group.

Figure 2a) shows the mean network for the theory group, where the strongest connection is between the theorizing and questioning codes, and the weakest connection is between the questioning and supporting discussion codes. Figure 2b) shows the mean network for the question group, where the strongest connection is between the theorizing and questioning codes, and the weakest connection is between the theorizing and obtaining evidence codes. In this network, there is no connection between the obtaining evidence and supporting discussion codes. Figure 2c) shows the mean network for the source group, where the strongest connection is between the theorizing and obtaining evidence codes, and the weakest connection is between the theorizing and questioning codes. In this network, there is no connection between the questioning and supporting discussion codes. It is interesting to note that the three networks complement one another based on their strongest and weakest connections, with the theory group producing the only network that holds all the codes together (e.g., questioning, theorizing, obtaining evidence, supporting discussion).

Our preliminary findings reinforce the centrality of theorizing and explaining in Knowledge Building discourse to engage students in working toward creating coherence among multiple sources of information, and in this case, multiple forms of contributions. As Chuy and colleagues (2010, p. 7) noted, “Different ways of contributing do not represent independent entities, but function as an inter-related system”. Based on this perspective, we anticipate that as students continue engaging in Knowledge Building discourse, the two codes – working with evidence and creating syntheses/analogies – will emerge, possibly in the empty quadrant on the bottom-right. Over time, we expect to see students designing new Knowledge Forum scaffolds to shape their discourse and epistemic networks as means to drive new cycles of knowledge advancement. Our study offers ENA as a promising approach to assess Knowledge Building discourse. Additional analyses are underway to compare changes in group and individual networks using network difference graphs and to understanding differences between various educational models. For example, inquiry learning is question-driven. Future studies will use ENA to analyze discourse moves associated with evolution of thought in different discourse communities.

## References

- Bereiter, C., & Scardamalia, M. (2017). “Good Moves” in knowledge-creating dialogue. *QWERTY-Open and Interdisciplinary Journal of Technology, Culture and Education*, 11(2), 12-26.
- Chuy, M., Resendes, M., & Scardamalia, M. (2010, August). Ways of contributing to knowledge building dialogue in science. Paper presented at the *Knowledge Building Summer Institute*, Toronto, Canada.
- Marquart, C. L., Hinojosa, C., Swiecki, Z., Eagan, B., & Shaffer, D. W. (2018). Epistemic Network Analysis (Version 1.5.2) [Software]. Available from <http://app.epistemicnetwork.org>
- Scardamalia, M. (2017). Knowledge Forum. In K. Peppler (Ed.), *The SAGE Encyclopedia of Out-of-School Learning* (pp. 401-403). Thousand Oaks, CA: SAGE.
- Shaffer, D. W. (2017). *Quantitative Ethnography*. Madison, WI: Cathcart Press.

# Identifying Learning Leaders in Collaborative Learning

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**Abstract:** This study applies social network analysis to identify learning leaders in online collaborative learning. We used indegree, outdegree, and betweenness to categorize learners by their learner participation roles. Three learner roles (full facilitator, transactional facilitator, and attractive facilitator) fit the theories of learning leadership and were effective in identifying learning leaders. The findings pave the foundation for further research developing real-time instrument for instructors to identify learning leaders, and provide timely learning support.

## Introduction

The purpose of this paper is to explore a computational approach to identifying learning leaders in online collaborative learning. Specifically, we used three network metrics—degree, outdegree, and betweenness—generated from social network analysis (SNA) to examine social dynamics in online discussions and thus identify learning leaders. Given the social nature of learning leadership, learners' social interactions can be tracked in online learning systems. The data on social interactions can thus enable us to identify learning leaders. However, the literature on leadership and online learning has been mostly running in parallel with little overlap. In this study, we first integrate the literature on leadership and online learning, and then applies social network analysis to develop and compare two leadership classification models to identify learner leaders. Specifically, we ask two research questions:

- How do we use social network metrics to characterize different learner roles in online discussion?
- How do we identify learning leaders from the learner participation model?

Prior literature has proposed a computational approach to classify different learner roles in online learning by using three social network analysis metrics in combination: (1) indegree—the number of messages sent by a learner; (2) outdegree—the number of messages received by a learner; and (3) betweenness—the extent to which a learner controls the communication between two other students in a community (Kim et al., 2018, in press). The three metrics correspond to popularity, influence, and mediation, respectively. Drawing on prior literature, the current study defines different learner roles in online collaboration each of which is matched with a combination of the thresholds of the three metrics (see Table 1). In our previous studies (Kim et al., 2018), we introduced two models of learner participation classification: three-level model (full participant, inbound participant, and peripheral participant) and four-level model (full participant, engaging participant, peripheral participant, and marginal participant). We hypothesize that full participants, given the social nature of leadership (Wang, 2018), can be identified as learning leaders but insufficient to detail various characteristics of learning leaders.

Table 1: Learner roles

Learner Role	Thresholds for the Metrics		
	Indegree	Outdegree	Betweenness
Full Facilitator	> 75	> 75	> 75
Transactional Facilitator	< 75	> 75	> 75
Attractive Facilitator	> 75	< 75	> 75
Topical leading discussant	> 75	> 75	< 75
Issue Seeker	< 75	< 75	> 75
Active Commenter	< 75	> 75	< 75
Attractive participant	> 75	< 75	< 75
Transitioning Participant	< 75	< 75	< 75
Occasional Participant	> 75	zero or 1	< 75
Marginal Participant	< 75	zero or 1	< 75

## Methods

This exploratory study used 21 students (5 male and 16 female) enrolled in a graduate-level online course that taught foundations of instructional design and technology. For 12-weeks asynchronous discussions, Each student was assigned at least a week to serve as a peer-moderator. For the online discussion each week, we extracted social network data on who communicated with whom, how often the learners communicated, and what the

content of their communication was. We used the NodeXL software to calculate the indegree, outdegree, and betweenness-centrality metrics. Using the filtering approach (i.e., the 75<sup>th</sup> percentile) described earlier, we classified individuals' participation profiles for each week, centering on the three learner roles: full facilitator, transactional facilitator, and attractive facilitator.

## Results

As expected, the number of leaders varied across weeks, ranging from 2 to 5 (not including topical discussants), which seemed reflecting dynamic and situational learner interaction in that community. Concerning the topical discussant, at least one topical discussant per week was identified (see Table 2). We decided to take the first three roles as leadership in online discussion community, because those roles fit our theoretical justification of learning leaders, and conservative approach to identifying leaders seemed better for a small group discussion ( $N = 21$ ).

Table 2: The number of learning leaders in each week by corresponding learner roles

	WK2	WK3	WK4	WK5	WK6	WK7	WK9	WK10	WK11	WK12	WK13	WK15
Full Facilitator	2	1	3	1	4	1	1	1	2	2	1	2
Transactional Facilitator			1	1		2		2		1	2	
Attractive Facilitator	2	3		1			1	2	3	1		1
Topical Discussant	2	1	1	2	1	1	1	1		2		1

We then further reviewed topical discussants. For example, as depicted in the network visualization of week 12 (see Figure 1), two topical discussants (i.e., 216 and 223) positioned around the leaders (i.e., 205, 208, 214, and 219), building their subgroups. We viewed that as far as their participation level is concerned, topical discussants would be at the fully engaged level (i.e., full participant), but still grow to becoming leaders. Therefore, we determined not to have the topical discussant in the leader classifications.

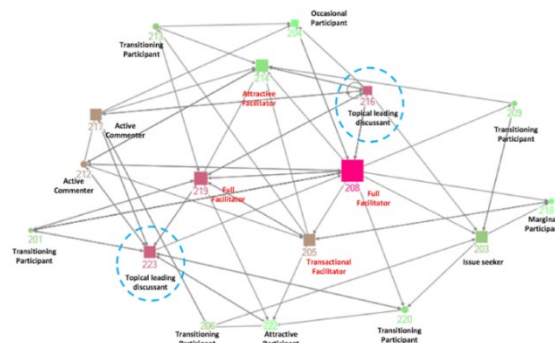


Figure 1. Network visualization of the learner roles

This study proposed how to use social network analysis to identify learning leaders in collaborative learning. This approach paves the foundation for further research that develops real-time instrument for instructors to identify and classify learning leaders, and provide learning intervention and support in a timely manner.

## References

- Kim, M., & Ayer, T. (in press). Learner participation profiles in an asynchronous online collaboration context. *Internet and Higher Education*.
- Kim, M., Ayer, T., & Bakshi, S. (2018, April). Profiling learner engagement in asynchronous online discussions: Validity and associations with motivation and performance. Paper presented at the American Educational Research Association Annual Meeting, New York, NY.
- Wang, Y. (2018). It all starts with social ties: Developing school leadership from the social network perspectives. *NAESP Bulletin*, 102(4), 323–340.

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# Supporting Meaningful Revision of Scientific Ideas in an Online Genetics Unit

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**Abstract:** This research investigates two ways to encourage revision of scientific essays an online genetics unit. Revising is difficult for students, due partly to lack of practice and guidance. We examine the effects of two activities designed to support gaining ideas from evidence by comparing an essay annotator activity that models the essay revision process (*text*) to an activity in which students annotate screenshots of interactive models from the unit (*model*). All students improved in their ability to revise, but low prior knowledge students benefited more from the *text* annotator condition.

## Introduction

Complex scientific topics such as genetic inheritance are notoriously challenging for students; understanding inheritance requires integration of phenomena occurring at various levels, ranging from DNA, genes, and alleles to inheritance of chromosomes to phenotypic expression (Jacobson & Wilensky, 2006). Students especially struggle with revising explanations after encountering new evidence (Berland & Reiser, 2009). Typically, students' revisions include only surface-level or grammatical fixes rather than integration of new content (Crawford et al., 2008; Bridwell, 1980), resulting in a collection of disconnected ideas. We explore revision guidance in the form of a *text* annotator (Fig 1), designed to make the revision process more visible, and a *model* annotator, designed to reinforce interpretation of evidence from the output of genetics simulations and models.

We employ the knowledge integration (KI) framework for curriculum design and analysis of student work since it emphasizes eliciting and building on students' prior ideas, making it an ideal framework for promoting integrated revision (Linn & Eylon, 2011). Within the knowledge integration framework, revising ideas can help students integrate new concepts, and may especially help students who come in with low prior knowledge (LPK). Our goal in this work is to encourage revision to help students move beyond rote skills and towards purposeful and usable construction of knowledge. The genetics unit employed in this study was designed according to the knowledge integration framework to promote building on students' prior knowledge.

## Methods

Six classes of 6th grade students (N=173) from one teacher participated in this study (94% non-white, 89% free/reduced lunch, 30% ELL). Students completed our 10-day Genetics and Simple Inheritance unit during class periods, working individually on the pretest and posttest, and working in pairs or groups of 3 on the unit itself. A revision question was also included on the pre/post test, asking students to revise their explanation after receiving new information about a pedigree. This question allowed us to assess students' ability to incorporate new knowledge in their scientific explanations before and after completing the unit. Two essay revision assessments that were embedded in the curriculum unit were analyzed as well (*Sibling* and *Punnett Square*). After answering each of these questions, student groups received one of the two types of experimental guidance (*text* or *model* annotation), and were then prompted to revise their initial response.

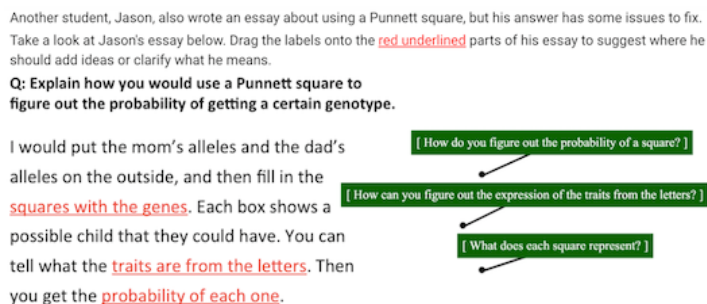


Figure 1. Example revision guidance activity for the *text* annotator condition.

All items were scored using a 5-point Knowledge Integration (KI) scale, which rewards making connections between scientific ideas. For each revision item (pre/post and embedded), KI scores were given to both the initial and revised essays and revision gain was calculated (revised score minus initial score). For some

analyses, we categorized students that received a score of 1 or 2 on their pretest essay as “low prior knowledge” (LPK) and students that received a 3-5 as “high prior knowledge” (HPK). This cutoff was chosen because a KI score of 3 must include at least one normative scientific idea, while a score of a 2 does not. Qualitative revision codes were also given to the embedded essay revisions and pre/post revision item based on how a student revised. A code was given for whether students made connected (C) or disconnected (D) revisions. Another code was given for whether students added new (N) ideas in their revision or expanded existing (E) ideas that were already present in their initial response.

## Results

All students improved in KI score from pretest (mean=1.89) to posttest (mean=2.61) [ $t(152)=9.66$ ;  $p<0.001$ ] and students’ revision gain score improved significantly from pre to posttest, regardless of condition [ $t(86)=4.40$ ;  $p<0.001$ ]. Students gained, on average, only 0.02 points from their revisions on the pretest, but gained 0.62 points from their revisions on the posttest. This shows the revision activities can improve students’ revision skills. Low prior knowledge students gained an average of 0.56 points more than high prior knowledge students from pretest to posttest [ $t(152)=2.17$ ;  $p<0.05$ ] across both conditions. We also found that LPK students revised by adding new ideas more often on the posttest than in their pretest revisions [ $t(143)=3.82$ ,  $p<0.001$ ].

For both embedded items, all students improved from initial to revised score (*Siblings*: [ $t(175)=4.19$ ,  $p<0.001$ ]; *Punnett Square*: [ $t(175)=5.90$ ,  $p<0.001$ ]), with an average gain of about 0.20 points on each. Students in the *text* annotator condition were more likely to revise by adding new ideas on the *Siblings* item, approximately 2.94 times as often as students in the *model* annotator condition [ $z(175)=2.40$ ;  $p<0.05$ ].

The *text* annotator provided the greatest advantage on the *Siblings* item for LPK students; they revised 2.64 times as often as those in the *model* condition [ $z(98)=1.99$ ,  $p<0.05$ ] and were 2.58 times as likely to revise by adding new ideas as compared to LPK students in the *model* condition [ $z(155)=1.97$ ;  $p<0.05$ ].

On the embedded *Siblings* item, high prior knowledge students were 4.54 times as likely to revise in a connected way as compared to LPK students [ $z(169)=2.53$ ;  $p<0.05$ ]. Similarly, on the *Punnett Square* question, high prior knowledge students were 3.43 times as likely to revise in a connected way [ $z(169)=2.13$ ;  $p<0.05$ ]. Our curriculum activities not only supported LPK students in adding ideas, but also helped HPK students successfully connect their prior knowledge to new science content.

Students who made any revisions at all on either embedded question achieved an average revision gain score of 0.33 points higher from pre to post than students who did not revise at all during the unit [ $t(118)=6.65$ ;  $p<0.001$ ]. In addition, making connected revisions on the embedded revision questions resulted in, on average, a pre to posttest gain of 0.44 points more than students who did not make connected revisions on the embedded assessment questions [ $t(152)=2.10$ ;  $p<0.05$ ]. This suggests that practice making connected revisions during the unit resulted in increased pre/post learning gains.

## Significance

This study reveals that students can improve their understanding of genetics as well as their ability to revise their ideas after encountering new evidence by using curricular supports designed to help with revisions. Engaging in integrated revision during instruction is connected to significantly greater pre to post learning, supporting our KI perspective that making connections is a powerful learning strategy. In addition, our *text* annotator activity was more effective in supporting low prior knowledge students to add more new ideas to their revised explanations, and to revise more often. This reveals that students, especially LPK students, perhaps need less guidance directed toward helping them interpret model output and instead need help distinguishing which of their ideas are relevant for their explanations. This activity may help by making the revision process more visible.

## References

- Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education*, 93(1), 26–55. <http://doi.org/10.1002/sce.20286>
- Bridwell, L. (1980). Revising strategies in twelfth grade students’ transactional writing. *Research in the Teaching of English*, 14, 197–222.
- Crawford, L., Lloyd, S., Knoth, K.: (2008) Analysis of student revisions on a state writing test. *Assessment for Effective Intervention*, 33, 108–119.
- Jacobson, M.J & Uri Wilensky (2006) Complex Systems in Education: Scientific and Educational Importance and Implications for the Learning Sciences, *Journal of the Learning Sciences*, 15:1, 11-34.
- Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking Advantage of Technology to Promote Knowledge Integration*. Routledge.



# Use of Spatial Sensemaking Practices in Spatial Learning

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**Abstract:** This paper describes an approach to understanding how 11-12-year-old students (N=185) engage in spatial thinking through use of sensemaking practices. There is limited research on nature of students' spatial thinking when learning discipline-specific content knowledge during classroom instruction. We use embodied cognition to examine the kinds of sensemaking practices students use when applying perspective-taking skill to learn seasons and lunar phases, and the teacher's role in shaping those practices.

## Introduction

Spatial thinking is important in predicting students' success and achievement in the fields of science, technology, engineering, and mathematics (Wai, Lubinski & Benbow, 2009). However, there is limited research on *how* students learn spatial thinking and what kinds of practices or strategies might be useful in improving students' spatial thinking. We begin to fill this gap in the literature by analyzing the nature of students' engagement in spatial problem-solving, and examining the role of the teacher in supporting students' spatial sensemaking. We analyzed how students from 6<sup>th</sup> grade science classrooms applied the spatial skill of perspective taking (PT hereafter, Liben & Downs, 1993) to astronomy topics. PT skill has been found to be correlated with students' explanations of astronomical phenomena (Plummer et al., 2016). In this study, we examined physical and interactions (dialogues with peers and teachers) to study the nature of sensemaking practices used in the classroom. This study adapts Ramey and Uttal's (2017) analytical framework of *spatial sensemaking practices*, which they developed to examine students' use of spatial skills to solve engineering design problems. However, the present study identifies practices that capture participants' use of perspective taking when they are making sense of concepts related to seasons and lunar phases. We refer to this framework as *PT sensemaking practices*. This study is guided by the following **research question**: *How do middle-school students engage in perspective-taking sensemaking practices when participating in a seasons and lunar phases curriculum?*

## Theoretical framework – Embodied cognition

We used the following principles of embodied cognition in analyzing the nature of PT sensemaking practices: 1. *we offload cognitive work onto the environment* (Kirsh & Maglio, 1994), 2. *offline cognition is body based* (Wilson, 2002), and 3. *embodied cognition can manifest in social interactions* (Abrahamson & Lindgren, 2014). These principles were used to connect how participants' actions contribute to their PT sensemaking practices by supporting their cognitive activities.

## Context and methodology

The study took place in a suburban public middle school in the Northeastern U.S. A total of 185 students (ages 11-12 years) participated in a 10-day curriculum, which was taught by a member of the research team. The curriculum was designed by our team of researchers to promote the use PT skill while teaching seasons and lunar phases. We videorecorded all 10-days of instruction to capture talk, actions such as gaze and gestures, turn transitions, and collaborative activities, which are otherwise difficult to capture through field notes. Each class period was 45 minutes per day. We analyzed the data using interactions analysis (Jordan & Henderson, 1995).

## Findings

We found two main themes for PT sensemaking practices in the classroom – students themselves used practices to aid their perspective taking and the teacher used practices to support students' use of perspective taking. The analysis revealed three PT sensemaking practices that were unique to the teacher - a) *PT questioning*, b) *eliciting students' gestures* (Nathan, 2008), and c) *grounding students' thinking with gestures* (Nathan, 2008). We found four PT sensemaking practices common to both students and the teacher – a) *using gestures* (enhancing speech, complimenting speech, with bodily movement), b) *PT epistemic actions* (physical and virtual object manipulation, Kirsh & Maglio, 1994), c) *PT representations* (sketching), and d) *using fixed objects as proxy*.

*PT questioning* refers to a question asked either by the teacher or the student that requires PT skill to answer it. e.g. “who [on earth] should see the sun [rising] first?” This question requires the students to imagine the sun's path from an earth-based perspective and then connect it to space-based perspectives, to visualize which

part of the earth would face the sun first as it rotates. *Eliciting students' gestures* refers to prompts for students to use gestures to support their sensemaking. *Grounding students' thinking in gestures* refers to instances when the teacher used gestures to emphasize meaning of students' responses by making their thinking visible.

From the common PT sensemaking practices observed, *using gestures* refers to participants using their hands to simplify visualization of different perspectives. *PT epistemic actions* include practices when the participant manipulates objects in the environment to reduce cognitive load. Examples include using a model earth and rotating it to figure out the directionality of its rotation instead of mentally visualizing. *PT representations* refers to translating mental visualizations with a drawing. For instance, the teacher drew a sketch of earth and sun model to show how the sun's rays hit a specific location on earth because of its tilted axis. *Use of fixed objects as a proxy* refers to a visualization practice such as using a wall-clock as a proxy for the North Star, which was then used as a reference to determine direction of earth's tilt by visualizing a space-based perspective.

## Discussion

This research study examines how 6<sup>th</sup>-grade students and their teacher engaged in perspective taking through sensemaking practices and how those practices are enabled by elements of their learning environment. The principle of embodied cognition - *we offload cognitive work onto the environment* - suggests that use of external tools or objects helps in simplifying cognitive processes. We saw evidence of that when students, as well as the teacher, used earth models to simulate earth's motion that simplified application of PT skill. The second principle - *offline cognition is body-based* - suggests that gestures are useful in externalizing thinking processes. The word "offline" suggests processes in the world that are removed from the context. Body-based actions such as gestures or movement, become a part of the learner's "toolbox," providing ways to organize their thinking and cognition. In our study, we found that this principle was operationalized when students and the teacher communicated through gestures and used gestures for externalizing their mental visualizations of space- and earth-based perspectives. We also observed that the teacher encouraged students to use their models and gestures to clarify their thinking and helped in breaking down the process of using PT skill. Thus, embodied cognition sometimes *manifested through social interactions* (Abrahamson & Lindgren, 2014).

A close examination of students' actions, interactions, and the teacher's enactment of the curriculum provided insight into how spatial information is communicated and is used for constructing explanations of astronomical phenomena. In essence, gestures, speech, external objects, and linguistic prompts together seem to create fluidity in students' spatial thinking as they engage in constructing explanations, follow teacher prompts, and collaborate with peers. This study has implications for how students' spatial thinking can be effectively fostered through intentionally designed learning environments, curriculum, and instruction that leverage students' spatial skills to support their spatial learning using principles of embodied cognition.

## References

- Abrahamson, D., & Lindgren, R. (2014). Embodiment and embodied design. *The Cambridge handbook of the learning sciences*, 2, 358-376.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, 4(1), 39-103.
- Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive science*, 18(4), 513-549.
- Liben, L. S., & Downs, R. M. (1993). Understanding person-space-map relations: Cartographic and developmental perspectives. *Developmental psychology*, 29(4), 739.
- Nathan, M. J. (2008). An embodied cognition perspective on symbols, gesture, and grounding instruction. *Symbols and embodiment: Debates on meaning and cognition*, 18, 375-396.
- Plummer, J. D., Bower, C. A., & Liben, L. S. (2016). The role of perspective taking in how children connect reference frames when explaining astronomical phenomena. *International Journal of Science Education*, 38(3), 345-365.
- Ramey, K. E., & Uttal, D. H. (2017). Making sense of space: Distributed spatial sensemaking in a middle school summer engineering camp. *Journal of the Learning Sciences*, 26(2), 277-319.
- Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Jrnl of Educational Psychology*, 101, 817.
- Wilson, M. (2002). Six views of embodied cognition. *Psychonomic bulletin & review*, 9(4), 625-636.

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# Teacher Perceptions on Collaborative Online Professional Development for In-Service Teachers on a MOOC Platform

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**Abstract:** This study seeks to address the growing need for greater access to effective, on-demand, low-cost professional development (PD) through the development of a small private online course (SPOC) as a pilot test for a scale-up to a full massive open online course (MOOC). Traditional MOOCs are not designed for collaboration and social interaction among participants that build communities, which has been shown to be an important aspect of effective PD. This study provides insights in designing for collaboration on a traditional MOOC platform (in our case edX). A pilot study was run with a small group of in-service teachers to test a collaborative design with an eye to how the design will scale to a full MOOC.

## Objectives and theoretical framework

There is a growing need among teachers for greater access to effective, on-demand, low-cost professional development (PD) (Fishman et al., 2013). Traditional face-to-face PD is expensive, and limited in relevance, applicability, and ability to scale (Hill, 2015). Online PD is a rapidly growing option that can make it more broadly accessible. PD offered online can be as successful as face-to-face (Fishman et al., 2013). Massive open online courses (MOOCs) provide the opportunity to explore the viability of such online approaches at larger scales. However, there are drawbacks to MOOC participation that pose barriers to implementing effective PD. collaboration among participants and social interaction that build communities are two conditions that encourage engagement but are not well-supported technologically in MOOCs (Kop, 2011). We seek to design a MOOC that overcomes these barriers to collaboration and community building. In order to do this research, a pilot study was run with a small group of teachers in order to explore how successfully a MOOC platform and framework can be used to encourage collaboration with the aim of eventually scaling to larger participation.

We build on research that positions teachers as knowers and agents of change (Cochran-Smith & Lytle, 1999). This posits that teachers are active participants in building their own knowledge rather than passive recipients (Fenstermacher, 1994). Through a cross-case study Booth (2012) found that social learning was able to build knowledge sharing and trust among teachers. Other studies have demonstrated that collaboration can increase knowledge creation and sharing in an online space (e.g., Duncan-Howell, 2010). In order to encourage collaboration in our SPOC, we built on existing best practices for encouraging collaboration in online PD (e.g. Booth, 2012; Hew & Cheung, 2014). These findings were used directly in the development of the collaborative learning portion of the course and the prompts that led teachers into that space.

## Methods

This paper is part of a long-standing program of research funded by the U.S. National Science Foundation which undertakes the design and dissemination of a curriculum to teach common topics in high school biology through complex systems simulations (Yoon et al., 2017). In adapting the PD for the complex systems curriculum to a wider audience, the PD was moved to an online platform: Edge, the pilot testing platform for edX. We used three design categories which emerged from the literature to promote collaboration throughout the course: 1) periodic required discussions in the online forum; 2) open-ended questions based on course content to prompt the sharing of reflections on practice; and 3) expectation of participant comments on others' reflections. The participants in the first implementation of the course were eight in-service teachers from six different schools in three urban districts in the Northeastern US.

This paper is part of a larger study which collects data at both the teacher and student level over an entire year. A selection of the data from the summer PD was analyzed: teacher enrollment forms, teacher interviews, and teacher post-surveys were used as primary sources of data, while preliminary data from the discussion board posts was used to triangulate some of the findings. We combined the open-ended responses from the enrollment forms, satisfaction surveys, and interview transcripts which were all then inductively mined for themes. The themes were given positive and negative levels and a coding manual was created representing the themes and

levels. Two researchers achieved an inter-rater reliability Cohen's kappa score of 0.87.

## Results and discussion

Six themes emerged in terms of the way that participants collaborate within the SPOC: (a) asynchronicity is a hinderance to collaboration; (b) online delivery is not a hinderance to collaboration; (c) struggle is a motivator for collaboration; (d) participants view each other as resources; (e) not all open-ended questions are created equal; and (f) individual motivations have an effect on collaboration. The course was run fully asynchronously based on assumptions about teachers' available time and schedules during the summer. These assumptions, though supported by some of the teachers' comments, led to a level of asynchronicity that was a hinderance to collaboration. Based on the first finding and supported by previous research that suggests a combination of synchronous and asynchronous technologies create an ideal space for interaction (e.g. Hew & Cheung, 2014) a semi-synchronous design that allows teachers freedom to complete the course on their own time but within a synchronous framework of weeks would be a better design than a fully asynchronous one.

Participants' responses to the question about face-to-face delivery combined with the moments when they most wished for support provides a guideline for when synchronous check ins may be the most useful during the course. Portions of the course where teachers were asked to learn new academic content (e.g., programming, scientific argumentation) were places where participants struggled the most and when they wished for greater collaboration. As participants were shown to view each other as resources, increased synchronicity may be enough to provide peer support to participants at these points of struggle, especially if prompts are modified to ensure that they not only encourage participants to share their thoughts but also be rigorous or controversial in a way that elicits a range of responses. Prompts were designed to do this as per previous research that supports these findings (e.g. Booth, 2012) however, the level to which prompts were successful depended on the motivations of the participants for engaging in the course.

A number of participants commented that though they found reading others' posts useful, they were not motivated to respond. Further research into phrasing for discussion prompts and how they can support active knowledge development is needed to better address the needs and motivations of a diverse participant group, especially as this project moves towards scale. The goal of this project is to scale the current course up to true MOOC participation levels. As such, the small number of participants in our pilot run of the course is a limitation of this study. However, each of the findings presented in this paper has implications for future iterations on the design of collaborative MOOCs for in-service teachers. As researchers develop meaningful PD within MOOCs, a comprehensive list of best practices for creating and sustaining collaboration is necessary. Our research suggests several themes that may be promising for future content development.

## References

- Booth, S. E. (2012). Cultivating knowledge sharing and trust in online communities for educators. *Journal of Educational Computing Research*, 47(1), 1-31.
- Cochran-Smith, M., & Lytle, S. L. (1999). Chapter 8: Relationships of knowledge and practice: Teacher learning in communities. *Review of research in education*, 24(1), 249-305.
- Duncan-Howell, J. (2010). Teachers making connections: Online communities as a source of professional learning. *British Journal of Educational Technology*, 41(2) 324-340.
- Fenstermacher, G. D. (1994). Chapter 1: The knower and the known: The nature of knowledge in research on teaching. *Review of research in education*, 20(1), 3-56.
- Fishman, B., Konstantopoulos, S., Kubitskey, B. W., Vath, R., Park, G., Johnson, H., & Edelson, D. (2013). Comparing the impact of online and face-to-face professional development in the context of curriculum implementation. *Journal of Teacher Education*, 64(5), 426-438.
- Hew, F., & Cheung, W. (2014). Students' and instructors' use of massive open online courses (MOOCs): Motivations and challenges. *Educational Research Review*, 12, 45-58.
- Hill, H. (2015). *Review of The Mirage: Confronting the hard truth about our quest for teacher development*. Boulder CO: National Education Policy Center.
- Kop, R. (2011). The challenges to connectivist learning on open online networks: Learning experiences during a massive open online course. *Intl Review of Research in Open and Distance Learning*, 12(3), 19-38.
- Yoon, S., Anderson, E., Koehler-Yom, Evans, C., Park, M., J., Sheldon, J., Schoenfeld, I., Wendel, D., Scheintaub, H., & Klopfer, E. (2017). Teaching about complex systems is no simple matter: Building effective professional development for computer-supported complex systems instruction. *Instructional Science*, 45(1), 99-121.

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# Shall We Learn Together in Loud Spaces? Towards Understanding the Effects of Sound in Collaborative Learning Environments

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**Abstract:** In this paper we question the role of environmental sound on the process of CL. The first pilot study is presented where we investigated effects of environmental sound on EDA and voice VA of the participants. The created visualization presents the dependence between mentioned parameters and serves as an awareness tool for participants in CL. Preliminary results are provocative; there seems to be mentioned dependences and participants accept the proposed visualization as a useful tool to support self-regulation during CL.

## Introduction

Investigating the process of collaboration in learning remains challenge due to many unclear aspects of socio-emotional and cognitive interactions (Pijeira-Díaz, Drachler, Järvelä & Kirschner, 2016). Additionally, broad application of collaborative learning finds its challenges in implementation because it is “so noisy” due to participants’ interaction that can hinder learning (Graetz & Goliber, 2002). As in any other activity, interactions are tightly related to the environment (Malmberg, et al. 2018), and successful learning should be supported by the space where it takes place (Yeoman, 2008). The effect of environmental sound on CL has been underexplored in the sense of its effect on aspects of collaboration such as cognitive and socio-emotional interactions, that are reflected through physiological changes and conversation. Electrodermal activity (EDA) and voice activity (VA) measurements could help us understand and further explore connection between the environmental sound and collaborative learning process. Examples in the literature show different ways of visualizing physiological data with graphical user interface such as SLAM-KIT (Noroozi et al, 2018) and voice data with Reflect, a reactive table that monitors the collaborative interaction based on voice activity of participants (Bachour, Kaplan & Dillenbourg, 2010). We focus on loud spaces within university campus, used for collaborative activities, given their pedagogical interest, orchestration complexity and their direct relation to the sound footprints of learning spaces. We present a pilot study that opens the question of the role of environmental sound in Collaborative Learning (CL), using multimodal learning analytics (MMLA), that supports CL in many ways (Ochoa et al, 2013; Spikol, Ruffaldi & Cukurova, 2017). We also propose visualization of the changes of EDA and VA and their relation to sound footprints of learning spaces.

## Understanding the effect of sound in CL through a pilot study

We have conducted a first pilot study, measuring EDA and VA, where qualitative data is also collected through interviews with participants. Two types of environments were identified (a quiet room where only the participants stayed and a loud space with many people). The same type activity was carried out in both spaces, with the same level of difficulty and duration of activity. The first group performs activity first in the loud environment, then in a quiet one, while the other group first performs activity in a quiet environment, and then in a loud one. Activity is based on learning a set of words in Swahili language (Carpenter, et al, 2008), where participants receive a list of English-Swahili pairs of words from where they should learn. Participants had no prior knowledge of Swahili.

## Visualization and discussion of preliminary results

We propose a visual representation (Figure 1) that aims to clearly present two measured parameters from participants (EDA and VA) and characteristics of environmental sound, where it is possible to understand the changes that occur in time. The level of sound from the environment was expressed by means of decibels, EDA by number of peaks in the signal occurred above the certain threshold that indicates arousal, while the voice activity was presented by time periods during which the speech occurred. Results indicate that there may be a dependence between the environment and the behaviour of the participants as shown in the Figure 1, where the EDA and VA values greatly differ in two environments. The visualization of the data was shown to all participants in order to understand if it can be used as an awareness tool. All participants stated that the visual representation is an effective way to look at all the parameters at the same time as it can be used as a tool for determining interdependence of collaboration parameters.

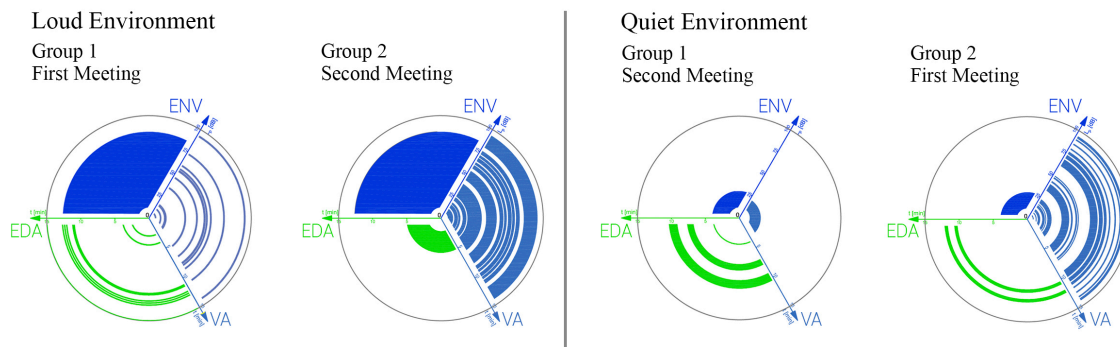


Figure 1. Visualization – unique graphic presentation for three measured parameters.

## Conclusion

Based on the pilot study, we cannot make clear conclusions because of the small sample in which the experiment was conducted, but we can see that there are differences in EDA and VA measured in different environments. This tells us that it is necessary to expand the study to a larger number of samples in order to see how and to what extent the sound from the environment affects the aspects of collaborative learning. The future work implies the extension of the study towards understanding what kind and level of environmental sound can be beneficial for collaboration, as well as the further development of visualization and its implementation in the process of collaboration as a conscious tool.

## References

- Bachour, K., Kaplan, F., & Dillenbourg, P. (2010). An interactive table for supporting participation balance in face-to-face collaborative learning. *IEEE Transactions on Learning Technologies*, 3(3), 203-213.
- Carpenter, S. K., Pashler, H., Wixted, J. T., & Vul, E. (2008). The effects of tests on learning and forgetting. *Memory & Cognition*, 36(2), 438-448. <https://doi.org/10.3758/mc.36.2.438>
- Graetz, K. A., & Goliber, M. J. (2002). Designing collaborative learning places: Psychological foundations and new frontiers. *New Directions for Teaching and Learning*, 2002(92), 13-22. <https://doi.org/10.1002/tl.75>
- Malmberg, J., Järvelä, S., Holappa, J., Haataja, E., Huang, X., & Siipo, A. (2018). Going beyond what is visible: What multichannel data can reveal about interaction in the context of collaborative learning?. *Computers in Human Behavior*.
- Noroozi, O., Alikhani, I., Järvelä, S., Kirschner, P. A., Juuso, I., & Seppänen, T. (2018). Multimodal data to design visual learning analytics for understanding regulation of learning. *Computers in Human Behavior*.
- Ochoa, X., Chiluíza, K., Méndez, G., Luzardo, G., Guamán, B., & Castells, J. (2013, December). Expertise estimation based on simple multimodal features. In *Proceedings of the 15th ACM on International conference on multimodal interaction* (pp. 583-590). ACM.
- Pijera-Díaz, H. J., Drachsler, H., Järvelä, S., & Kirschner, P. A. (2016). Investigating collaborative learning success with physiological coupling indices based on electrodermal activity. In *Proceedings of the sixth international conference on learning analytics & knowledge* (pp. 64-73). ACM. <https://doi.org/10.1145/2883851.2883897>
- Spikol, D., Ruffaldi, E., & Cukurova, M. (2017). Using multimodal learning analytics to identify aspects of collaboration in project-based learning. Philadelphia, PA: International Society of the Learning Sciences.
- Yeoman, P. (2018). The Material Correspondence of Learning. In *Spaces of Teaching and Learning* (pp. 81-103). Springer, Singapore. <https://doi.org/10.1007/978-981-10-7155-3>

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# Assessing Collaborative Problem Solving in the Context of a Game-based Learning Environment

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**Abstract:** Game-based learning environments provide students with the opportunity to collaborate with peers and solve ill-defined problems that align to a problem-based learning (PBL) inquiry cycle. However, game-based assessments must not only be psychometrically valid, but also fun. Drawing on problem-based learning (Hmelo-Silver, 2004) and a collaborative problem-solving framework (Liu et al, 2016), we present a conceptual piece detailing the design of collaborative work products and PBL assessments in the context of our game-based learning environment.

Problem-Based Learning (PBL) refers to an instructional method that presents an ill-defined problem that students solve collaboratively with the aid of scaffolds (Hmelo-Silver, 2004). Although PBL has often been used in the classrooms, game-based learning environments can provide a rich context to situate problems. Shifting to a game-based learning environment means that generating a validated assessment can be challenging since it requires accounting for assessment design, psychometrics and the element of fun. To address this challenge, we utilize Liu et al.'s (2016) evidence-centered design (ECD) framework of collaborative problem solving (CPS). We aim to explore the relationship between scaffolds and the impact it has on group collaboration and learning outcomes. In this conceptual paper, we highlight how CPS framework aligns with steps in the PBL process and the design of collaborative work products in the context of a game-based learning environment<sup>1</sup>. It is hoped that by making these aspects visible in our work, we can facilitate discussions about how to design game-based PBL assessment in collaborative settings.

## Evidence-Centered Design (ECD) approach to game-based assessments

Evidence-centered design (ECD) is an approach towards designing assessments by attending to evidentiary arguments, wherein claims about what students know can be reasoned from what they do (Mislevy et al., 2014). There are multiple layers that need to be addressed in the design of assessments; domain analysis, domain modeling, conceptual assessment framework (CAF), assessment implementation and delivery (Mislevy et al., 2014). The ECD framework has been widely utilized in game-based assessments, allowing researchers to examine constructs such as emotional engagement (Kim & Shute, 2015). Given the centrality of collaboration in PBL, we utilize the collaborative problem solving (CPS) model designed by Liu et al. (2016) who outline four categories of skills (table 1), that were crucial to successful collaborative problem solving. In their work, the authors found that individuals who were able to share ideas with others performed significantly better at understanding seismic events (i.e., their outcome of interest) than those working on their own. In table 1, we present an alignment between CPS, the PBL cycle and activities in CRYSTAL ISLAND: ECOJOURNEYS. In ECOJOURNEYS, students work in groups of four and have to solve an aquatic problem. As students engage in the game, they use a whiteboard tool, hypothesis board and chat to share their ideas and solve the problem.

Table 1: Mapping of the CPS model, PBL cycle and activities in the game

CPS skills	Problem-solving in PBL	Activities in the game
1.CPS Sharing ideas 2.CPS Negotiating ideas	1.PBL Identifying facts 2.PBL Generating hypothesis 3.PBL Understanding gaps in knowledge 4.PBL Presenting solutions to the problem	<b>Whiteboard &amp; Hypothesis board:</b> A shared environment where students identify facts and share information after meeting assigned stakeholders and gathering data. Students evaluate evidence to generate hypothesis and solutions to solve the

		problem
3.CPS Regulating problem solving activities 4.CPS Maintaining communication	5.PBL Engaging in self-directed learning	<b>Chat environment:</b> Use chat to discuss ideas, resolve conflicts and identify knowledge deficiencies; regulate group process and return to the game to look for more information <b>To-do list:</b> Helps regulate problem solving

In our work, the student model is an integration of the CPS model and the problem-solving processes in the PBL cycle. Based on both the CPS and problem-solving processes in the PBL cycle, we identify two dimensions of interest: collaboration skills as it relates to sharing and negotiating ideas and process management skills. Based on this alignment, it is reasonable to assume that there is a strong relationship among process management skills, problem-solving skills, and content learning. To unpack the relationship between the student model and the task model (i.e., student activities), we provide an outline of work products (Mislevy et al., 2014) in the game that and that would help elicit evidence of desired student competency (i.e., CPS skills).

Table 2: Work products from students' game play in Crystal Island: Eco Journeys

Pre-defined	Contingent	Log file data
<i>A whiteboard.</i> Students place evidence that support hypothesis provided. (1.CPS & 2CPS) <i>A short report:</i> Students submit a report detailing their hypothesis and supporting evidence to the characters in game (4.PBL & 1.CPS)	<i>A hypothesis board:</i> After evaluating evidence and claims at the brainstorming board, students present a model-based hypothesis (1.CPS, 2.CPS, 4.PBL, 5.PBL) <i>Whiteboard:</i> Students are prompted to evaluate peer claims and evidence. They are prompted to use chat to negotiate (all CPS & PBL skills)	Data mined from students' written interactions in chat, a space that offers opportunities for all four CPS and 5 PBL skills to be elicited via prompts. Student actions in the game related to who is chatting, when they are chatting as they play the game, and discourse features

These work products are associated with designed scaffolds in the game, such as the whiteboard, a hypothesis board and prompts provided in the chat space to students. Based on when and how scaffolds were delivered to students, we will leverage a time-series analysis (Sawyer, Rowe, Azevedo & Lester, 2018) to understand the relationship between the scaffolds provided and collaborative problem skills at both individual and group level.

## References

- Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235-266.
- Kim, Y. J., & Shute, V. J. (2015). The interplay of game elements with psychometric qualities, learning, and enjoyment in game-based assessment. *Computers & Education*, 87, 340-356.
- Liu, L., Hao, J., von Davier, A. A., Kyllonen, P., & Zapata-Rivera, J.-D. (2016). A tough nut to crack: Measuring collaborative problem solving. In *Handbook of research on technology tools for real-world skill development* (pp. 344-359): IGI Global.
- Mislevy, R. J., Oranje, A., Bauer, M. I., von Davier, A., Hao, J., Corrigan, S., . . . John, M. (2014). Psychometric considerations in game-based assessment. *GlassLab Report*.
- Sawyer, R., Rowe, J. P., Azevedo, R., & Lester, J. C. (2018). Filtered Time Series Analyses of Student Problem-Solving Behaviors in Game-based Learning. Paper presented at the Proceedings of the Eleventh International Conference on Educational Data Mining. Buffalo, New York.

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# Structure for Agency: Possibilities and Challenges for Adaptive Collaborative Learning Support in Educational Equity Projects

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**Abstract:** Adaptive collaborative learning support (ACLS) has potential to support educational equity projects. We outline how student agency might be conceptualized in CSCL environments, discussing content-focused, inquiry-based, and dialogical learning environments. For each, we consider the potential and challenges of ACLS for supporting student agency and conclude with open questions for CSCL researchers who seek to program, design, and evaluate the role of ACLS in equity-oriented CSCL environments.

## Introduction: Structure, agency, and equity

In CSCL, there has been increasing interest in issues of educational equity. For example, consider Wise and Schwarz's (2017) provocations that ask whether or not CSCL should give up on educational change, or Rummel, Walker, and Alevén's (2016) discussion of what an adaptive support educational utopia should be. This reflects a political turn in the learning sciences broadly that seeks to understand what role learning research can play in improving lives and in social justice (e.g., Politics of Learning Writing Collective, 2017). This is a timely goal, particularly in light of the increasing need for global citizenship education (UNESCO, 2014).

We argue that when educational equity is defined as equitable access to ambitious collaborative practices that promote learner agency, dialogue, and identity development, CSCL's understanding of scripts and scaffolding has the potential for unique and useful contributions to educational equity projects. However, there is tension between viewing scripts as compromising learner agency versus viewing scripts as supporting new forms of learner agency (Wise & Schwarz, 2017). Building on a series of NSF-sponsored workshops, we explore the possibilities and challenges of ACLS for supporting student agency and educational equity projects.

## Adaptive support for agency

As Calabrese Barton and Tan (2010) illustrate, from a sociopolitical perspective, learning is about recreating "practices in socially and culturally situated ways that confer on one more (or less) agency with which to participate across communities" (p. 190-191). These approaches understand and position students as cultural-historical actors (agents), rather than the passive recipients of education (Freire, 1972; Vossoughi & Gutiérrez, 2017). We see agency as linked to identity development defined broadly, where in equitable learning situations students can take on and take up disciplinary identities rather than be rejected by them (Bell, van Horne, & Cheng, 2017). We also understand learner agency as including students' ability to question knowledge, including how that knowledge was generated and what purposes it has been and might be used for.

There is evidence that ACLS can support cognitive learning outcomes (e.g., Rau, Bowman, & Moore, 2017). One tension is the role of ACLS in learning when content is considered more fluid. Rummel et al. (2016) imagine a dystopian scenario for learning in a chemistry class where students (and teachers) have no way to override their school's ACLS technology, students are paired with frustrating partners because such pairs are marked by the ACLS as supporting "constructive conflict," and predictive mechanisms write off students' potential early. By contrast, in the utopian scenario, the teacher and the ACLS technology confer on next steps and the ACLS orients to the students in a more human way (e.g., by encouraging them to take a break as they feel frustrated). What is the same, however, is the content of each lesson: standard chemistry. We argue that a real concern by CSCL with issues of disciplinary agency must attend more deeply to questions about the content of learning. CSCL has long known that learning is especially productive when students engage in real-world problems, problems that are of personal meaning, or open problems in a discipline (Hmelo-Silver, 2004; Papert, 1980). For example, in a science class this could be sustained engagement with a science-based simulation (e.g., *Wallcology*; Slotta, Quintana, & Moher, 2018), in which scripted grouping and activity sequences support students in enculturating into a scientific community of practice.

While these approaches reposition students as problem solvers rather than recipients of knowledge, they pose significant problems for adaptive support. For example, it is much more difficult in such environments for ACLS to take on the role of "intelligent tutor," able to understand best pathways through known-answer problems and guide students to and through such pathways. Instead, we imagine that adaptive support can focus on collaborative practices. In this way, even when agnostic to content, support could help

students it understands as frustrated by prompting collaborative learning strategies or could, based on what it hears and sees, prompt teachers to visit groups that appear especially sullen or enthusiastic.

From a critical Freirian perspective, “Simply replacing the *content* of teaching (from hegemonic to counter-hegemonic ideas) does not unsettle the social and intellectual relations that sustain an unequal society” (Vossoughi & Gutiérrez, 2017, p. 141). With this in mind, it is also important that collaborative environments do not simply seek to support students’ agency through robust content, but rather also through fostering more dialogical forms of learning. For example, Kolikant and Pollack (2015) used the notion of “dialogical agency” to study the computer-mediated discussions between Jewish and Arab Israeli high schoolers as they analyzed loaded historical documents. They recognized that from a conception of collaboration that focuses on dialogue rather than convergence, “the role of the Other is to generate a dialogic agency in oneself” (p. 331). While we can imagine ACLS playing the role of an “other” in supporting dialogue and agency, we are weary of a “critical” classroom in which learners talk only to machines throughout the day. Additionally, there are significant technological barriers to creating ACLS that can respond to the wider range of comments students might make in dialogical rather than acquisitionist learning environments.

### **Conclusion: Challenges in structuring for agency**

Clearly, ACLS has immense potential for supporting content agency and disciplinary identification. Given ACLS’s ability to support teachers, it might also be especially transformative in under-resourced classrooms. Therefore, CSCL should not give up on educational change but instead consider how ACLS can (a) increase access to (b) learning environments that support deep rather than shallow learner agency. Moving forward, the CSCL community must therefore contend with how to program, design, and evaluate the use of ACLS for environments where content is not pre-determined and where dialogical forms of learning are valued.

### **References**

- Bell, P., Van Horne, K., & Cheng, B. H. (Eds.). (2017). Designing learning environments for equitable disciplinary identification [Special issue]. *Journal of the Learning Sciences*, 26(3).
- Calabrese Barton, A., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences*, 19(2), 187-229.
- Freire, P. (1972). *Pedagogy of the oppressed* (M. B. Ramos, Trans.). New York, NY: Herder & Herder.
- Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational psychology review*, 16(3), 235-266.
- Kolikant, Y. B. D., & Pollack, S. (2015). The dynamics of non-convergent learning with a conflicting other: internally persuasive discourse as a framework for articulating successful collaborative learning. *Cognition and Instruction*, 33(4), 322-356.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc..
- Politics of Learning Writing Collective (2017). The learning sciences in a new era of US nationalism. *Cognition & Instruction* 35(2), 91-102.
- Rau, M. A., Bowman, H. E., & Moore, J. W. (2017). An adaptive collaboration script for learning with multiple visual representations in chemistry. *Computers & Education*, 109, 38-55.
- Rummel, N., Walker, E., & Alevan, V. (2016). Different futures of adaptive collaborative learning support. *International Journal of Artificial Intelligence in Education*, 26(2), 784-795.
- Slotta, J.D., Quintana, R.M., & Moher, T. (2018). Collective inquiry in communities of learners. In F. Fischer, C. Hmelo-Silver, S. Goldman, & P. Reimann (Eds.). *International Handbook of the Learning Sciences*. New York. Routledge.
- UNESCO (2014). Global citizenship education: Preparing learners for the challenges of the twenty-first century. Paris: Unesco. Retrieved from <http://unesdoc.unesco.org/images/0022/002277/227729E.pdf>.
- Vossoughi, S. & Gutiérrez, K.D. (2017). Critical pedagogy and sociocultural theories. In I. Esmonde & A. N. Booker (Eds.). *Power and privilege in the learning sciences: Critical and sociocultural theories of learning*. New York, NY: Routledge.
- Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 423-467.

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# Conceptualizations of Learning in ijCSCL

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**Abstract:** This paper presents an analysis of conceptualizations of learning in International Journal of Computer-Supported Collaborative Learning articles from a 5-year period and a comparison data set of articles in the same period from the Journal of Educational Psychology. Findings are interpreted through the lens of critical pedagogy. Findings reveal a conceptualization of learning in the educational psychology articles that is problematic in terms of supporting and reproducing systems of oppression but learning scientists who study computer-supported collaborative learning tend to use a conceptualization of learning that is agentic, empowering, and aligned with critical pedagogy.

## Conceptual metaphors and conceptualizations of learning

This study used conceptual metaphor theory and critical theory lenses to understand conceptualizations of learning among computer-supported collaborative learning researchers. Conceptual metaphor theory suggests that the metaphors of learning we use dictate our practices in teaching and learning and influence what we value (Deignan, 2010; Lakoff & Johnson, 1999). Conceptualizations of learning are grounded in conceptual metaphors and related worldviews and paradigms (Gibbs, 2014). Critical theorists have argued that the dominant positivist *transfer/acquisition/banking* conceptualization of learning must be rejected and have characterized critical pedagogy through the *construction* conceptualization of learning (Apple, 2014; Freire, 1970; Giroux, 2013; Kincheloe, 2007). The construction conceptualization of learning has been used by educational researchers for over a century (see Dewey, 1897).

## Methods

Conceptual metaphor analysis (Deignan, 2010) was used to characterize conceptualizations of learning, and axial coding (Corbin & Strauss, 2015) to analyze alignments between conceptual metaphors, practices, and worldviews. Conceptual metaphors are characterized by analyzing clusters of surface metaphors people use when discussing a particular concept (Gibbs, 2014). Seventy-eight articles in the International Journal of Computer-Supported Collaborative Learning (ijCSCL) and a comparison set of 211 articles in the Journal of Educational Psychology (JEP) from 2013 to 2017 were analyzed. Analysis of co-occurrence patterns was used to describe underlying conceptual metaphors. Co-occurrence patterns between conceptual metaphors of learning, practices, and worldviews were analyzed. Findings were then analyzed through critical metaphor analysis to identify and characterize conceptual metaphors and patterns in worldviews, paradigms, and practices through which systems of power are enacted and reproduced (Charteris-Black, 2004).

## Findings

Seventy-eight percent of articles in JEP used the *transfer/acquisition* conceptualization of learning, and only 6.6% used the *construction* conceptualization. In contrast, 22.3% of articles in ijCSCL used the *transfer/acquisition* conceptualization, and 53.6% the *construction* conceptualization (Fig. 1).

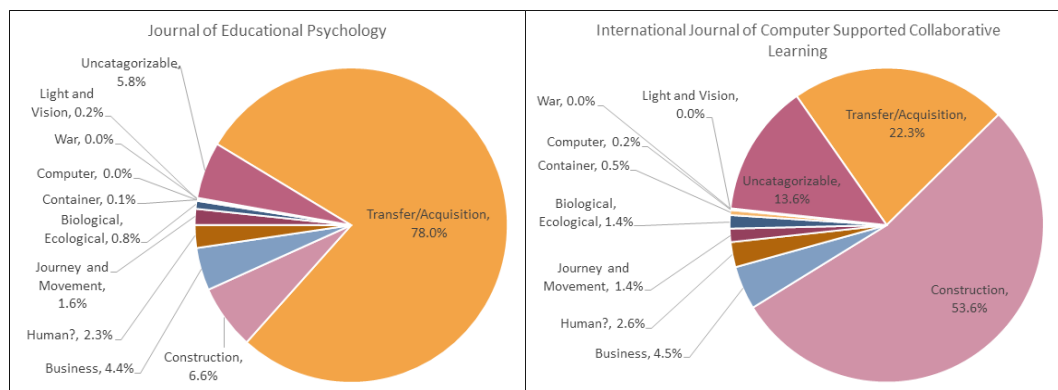


Figure 1. Conceptual metaphors in JEP and ijCSCL.

In JEP 37.1% assumed that learning is quantifiable, and 36.6% that test scores measure learning. None used situative or sociocultural perspectives. On the other hand, in ijCSCL 11.6% assumed that learning is quantifiable, and 10.5% that test scores measure learning. Over half (51.2%) used situative or sociocultural perspectives. Practices endorsed by JEP researchers included textbooks (14.8%), learning standards (13.3%), lectures (11.9%), workbooks (5.9%), and grades (5.2%). Practices endorsed by ijCSCL researchers included collaboration (22.3%), discussion (12.2%), reflection (12.2%), and identity development (4.3%). Across the entire data set (both JEP and ijCSCL) there were strong relationships between the *transfer/acquisition* conceptualization, a set of practices (testing, lecturing, textbooks), and a belief that the purpose of education is for career/workforce demand. There was a strong relationship between the *construction* conceptualization, a set of practices (discussion, projects, community, agency), and beliefs that the purpose of education is for social change, social justice, empowerment, or community engagement.

Critical theorists have asserted that the *transfer/acquisition* conceptualization of learning is dominant in society, and sees learning as the transfer of pieces of knowledge from teachers and books into the minds of learners who are then expected to be able to transfer the acquired knowledge to new contexts (Kincheloe, 2007). Hager and Hodkinson (2009) argued that although this is the dominant metaphor in society today, it is rarely recognized as such. The findings of this study suggested that this *transfer/acquisition* conceptual metaphor of learning is prominent among educational psychologists, and consists of a constellation of interrelated surface metaphors for knowledge, mind, learning, and education. These surface metaphors provide the structure for the underlying conceptual metaphor, which is then framed, reinforced, and filtered through particular worldviews and paradigms. CSCL researchers tend to have conceptualizations of learning grounded in a *construction* conceptual metaphor: meaning is individually, collaboratively, and collectively constructed.

## Significance

Despite the long history of the *construction* conceptualization among educational researchers, the findings in this study indicate that within the domain of educational psychology the positivist *transfer/acquisition* conceptualization of learning remains dominant, and *construction* conceptualizations compatible with social justice, critical pedagogy, and empowerment work remain marginalized. On the other hand, among learning scientists who work with computer-supported collaborative learning the *construction* conceptualization of learning is dominant, but the *transfer/acquisition* conceptualization continues to be used and reproduced. This research provides strong empirical evidence supporting arguments by critical theorists suggesting that efforts toward changing conceptualizations of learning is not only crucial in our work in informal and formal learning contexts, but also in our work with students in learning sciences programs and in our work with fellow researchers. This conceptual change work for critical pedagogy will involve critical reflection and action regarding the metaphors we use, as well as practices in our designs for learning. Furthermore, this study suggests that the critical work of problematizing and changing worldviews and values may require problematization and perhaps even rejection of metaphors of learning, knowledge, mind, and education that perpetuate and reproduce oppressive conceptualizations of learning.

## References

- Apple, M. W. (2014). *Official knowledge: Democratic education in a conservative age*. NY: Routledge.
- Charteris-Black, J. (2004). *Corpus approaches to critical metaphor analysis*. New York: Palgrave Macmillan.
- Corbin, J. M., & Strauss, A. L. (2015). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (4th ed.). Los Angeles: SAGE.
- Deignan, A. (2010). The cognitive view of metaphor: Conceptual metaphor theory. In R. Maslen & L. Cameron (Eds.), *Metaphor analysis: Research practice in applied linguistics, social sciences and the humanities* (pp. 44-56). London: Equinox Publishing.
- Freire, P. (1970). *Pedagogy of the oppressed*. New York: Continuum.
- Gibbs, R. W., Jr. (2014). Conceptual metaphor in thought and social action. In M. Landau, M. D. Robinson, B. P. Meier, M. Landau, M. D. Robinson, & B. P. Meier (Eds.), *The power of metaphor: Examining its influence on social life*. (pp. 17-40). DC: American Psychological Association.
- Giroux, H. A. (2013). *On critical pedagogy*. New York: Bloomsbury Academic & Professional.
- Hager, P., & Hodkinson, P. (2009). Moving beyond the metaphor of transfer of learning. *British Educational Research Journal*, 35(4), 619-638. doi:10.1080/01411920802642371
- Kincheloe, J. L. (2007). Critical pedagogy in the twenty-first century. In P. McLaren & J. L. Kincheloe (Eds.), *Critical Pedagogy: Where Are We Now?* (pp. 9-42). New York: Peter Lang Publishing, Inc.
- Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to Western thought*. NY: Basic Books.

# The Role of Asynchronous Digital Feedback in Youth Maker Projects

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**Abstract:** The aim of this work is to make engagement with ideation, iteration, and critique more accessible to learners and to understand the value of these art-making practices for learning (Clapp et al., 2016). While these terms may be unique to arts disciplines, giving and getting feedback are core tasks across almost any discipline. Here we are referring to formative feedback, dialogic interactions either among that focus on the whole process of creation (Bangert, 2004). In this paper, we share results from a design experiment that included the introduction of asynchronous, digital feedback into a making process. This making process, a six-week project with a group of fifth graders is described in other work (Litts & Halverson, in press). Here, we ask the following research questions: What is the role of asynchronous, digital feedback in young people’s maker projects? Specifically, what kind of feedback is offered and how does this feedback influence subsequent project iterations?

## Build in Progress: The goldilocks model of e-learning platforms

We partnered with three different platform designers over the course of a two-year period to find a tool that was both non-disruptive to the making process and amenable to a range of makerspace contexts. We termed our selection process the “Goldilocks” model: the first tool afforded deep engagement between makers around iteration and critique but was far too constrained to support the learning arrangements. The second tool was very easy to use and could be dropped in to a range of settings but did not offer enough scaffolding to encourage younger makers to engage in productive critique and iteration. The third tool, Build in Progress, an online, open-source project sharing and development tool which includes over 2,000 shared projects became the platform of choice for a range of design experiments. Build in Progress was “just right”; it proved easy to use, scaffolded to encourage iteration and critique, and seemed to not disrupt the making process.

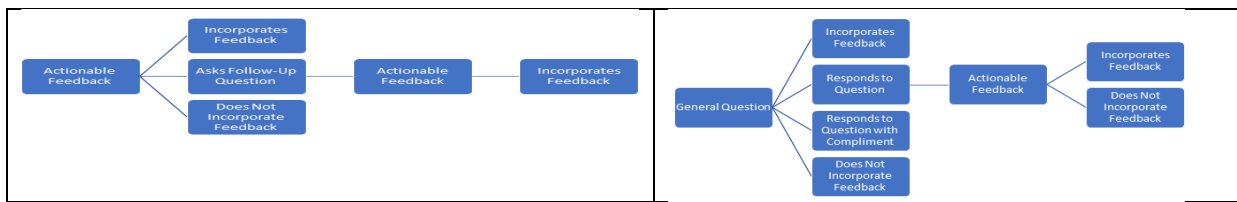
Our work with Build in Progress involved a six-week design experiment; a maker experience that stretched across school and museum spaces. Three sessions were in the students’ classroom and the other three were in the makerspace of the nearby children’s museum. All sessions were facilitated by the museum’s lead teaching artist, assisted by museum staff and researchers. At the end of the project, 11 teams of two and three presented two-minute puppet shows that were recorded and shared at the museum space for younger students. Build in Progress was used to document weekly progress, get feedback from researchers on the work, and to share ideas with one another. Each week, students documented their work by taking photos and writing reflections in Build in Progress where they could get feedback from their peers and from adult maker mentors, who were researchers working on the project with expertise in making. Our data analysis focused on the information entered in the Build in Progress application by the student participants and their maker mentors.

## How mentors give feedback

At the beginning of the project the maker mentors were given specific guidelines for how to give students feedback based on the Harvard based Project Zero “Visible Thinking” core thinking routine of “I see... I think...I wonder”. We placed mentor feedback into one of three categories: actionable feedback, compliments, and general questions. Actionable feedback was designated as specific actions that students could incorporate into their puppet. For example, one maker mentor suggested, “Have you thought about adding more fabric to conceal the battery pack?” Another type of feedback was general questions. These were less specific such as a mentor who asked, “I wonder what type of personality your puppet has?” While these general questions offered things for students to consider they did not offer a specific course of action to take next. Finally, mentors may have offered compliments to students such as “great idea” or “I am so impressed...”.

## How learners engage with the feedback

After considering how mentors offer feedback and separating it into three distinct categories, we then analyzed how students engaged with the mentor feedback through the Build in Progress app. Students primarily responded to the actionable feedback (Figure 1) and general questions (Figure 2) within a common framework.



**Figure 1.** Student engagement paths with asynchronous digital actionable feedback.

**Figure 2.** Student engagement paths with asynchronous digital general questions feedback.

**Table 1:** Student overall engagement with the asynchronous digital feedback while working individually

	Actionable Feedback	General Question	Compliments
Total Given	25	23	2
Total Incorporated	13	5	N/A

**Table 2:** Student engagement with the asynchronous digital feedback while working collaboratively

	Actionable Feedback	General Questions	Compliments
Total Given	5	1	5
Total Incorporated	4	1	N/A

## Discussion

Our data indicate that when students are given actionable, specific feedback they tend to incorporate it into their projects. Interestingly, the critique and iteration cycle is not as linear as we might typically see in a formal classroom setting; students’ incorporation of feedback often happened weeks after the feedback was first offered. Additionally, students seem to incorporate feedback at a higher rate when they work collaboratively. Students who did not incorporate feedback while working individually were more likely to incorporate it when working in a group, indicating that there is something about working with others that promotes engaging with feedback. We also find that the student engagement paths mirror the features of peer feedback and the indicators of whether this feedback was taken up as described in Nelson & Schunn (2009). What we termed “actionable feedback” shared many of their cognitive features, notably feedback specificity. Feedback seems to be most useful when it refers to a particular design feature or artistic decision. General questions seemed less useful, especially when those general questions did not ask students to reflect on how an audience or user might interact with their design. “Compliments” looked a lot like the affective feedback Nelson and Schunn described. And while it may be true that the students in our study agreed with these compliments, their presence did not encourage students to make changes to their work.

## References

Bangert, A. W. (2004). The seven principles of good practice: A framework for evaluating online teaching. *Internet and Higher Education*, 7(3), 217–232.

Clapp, E. P., et al. (2016). *Maker-centered learning: Empowering young people to shape their worlds*. John Wiley & Sons.

Litts, B. & Halverson, E. R. (in press). Taking up multiliteracies in a constructionist design context. In N. Holbert, M. Berland, & Y. Kafai (Eds.), *Constructionism in context*. Cambridge, MA: MIT Press.

Nelson, M. M., & Schunn, C. D. (2009). The nature of feedback: How different types of peer feedback affect writing performance. *Instructional Science*, 37(4), 375–401.

# Using Collaborative Agent-based Modeling to Explore Complex Phenomena with Elementary Preservice Science Teachers

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**Abstract:** This poster investigates preservice teachers' abilities to use, evaluate, and revise participatory agent-based models deployed with the Group-based Cloud Computing (GbCC) platform. This poster discusses two cases within a larger design-based implementation research study with preservice elementary science teachers. By implementing models with preservice teachers, we hope to (a) make adjustments to the GbCC learning technologies, and (b) develop more informed and aligned pedagogies for teaching in socially-mediated and generative learning environments.

## Introduction

For classrooms to engage in more socially mediated and generative teaching and learning, instructors must design situations for students to construct relations between prior knowledge, experience, and new information (Wittrock, 1991). Using, building, evaluating, and revising agent-based models are critical to the practice of science (Petrosino, 2003; Schwarz et al., 2009); however preservice teachers require support before feeling confident in implementing modeling lessons in the classroom (Valanides & Angeli, 2006). To address this, agent-based models, such as *NetLogo* (Wilensky, 1999), engage users in manipulating variables and recompiling code as they run simulations using multiple agents, extending our ability to understand emergent phenomenon. Furthermore, engaging in models in classrooms can typically be done independently, which doesn't leverage the group-nature of classrooms.

Group-based Cloud Computing (GbCC) is a web-deployed, agent-based modeling program, powered by NetLogo Web, that allows learners to collaborate, reprogram, and share models (Petrosino & Stroup, 2017). In line with the focus of this conference, GbCC models provide opportunities for *extending* and *embedding* learning about complex phenomenon. This study discusses two cycles of research using GbCC models with preservice teachers to explore ecosystem change and disease transmission. The GbCC platform is a powerful computational tool; however, "powerful technological tools, in the absence of powerful pedagogy, detract from rather than contribute to learning" (Philip & Garcia, 2013, p. 313). With this insight in mind, the goal of this poster proposal is to:

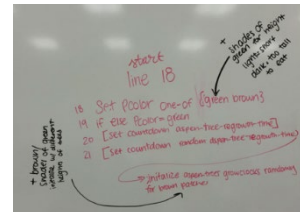
- 1) discuss two efforts to engage preservice teachers in higher-order modeling uses (evaluating and revising); and
- 2) determine supports for engaging teachers in developing knowledge and practices of using models in instruction.

## Methods

This research is part of a larger design-based implementation research study (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013). This poster summarizes two sequential case studies which seek to explore how preservice teachers engage with and attempt to evaluate and revise computational models about collaborative models. Each case study occurred in an elementary science methods course in a teacher preparation program. Both case studies involved two 3-hour lessons with between 20 and 30 students enrolled in the course. Both cases used a modeling framework to engage teachers with the simulations; which includes: (a) exploring models; (b) planning and revising models based on a task; and (c) discussing affordances and limitations for teaching. Classroom artifacts were collected after teachers evaluated and attempted to revise the models (photographs of student work, pictures of white board plans, and notes). Pre- and post-questionnaires were delivered, collected, and open-coded in both case studies to investigate: (a) conceptions of models and simulations in case one; and (b) beliefs about the necessity of vaccination in case two.

## Cycle 1: Ecological modeling

Our first modeling lesson engaged 24 preservice teachers in using GbCC models to learn about tritrophic cascades in Yellowstone. Using a modified NetLogo Wolf Sheep Predation model (Wilensky, 1999), participants were encouraged to explore the model, evaluate the model for affordances and limitations, and attempt to modify the model. Findings from this cycle of research showed that preservice teachers were hesitant to make programming



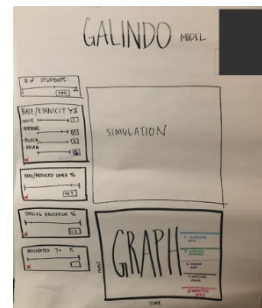
**Figure 1.** Example of attempted code



modifications using the GbCC recompile and share features; however, they demonstrated significant efforts to show what their model *would* look like, and even engaged in pseudo-coding and some coding (Figure 1) to plan *how* the model might function. Pre- and post-questionnaires asked participants to reflect on the nature of models and simulations as well as their functions for science and science education. Results showed that students tended to view models as only static and simulations as dynamic; and attributed most functions to simulations rather than their idea of models.

Table 1: Frequency of codes related to theme 3 - functions of models and simulations

Function (model)	Pre	Post	Change	Function (simulation)	Pre	Post	Change
Dynamic	0	0	0	Dynamic	5	8	3
Interactive	0	0	0	Interactive	7	9	2
Observe	0	0	0	Observe	2	0	-2
Static	1	2	1	Static	0	0	0



These findings illuminate the need to: (a) provide more supports for ways to re-program the models; and (b) provide more time to engage in drawing and pseudo-coding before engaging in actual reprogramming of the models.

Figure 2. Example of participant model

## Cycle 2: Disease transmission modeling

In the Fall of 2018, 44 preservice teachers engaged in a series of GbCC modeling experiences related to vaccination and disease transfer in populations. Similar to case one, participants were asked to modify the model to think about a new scenario where the model would represent schools with varying socioeconomic conditions and vaccination rates. Learning from the first case, the researchers provided participants with more time to visually plan their model modifications before attempting to pseudo-code or code to make changes. All participants were able to generate complex *visual* models which incorporated many social variables to predict vaccination rates for differing schools. Planned models were all visual, and the researchers ran out of time before encouraging participants to make programming changes to the models. Models tended to either show three screens to represent three differing schools or were more sophisticated and planned models which could *predict* the rate of vaccination based on socioeconomic status (Figure 2).

## Implications of the work

These data as well as other information not included in this poster abstract support that preservice teachers are able to engage with and evaluate models which represent complex phenomena which are socially and ecological relevant. Future cases and design work will provide more time to move from visual modifications to computational changes as well as supporting preservice teachers in planning with collaborative agent-based models.

## References

- Fishman, B. J., Penuel, W. R., Allen, A.-R., Cheng, B. H., & Sabelli, N. (2013). Design-Based Implementation Research: An Emerging Model for Transforming the Relationship of Research and Practice. *Yearbook of the National Society for the Study of Education*, 112(2), 136–156.
- Petrosino, A. (2003). Commentary: A framework for supporting learning and teaching about mathematical and scientific models. *Contemporary Issues in Technology and Teacher Education*, 3(3).
- Petrosino, A. J. & Stroup, W. M. (2017, June). Group-based cloud computing for STEM education. Paper at the annual convention of the American Society of Engineering Education, Columbus, OH.
- Philip, T., & Garcia, A. (2013). The importance of still teaching the iGeneration: New technologies and the centrality of pedagogy. *Harvard Educational Review*, 83(2), 300-319.
- Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., ... Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, 46(6), 632–654. doi:10.1002/tea.20311
- Valanides, N., & Angeli, C. (2006). Preparing preservice elementary teachers to teach science through computer models. *Contemporary Issues in Technology and Teacher Education*, 6(1), 87-98.
- Wilensky, U. (1997). NetLogo Wolf Sheep Predation model. *Center for Connected Learning and Computer-Based Modeling*. Retrieved from <http://ccl.northwestern.edu/netlogo/models/WolfSheepPredation>
- Wilensky, U. (1999). NetLogo. Northwestern University, Evanston, IL: Center for Connected Learning and Computer-Based Modeling. <http://ccl.northwestern.edu/netlogo>.
- Witrock, M. C. (1991). Generative teaching of comprehension. *The Elementary School Journal*, 92, 169-184.



# Robots to Help Us Feel Safe: A Problem-Based CSCL Experience

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**Abstract:** This case study works to understand the trajectory and success of one computer-supported collaborative learning (CSCL) experience highlighted as transformational by the instructor who taught it. Reflective co-design sessions held between researcher and instructor, which featured shared viewing of video data collected throughout this CSCL experience, is analyzed in order to unpack this implementation and how it might inform the design of other CSCL experiences that address locally relevant problems.

**Keywords:** Problem-based learning, case study, engineering design, robotics

## Introduction

Opportunities to grapple with current events and to learn through the negotiation of real human problems are essential as we work to give voice to citizens of the world (Gutierrez, 2008). The case study presented here is motivated by the need to empower teachers and learners to address the events and problems that they perceive as relevant in their classrooms. Students engaged deeply in a problem-based CSCL environment as they identified a local need and designed, built, and programmed a robot to address it. This environment supported the development of user-centered design practices as students considered the social worlds around them and how to meaningfully design technologies for these spaces. The design task provided a CSCL context for students to negotiate shared goals and understanding (Suthers, 2006). This study examines what made this particular experience meaningful for students and the instructor and how this understanding can be used to inform broader CSCL design.

Problem-based learning (PBL), a student-centered instructional approach to collaborative learning that presents students with an ill-structured and authentic problem, provides a promising starting point in the effort to empower student voices (Savery, 2006). Well-designed PBL experiences provide a context for students to use their voices to create change in their local communities (e.g., Svihla & Reeve, 2016). This case study explores the emergence of a socially relevant problem in a PBL afterschool robotics experience. Over the course of ten weekly sessions, students grappled with the problem statement “design a robot that can serve a need in your local community.” The wider school community was concerned about student safety, a concern exacerbated by the increasing frequency of shootings in US schools. Following the shared experience of a “lockdown” procedure where students and staff are required to huddle in the back of their classrooms with doors locked, students designed a robot to help the school community to feel safer during these procedures.

## Method

Nine students ages 12-14 participated in this afterschool robotics curriculum in the rural Midwestern United States. This group included three female students and seven male students. All students were white. We identified critical events within the afterschool robotics unit to unpack this particular PBL experience. Interaction analysis (Jordan & Henderson, 1995) was used to zoom in on the interactional accomplishments that constructed this case. We asked: 1) What student actions and key facilitation moments are identified by the instructor as transformative within reflective co-design? 2) How did students take up the problem statement? 3) How can the trajectory of this unit inform the design of future PBL units that empower students to create change?

Data sources included video data collected for each afterschool session as well as video data collected during four debrief and co-design sessions held with the first author and instructor. These sessions were used to inform the design of the next iteration of the robotics unit. Joint video analysis of scenes from the afterschool club supported the effort to create, deepen, and sustain a locally meaningful experience for students. Co-design video was analyzed in order to better understand where the instructor highlighted critical events and how these events were taken up by students. Data sessions were held with research team members to identify critical events across the data set. Extracts will be presented in this poster highlighting key themes in facilitation and student uptake of the design problem.

## Results

The instructor of the afterschool club pinpointed this experience as the “realist PBL unit” she had ever facilitated. Preliminary analysis indicates several aspects of facilitation and student activity that made this robotics experience meaningful for students and instructor. The instructor highlighted students’ shared experience of a lockdown procedure (and her move as a facilitator to foreground this experience) as important in the trajectory of the

students' motivation to solve a local problem through the design of a hallway patrol robot. Time spent brainstorming, as well as probing questions provided throughout the brainstorming process, were also identified as supportive of students' engagement. For example, the extract featured below was highlighted by the instructor as a turning point in students' brainstormed design ideas. Here, students were able to articulate a design solution connected to the shared experience of a lockdown procedure:

Instructor: We don't know what's going on outside of our classrooms. We're just in here waiting to see when it's going to be over...So is there something that robots could do to help us know...what more is going on when we can't look out our windows?

Brandon: ...Maybe the robot could be outside with cameras and like the teachers can see on a tablet...what's going on using those cameras.

This initial brainstorm triggered a flurry of ideas related to a robot that could provide a live video feed of the hallways and make the school safer during lockdowns. The instructor was inspired to share student ideas with the school principal, office staff, and safety committee members. This discussion led to the organization of a feedback session where students presented initial design ideas and a user testing session where prototypes were tested by these stakeholders. Feedback sessions were recorded, and students had the opportunity to reflect on their presentations as they moved forward. Beyond the success of prompting related to shared experiences (seen in the extract above), the instructor found that students made great progress with their design ideas when they were given these chances to interact with local stakeholders and present their working ideas.

## Discussion and conclusions

The robot design challenge presented here provided an authentic context for students to collaborate around a problem that was personally meaningful and socially relevant. It was empowering for both students and teacher—as seen in a culminating design showcase held with community members, presentations given by participating students at a local schoolboard meeting, and ongoing co-design reflections with the instructor. In understanding this particular case, identified for its poignant social relevance, we understand how to better design future curricula that amplify student and teacher voices and create change. CSCL experiences hold great potential as contexts that can support learners as they communicate, co-construct, and shape their collaborative learning. Technology can provide some of this support, but the design of CSCL experiences must also consider facilitation and the structure of learning environments (Jeong & Hmelo-Silver, 2016). Across this curriculum trajectory, key moments of inspiring student engagement, identified within the work of co-design, were used to inform the design of future CSCL experiences. For example, design principles informed by this analysis include 1) situating problem statements within local contexts, 2) providing ample space and time for brainstorming, 3) modeling how to address unexpected challenges, and 4) providing opportunities for students to reflect on their ongoing work using video. These design insights not only informed the development of a next iteration of this particular robotics curriculum, but they might also be taken up in a wide variety of CSCL contexts.

## References

- Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly, 43*(2), 148-164.
- Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help?. *Educational Psychologist, 51*(2), 247-265.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences, 4*(1), 39-103.
- Savery, J.R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning, 1*(1), 9-20.
- Suthers, D. D. (2006). Technology affordances for intersubjective meaning making. *International Journal of Computer Supported Collaborative Learning, 1*, 315-337.
- Svihla, V., & Reeve, R. (2016). Facilitating problem framing in project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 10*(2), 10.

# An Exploration of Female Engagement and Collaboration: The Bricks and Bits Maker Project

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**Abstract:** This poster explores how learners engage in “maker” activities when collaborating and how participation can become more inclusive when framing activities in order to connect learners with children in their own community. We describe the first iteration of the Bricks and Bits project where undergraduate engineering students were challenged to re-design the toys of children. Bricks and Bits specifically reimagines making as a service learning project in order to increase the inclusion of female participants.

## Introduction

The institutionalization of makerspaces in schools and universities can be seen as a positive step towards the democratization of the maker movement. However, it can also have a detrimental effect on some of the most distinctive features of the movement such as spontaneity, creativity or innovation (Dougherty, 2012). Practitioners need to transform their discourses to involve those people who have traditionally been left out of these activities. The underrepresentation of women, for example, is a typical characteristic of the maker movement and many STEM careers caused by the lack of more adequate programs to cater for the interests of non-traditional maker groups (Davies, 2018).

Increasing the number of women involved in STEM domains can boost the quality of research as diversity enables more creative work while reducing bias (Marginson et al., 2013). However, enrolling a large number of women is not enough to assure their full inclusion in a project. Effective learning design of makers projects must include a more specific framework to favor the exchange of ideas among participants and enhance their collaboration during the design process.

An equity-oriented mindset characterized by shared activity, creativity and imagination, and the acknowledgement of a wider definition of learning, intelligence and science can contribute to a broader participation of underrepresented communities in STEM domains (Vossoughi et al. 2013). There have been different approaches to address the exclusion of women and other underrepresented groups in the maker movement by engaging them in gender-specific groups or implementing new fabrication tools (e.g. Kafai, Fields, & Searle, 2014). In this study, we conceive making as a purposeful activity, in which people can face meaningful challenges and raise awareness of their potential to respond to the needs of society (Unterfrauner & Voigt, 2017). By framing maker activities as activities that can connect participants with their communities and its circumstances, the participation of women can be broadened (Holbert, 2016).

## Current project

The maker project presented in this paper, Bricks and Bits, follows a project-based service learning (PBSL) approach to learning as it attempts to align the purpose of the project (engage learners in an inclusive environment to construct objects) with the development of a fruitful relationship with the wider community. Bricks and Bits engages participants to re-design a toy for children aged 6-7 based on the characteristics of the toy and the outcomes of an initial interview following a design thinking methodology (Brown and Katz, 2009). This transforms a typical tinkering project, such as building a toy, into a project in which all participants must consider the needs and values of a child, the constraints of the toy that is provided, and find balance between the child's expectations and the students' limitations and possibilities.

In this poster, we explore how female makers in activities framed to connect with the learners' community make positive contributions during the initial phases of the design process but take a more secondary role when dealing with primary features of the design process. Our analysis suggests that there was a significant enrollment of women whose participation influenced positive collaboration for all participants. We also suggest that women in this study tended to be excluded from decisions regarding primary features of the final design.

## Initial findings and discussion

Of the 35 students who participated in Bricks and Bits, 63% (22 out of 35) were male, and 37.1% (13 out of 35) were female. While the numbers are still not balanced, the participation of women is still higher than in

Engineering programs in Uruguay where women constituted only a 26.2% of students in 2017. This difference is even more dramatic when compared to the regional stats of this university where female participation in engineering programs is 6.25% (Ministerio de Educación y Cultura, 2017). This increase in female participation can be connected with the nature of the project, which rather than promoting the program as a space for tinkering and experimentation with robots or microcontrollers, was introduced as a Toy Factory for children in the community.

Despite the positive outcomes in terms of female students' own perception of their participation, it is evident that within this design process, female participants had few opportunities to contribute in the most distinctive features of the design. The analysis of the interactions shows that as each team progressed from the planning phase towards the prototyping and testing phase, the interactions of women decreased significantly.

It can be argued that the fact that female participants had less experience with fabrication tools could have hindered their participation. We believe, however, that a better design of the initial interview and the actions to be carried out immediately after, could prevent participants from jumping into conclusions too early in the process providing those with less experience in fabrication with more time to develop their own ideas.

Despite these challenges, women who took control of the aesthetic features of the toys, such as painting, decorating, sewing, or printing accessories with a 3D printer, felt they had made a positive impact on the final product taking their share of ownership of the final design. Another positive outcome of this design process is that 100% of the women (13 out of 13) claimed they would participate again in the project and that they would also like to be trained in the use of fabrication tools, more specifically 3D printing and e-textiles. Considering that the majority of the female participants did not mention "making" as a reason to join this program, this new interest in fabrication can turn into a positive entry point to engage female participants in maker projects. Female participants also showed great ability to work with people from different teams and benefit from their talents. This collaborative attitude among teams was mostly fostered by female participants and ended up making the whole design experience a more enjoyable one for all participants.

We offer the first iteration the Bricks and Bits project as an initial exploration for framing making activities as service learning projects in order to increase the inclusion of female participants. The high number of female participants who spontaneously signed up for this program encourage us to continue looking for evidence of the impact this framing can have on other similar contexts.

## References

- Brown, T., & Katz, B. (2009). *Change by design: How design thinking transforms organizations and inspires innovation*. New York: HarperCollins
- Davies, S. R. (2018). Characterizing hacking: Mundane engagement in US hacker and makerspaces. *Science, Technology, & Human Values*, 43(2), 171-197.
- Dougherty, D. (2012). The maker movement. *Innovations: Technology, Governance, Globalization*, 7(3), 11-14
- Holbert, N. (2016). Leveraging cultural values and "ways of knowing" to increase diversity in maker activities. *International journal of child-computer interaction*, 9, 33-39.
- Kafai, Y., Fields, D., & Searle, K. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review*, 84(4), 532-556.
- Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). STEM: country comparisons: international comparisons of science, technology, engineering and mathematics (STEM) education. Final report.
- Ministerio de Educación y Cultura (2017). *Anuario Estadístico de Educación*. [Statistic Annual Report of Education – Ministry of Education and Culture].
- Unterfrauner, E., & Voigt, C. (2017). Makers' ambitions to do socially valuable things. *The Design Journal*, 20(sup1), S3317-S3325.
- Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013). Tinkering, learning & equity in the after-school setting. In *annual FabLearn conference*. Palo Alto, CA: Stanford University.

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# The Development and Application of a Social Reading Platform and the Double-level Scaffolding

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**Abstract:** Social reading is a new mode of reading which facilitates students’ reading and interaction, encourage expressions of multiple ideas and promote collaborative inquiry. In this poster presentation, we describe our designs of a double-level scaffolding and a social reading platform. We then present findings of a preliminary experiment conducted to a group of students from a university reading workshop to examine the functionality of the scaffolding and the platform. The results indicate that the participants demonstrated an active utilization of the scaffolding and a relatively high level of acceptance of the platform.

## Introduction

From a sociocultural perspective, reading is a complex process of development that entails a transaction between readers and texts, and the meaning of texts and discourses are varied by different communities (Rosenblatt, 1978). One of the central tasks of reading instruction is to guide students to make sense of printed words and promote their knowledge building process (Hamilton & Paris, 2014). Pedagogical scaffolding can help reduce learners’ cognitive loads (Hmelo-Silver, et al., 2007), structure complex tasks (Reiser, 2004), and improve reading comprehension (Fisher & Frey, 2012). When learning tasks reach to a high level of complexity, students may need the aid of different types of scaffolds to support the process of reading and learning.

## Scaffolding and platform design

### The double-level scaffolding

According to Tabak’s (2003) distributed scaffolding patterns, we design a synergistic double-level scaffolding. One level of the scaffolding is called “Reading Discussion”, another is called “Knowledge Building”. “Reading Discussion” scaffolding is built on Taboada and Guthrie’s (2004) cognitive strategies for reading comprehension and Toulmin’s model of argument (Voss, 2006). It contains six elements: *problem inquiry, material support, opinion expression, opinion elaboration, view challenge, and summary making*. “Knowledge Building” scaffolding consists of six scaffolds from the Knowledge Forum (Scardamalia, 2002): *my theory, I need to understand, new information, this theory cannot explain, a better theory, and putting our knowledge together* (Figure 1). The arrangement of two scaffoldings can be adjustable to specific instructional demands and scenarios.

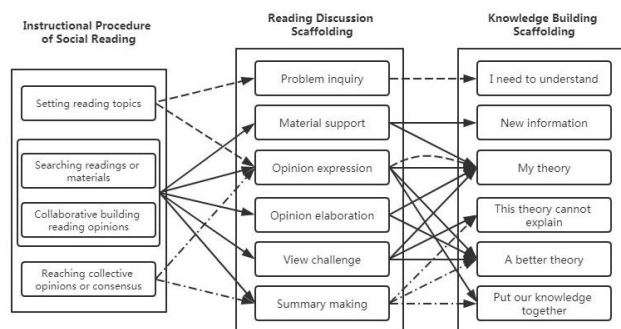


Figure 1. The double-level scaffolding for social reading.



Figure 2. Interface of the social reading platform.

### The social reading platform

Figure 2 shows a sample interface of the social reading platform. The platform has the following characteristics: (1) The setting of two different reading space: “Individual Reading Space” and “Group Reading Space”. The former space is designed for individual users to set reading plans, record reading progress, write reading notes and reflections and organize related materials. In the latter space, users can manage group readings, interact and discuss with others, and present information in groups. (2) The function of platform management: Users can make personalized settings, such as add and revise personal information, check reading status and select reading groups. (3) The integration of visualization tools in the platform: Adoption of the concept maps and chromatic nodes and

lines make it easy to clarify the logic and the connections among views and posts. (4) The customization of scaffolding: Instructors can choose to manage the scaffolding in various forms and provide to students according to different instructional or research requirements and contexts.

## Scaffolding and platform application

To examine the functionality of the scaffolding and the platform, sixteen students between the ages of 18 and 33 years old from a university reading workshop were invited for the preliminary application. They were reading a section of a book named *Homo Deus: A Brief History of Tomorrow* by Yuval Noah Harari (Harari, 2016) then. The participants launched a one-week online discussion activity on this book section in the social reading platform. They were suggested to post threads to raise questions, express opinions, add comments to other's posts and share related materials in the topic discussion module in the "Group Reading Space". For the arrangement of the double-level scaffolding, the "Reading Discussion" was designed as the first level and "Knowledge Building" as the second level. We investigated participants' engagement in the discussion activity and their usage of the double-level scaffolding. A total number of 105 posts were collected which covered five main topics related to the book section. We also conducted a brief survey to the participants to know their acceptance of the platform.

## Results

The experiment has three main findings: (1) The participants demonstrated an active discussion engagement (each participant posted 6.56 posts on average) and a relatively high level of collaborative learning and interaction (90% of the posts were add-on comments) during the social reading activity. (2) For the usage of the scaffolding, the most frequently-used scaffolds of the "Reading Discussion" scaffolding and the "Knowledge Building" scaffolding are *View Challenge* (26.42%) and *My Theory* (40.56%) respectively, which can indicate that participants generally had a good level of critical thinking skills and were willing to share personal thoughts and ideas on the reading material. (3) Most of the participants were satisfied with the platform designs and claimed its positive impacts on their reading and the interactions with others.

## Discussion

Although the complexity of the scaffolding and the designs of the platform need to be upgraded and improved, the experiment was not conducted in a standard reading classroom setting as well, this study has some pedagogical and academical implications: First, an online platform for social reading has been developed, which can be a functional tool for the development and organization of collaborative reading activities in either face-to-face and online reading courses. Second, this study proposes a synergistic double-level scaffolding with a firm theoretical footing. This scaffolding can meet the requirements of various types of reading instructions due to its flexibility and versatility. Third, this study provides a case of how scaffolding and online reading platform can be utilized to support collaborative reading inquiry and knowledge building among students.

## References

- Fisher, D., & Frey, N. (2012). Close reading in elementary school. *The Reading Teacher*, 66 (3), 179-188.
- Hamilton E. E. & Paris, S. G. (2014). The Development of Children's Reading Comprehension. In *Handbook of research on reading comprehension* (pp. 56-77). New York: Routledge.
- Harari, Y. N. (2016). *Homo Deus: A brief history of tomorrow*. London: Penguin.
- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark. *Educational psychologist*, 42(2), 99-107.
- Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning sciences*, 13(3), 273-304.
- Rosenblatt, L. M. (1978). *The reader, the text, the poem: The transactional theory of literary work*. Carbondale: Southern Illinois University Press.
- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. *Liberal education in a knowledge society*, 97, 67-98.
- Tabak, I. (2004). Synergy: a complement to emerging patterns of distributed scaffolding. *Journal of the Learning Sciences*, 13(3), 305-335.
- Taboada, A., & Guthrie, J. T. (2004). Growth of cognitive strategies for reading comprehension. In J. T. Guthrie, A. Wigfield, & K. C. Perencevich (Eds.), *Motivating reading comprehension: Concept-oriented reading instruction* (pp. 273-306). Mahwah, NJ: Erlbaum.
- Voss, J. F. (2006). Toulmin's model and the solving of ill-structured problems. In D. Hitchcock & B. Verheij (Eds.), *Arguing on the Toulmin model* (pp. 303-311). Berlin: Springer.

# Imagination in Adolescents' Collaborative Multimodal Science Fictions

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**Abstract:** Understanding how to cultivate students' imagination has been a challenge in STEM learning. We developed a program that engages adolescents in gaining STEM knowledge and digital literacies while collaboratively composing multimodal science fiction narratives. In this study, we identified instances in student products that signify imagination from a critical aspect: devising details. Through the examples described, an emergent framework for examining imagination is introduced as an outset for future work.

## Introduction

During the past decade, studies readdressing the importance of imagination in learning have increased considerably, partly because many of the complex problems in the 21<sup>st</sup> Century require unique and creative solutions (Glăveanu, Gillespie, & Valsiner, 2015). However, there has been little research on how imagination can be cultivated and evaluated in a multimodal learning environment. Emphasizing imagination, we have created an educational program to assist students in generating science fiction narratives. In this study, we analyzed student-generated artifacts in terms of imagination. The driving question of this study was: *How can imaginative capacity be identified and evaluated in students' collaboratively generated multimodal artifacts?*

## Theoretical framework

Vygotsky (2004) explained that imagination develops in an increasingly progressive and complex way through certain cultural tools such as language. Egan (1998) suggested some imaginative cognitive tools, which led Fettes (2010) to propose eight imaginative capacities. Among these capacities, grasping details is the focus of this study. Grasping details refers to "holding in one's imagination the individual richness of particular cases, situations, events, that makes them unique" (Fettes, 2010, p3). During the creative multimodal process, adolescents draw details from their experiences and popular media to devise characters, events, and plots, in unique combinations.

## Methods

The data for this study come from an informal educational program designed to engage adolescents (age 10-13; 3-5 students per team) in collaboratively producing multimodal science fictions while learning STEM and digital literacies. The program consisted of a five-day summer camp, a fall extension, and a final presentation in a local film festival. Each student adopted one or more specific roles (writer, designer, or scientist) and close collaboration was expected during the entire process. Students gained experience with a range of digital tools to create a variety of multimodal elements (e.g., comics, animation, sound, movie) to extend their narratives.

There were 42 students participated in the summer program and 21 of them continued with the fall extension. As a result, a total of 12 multimodal science fictions were generated. Multiple sources of data were collected, including pre-, mid-, and post-surveys, video records, group-based semi-structured interviews, and multimodal artifacts. To understand how imagination was incorporated in students' work, in this study we first examined their artifacts for three aspects: *characters* (i.e., people, such as protagonists and antagonists portrayed in the narrative), *events* (independent unit of action that, in sequence with other events, comprises the plot of the narrative), and *science* (scientific knowledge or facts incorporated in the fiction). For each aspect, we conducted a two-level coding. In the first level, we identified the instances that we considered as 'details'; in the second level, we analyzed these details into finer categories using a ground-up approach.

## Findings

Four themes emerged in our analysis and we illustrate them with concrete examples in the following.

### Theme 1: Creating deep characters in a fictitious world

Narratives with high imagination are those with sophisticated character-building schemes. The narrative, "Haluki Star" highlights several aspects that were also found in other strong examples: (a) *Descriptive details* (b) *Relationship with others*. (c) *Connection with the environment*. (d) *Expression of emotion*. For instance, a

character in the narrative is an alien species called Halukinumananluka, who was portrayed as having their own language (“they use different sounds connected with hand movement”, “they take long pauses between syllables”) and walking patterns (“go in zig zags”). They are “short and round, like barrels... have a face, like us humans, and long pointy, fingers and toes.... However, their eyes are as dark as night”.

## Theme 2: Crafting rich experiences in unfamiliar events

Another feature that is common in narratives with high imagination is that their events, especially unfamiliar ones, are filled with rich experiences and surprising twists. The narrative “What Would Happen If The World Stopped Spinning”, is an example of how different kinds of devising details give believability to the imaginative events. In the narrative, three friends struggle to survive after the Earth is hit by an asteroid, stops spinning, and is full of radiation and mutated former animals. Events of the story plot are enriched with devised details, many of which are from students’ everyday experiences. The key features include the following: (a) *Enumerating variety*. For example, when Luke builds a shelter, a variety of details that are not all directly associated with the actual building give depth to the event: Shelter is built underground to protect from radiation; a machine that extracts oxygen from water is used; wood, steel, and stone were found; and supplies were consumed. (b) *Opposing binaries with transitional inbetweenness*. For instance, in the narrative creatures are portrayed as “animals that we usually know and love evolved to vicious monsters”.

## Theme 3: Incorporating science details in creative ways

Narratives with high imagination tend to incorporate many science details in creative ways. These science details are used to support portraying the characters or explain why or how events happen. For instance, in the narrative “Haluki Star”, Lucy’s traveling through time and space is described with incredible details about personal feeling: “...I am being squeezed until there is nothing left of me. Then emptiness becomes black. It feels as if I am flying. An odd coolness passes over me. My whole body feels on fire....” (from narrative “Haluki Star”).

## Theme 4: Composing multimodal artifacts as a coherent a whole

Narratives in high level of imagination are often equipped with complementary and creative multimodal artifacts. For instance, Figure 1 shows a snapshot of a product that integrates three different modalities to create an ambiance and connect to settings in the plot.

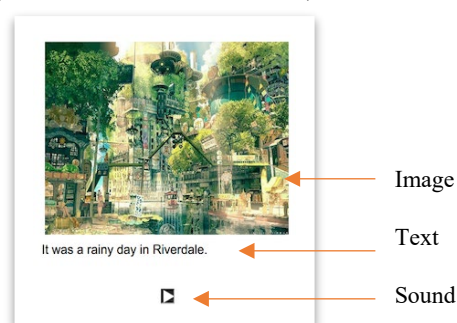


Figure 1. Sample page in “Tsunami Terror”.

## Discussion and implications

Our preliminary analysis shows the importance of devising details in creating highly imaginative multimodal science fictions. An emergent framework to identify and evaluate imagination in students’ multimodal artifacts can serve as a step for further exploration. What we have found at this stage includes the following. First, details can be devised in different ways to support character building, events unfolding, science incorporation, and multimedia integration. Writing techniques (e.g., inclusion of opposing binaries, metaphors) may equip students with ways to devising details that are more nuanced and humanized. Multimodal representations (e.g., comic/animation software) may provide a new cultural tool for young students to exercise and expand imagination. Future research will examine how students discuss, use, and externalize imagination when composing in a collaborative learning environment.

## References

- Egan, K., & NetLibrary, Inc. (1998). *The educated mind: How cognitive tools shape our understanding*. Chicago: University of Chicago Press.
- Fettes, M. (2010). The TIEs that bind: How imagination grasps the world. In K. Egan & K. Madej (Eds.) *Engaging imaginations and developing creativity in education* (pp 2-16). Newcastle: Cambridge Scholars.
- Glăveanu, V.P., Gillespie, A., & Valsiner, J. (2015). *Rethinking creativity: Contributions from social and cultural psychology (Cultural dynamics of social representation)*. New York, NY: Routledge.
- Vygotsky, L. (2004). Imagination and creativity in childhood. *Journal of Russian & East European Psychology*, 42(1), 7-97.



# Telepresence Robots as Embodied Agents in the Classroom

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**Abstract:** Telepresence robots are emerging as a way for distant or homebound students to attend face-to-face classes, but their influence on the classroom environment is not yet well understood. This in-progress study explores the experiences of students in a face-to-face classroom where one student attended via telepresence robot. The focus of this study is the extent to which the robot is perceived as an embodied agent in a shared physical space.

Telepresence robots are emerging as a way for distant or homebound students to attend face-to-face classes (Goodman, 2017). It is therefore important to understand how the use of these robots influences the classroom environment. This in-progress study explores the experiences of students in a face-to-face doctoral level course where one student attended class using a telepresence robot that allowed her to connect remotely but still maneuver through a shared physical space with her classmates.

## Learning with robots in shared space

The physical space of a classroom can affect the learning process by, for example, encouraging students and instructors to move around in the room when engaged in collaborative tasks (Brooks, 2012; Gurzynski-Weiss, Long, & Solon, 2015). While remotely-located students connecting to their classrooms through videoconferencing may be excluded from this physical engagement, or be dependent on others (e.g., relying on a classmate to move the device on which they are connecting), a telepresence robot allows remote students to move independently in the shared learning space. The presence of a robot in the classroom, however, has the potential to alter the classroom experience for both remotely-located and physically-present students in ways that are not yet well understood.

Research has shown that people tend to anthropomorphize machines, attributing human-like features to technology tools (Nass & Moon, 2000; Nass, Steuer, Tauber, & Reeder, 1994) and to perceive robots as embodied agents (Epley, Akalis, Waytz, & Cacioppo, 2008). That is, they perceive the robot as having a physical body and having agency over how that body moves in the physical space and interacts with humans. Perceptions of robot agency and independence are enhanced by a robot's ability to interact with humans within a shared physical space (Brincker, 2016). Brincker discusses interactions between agents in the context of *affordance spaces*. Gibson (1977) defined *affordance* as an opportunity for action provided by the environment. Brincker (2016) shifts the focus from "what the environment can be said to abstractly furnish one person seen in isolation" to an acknowledgment that "there are necessarily at least two perspectives and two embodied agents standing in...relation to the same environment" (p. 452). We can perceive other agents as either existing in their own affordance space or as sharing ours, allowing for "some level of mutual and reciprocal perceptible influence on each other's affordance field" (p. 452).

A remotely-located student connecting with classmates via telepresence robot is an embodied agent in his or her own affordance space, but how students in the classroom perceive a person mediated through a telepresence robot, and how this perception affects the learning environment, is not yet fully understood. When a medical issue prompted one student to attend class via telepresence robot for a large portion of one semester, we had an opportunity to explore students' experiences as embodied agents in a shared learning space in the presence of a robot. This in-progress study addresses the following research questions: (1) How did the remotely-located student experience the shared learning space when attending class using a telepresence robot? (2) To what extent did the student attending class via telepresence robot feel like an embodied agent? (3) How did face-to-face students experience a shared learning space that included a classmate attending via telepresence robot? (4) To what extent did the face-to-face participants view their remotely-located classmate to be an embodied agent?

## Methods

This study focuses on participants' subjective experiences of their interactions in the shared learning space. The setting is a doctoral level course in counseling psychology with an enrollment of 10 students. The course met face-to-face once per week for three hours and consisted mainly of student-led discussions on reading assignments. One student used a *Double 2* telepresence robot to attend class at a distance for the first 11 weeks of the 16-week semester. In the 12th week of the semester, she was able to begin attending class in-person.

Data for this initial exploratory study consisted of interviews with the student who used the telepresence robot and her classmates who interacted with her. The interview format was unstructured, giving the participants an opportunity to speak freely about their experiences with the robot, and allowing the researchers to adapt the interview based on the thoughts and ideas provided by the participants. However, the researchers were particularly interested in the degree to which the in-person students viewed the user of the robot as an embodied agent sharing their learning space, and the extent to which the robot user felt like an embodied agent in the classroom. Data were analyzed using the approach outlined by Saldaña (2009) to discern important themes that capture the essence of participants' experience.

## Significance

Results of this study will provide greater understanding of the experiences of learners in classrooms that contain a mix of face-to-face and remote students. This will help instructors design and manage these experiences to maximize the benefits of learning in a shared space while maintaining the increased access that telepresence robots provide.

## References

- Brincker, M. (2016). Dynamics of Perceptible Agency: The Case of Social Robots. *Minds and Machines*, 26(4), 441-466.
- Brooks, D. C. (2012). Space and consequences: The impact of different formal learning spaces on instructor and student behavior. *Journal of Learning Spaces*, 1(2), retrieved from <http://libjournal.uncg.edu/index.php/jls/article/view/285/275>.
- Epley, N., Akalis, S., Waytz, A., & Cacioppo, J. T. (2008). Creating social connection through inferential reproduction: Loneliness and perceived agency in gadgets, gods, and greyhounds. *Psychological Science*, 19(2), 114-120.
- Gibson, J. J. (1977). The Theory of Affordances. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting, and knowing: Towards an ecological psychology* (pp. 67-82). New York: Lawrence Erlbaum Associates.
- Goodman, J. (2017). Meet Sheldon, the Robot Student. Retrieved from <https://www.insidehighered.com/digital-learning/article/2017/04/26/robots-classrooms-connect-distance-learners-classrooms>
- Gurzynski-Weiss, L., Long, A., & Solon, M. (2015). Comparing Interaction and Use of Space in Traditional and Innovative Classrooms. *Hispania*, 98(1), 61-78.
- Nass, C., & Moon, Y. (2000). Machines and mindlessness: Social responses to computers. *Journal of Social Issues*, 56(1), 81-103.
- Nass, C., Steuer, J., Tauber, E., & Reeder, H. (1993). Anthropomorphism, agency, and ethopoeia: computers as social actors. In *INTERACT'93 and CHI'93 conference companion on human factors in computing systems* 111-112. ACM.
- Saldaña, J. (2009). *The coding manual for qualitative researchers*. Thousand Oaks: Sage Publications: Thousand Oaks, CA.

# Child-material Computing: Material Collaboration in Fiber Crafts

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**Abstract:** In computer science education, fiber crafts remain largely disconnected from their historical role as models for computers. This risks overlooking a compelling, low-cost context for computer science learning and for exploring human-machine collaborative learning processes. Building on bodily-material collaboration, we analyzed the computational concepts associated with fiber crafts during a middle school course and found that computation was contingent on child-fiber collaborations. This has implications for theorizing materials as active participants in collaborative learning.

## Introduction and background: Fiber crafts and computing

Fiber crafts are a compelling context for examining the material nature of collaboration in computer science learning, because textile manipulation occupies a pivotal role in the history of computing; the earliest computers were modeled after the Jacquard loom that used punch cards to program fabric patterns (e.g., Plant, 1995). Despite this connection, in computer science education fiber crafts remain largely disconnected from their historical role as models for computers. The field of e-textiles is a notable exception that highlights the potential of technology-augmented fiber crafts for high-quality STEM learning (Buechley, 2006). By swapping wires for conductive yarn, the practice of sewing becomes a way for youth to connect crafting, engineering, and computing (e.g., Peppler, 2013; Kafai, Fields, & Searle, 2014). However, we know little about the computational concepts used for non-technologically augmented fiber crafts or which learning processes they drive. Reinvigorating the historical connections of fiber crafts and computing promises a compelling low-cost context for computer science learning and for exploring human-machine collaborative processes.

The framework of bodily-material collaboration (Davidsen & Ryberg, 2015), focused on collaborative learning processes between children and new technological materials, invited us to expand notions of collaboration by framing materials as active participants. This poster examines youth's collaborative STEM learning processes as they perform fiber crafts. Our qualitative analysis of video data from a middle school craft course examines fiber crafts as a context for computer science education by showing how weaving mirrored the computer-programming notion of parallel processes. We discuss three child-material collaborative processes for computer science education and their implications for computer-supported collaborative learning.

## Methods

This qualitative study draws on data collected during a six-session craft course at a Midwestern public school to examine the inherent computational concepts of weaving and fabric manipulation. Each session lasted 60-90 minutes, was attended by eight middle school students, and was video-recorded. During the sessions, we also conducted 5- to 10-minute semi-structured interviews with the youth about their design process. The interviews were also video-recorded to capture the youths' embodied meaning making. We analyzed youth engagement with the fiber crafts by iteratively coding the video for computational concepts of the K-12 Computer Science Framework (e.g., programming: functions, loops; computing systems: software and hardware) and transformed them to Python programming. Then we coded how youth described body movements in relation to computational concepts (e.g., tools used and how). For this poster, we present an illustrative case of a beginner's lace pattern woven into a tapestry by a middle school fabric-based computer, Jasmine, who had little prior experiences in computing and crafting. We first present how the project relates to programming and then turn to software and hardware at the site of the child-material collaboration.

## Findings: Weaving parallel processes

When a computer program, the implementation of parallel processes requires the programmer to identify two patterns that progress simultaneously and to bring these together into a computer program. Through the creation of a lace pattern, Jasmine used this concept to move her project forward. Jasmine intended to weave an opening into her tapestry and explained her graphical project plan (Figure 1, left):

*So this is the hole right here. And [the yarn] goes one way. Then, [the yarn] goes the other way. And then [the yarn] goes this way and then you skip these strings, where the hole is going to be, and then you go the same way and then you go this way and do the same as you did.*

In her explanation of the first three project plan lines, which include the first lace line, Jasmine's use of "skip

these strings” suggests that she planned to use one yarn color on one shuttle (i.e., a carrier of yarn) to produce the design. The project plan arrows support this, where the arrow on line three points into the same direction before and after the “hole.” This seems to continue the row, rather than build both sides of the fabric in parallel.



Figure 1. Jasmine’s weaving pattern, loom project, and Python code of pattern design.

On the loom, Jasmine engaged two yarn colors, teal and rose, on two shuttles to create her lace pattern (Figure 1, center). Alternating, she moved the teal shuttle from left to right and the rose shuttle from right to left, before shifting warp-thread positions. Both sides of the tapestry advanced in parallel. On graph paper, this would have been represented as two arrows pointing toward one another rather than in the same direction. As part of our analysis, we transformed all students’ weaving patterns into Python programming language to discover their inherent computational concepts. As Jasmine and the loom came together, the pattern changed into a more complex task that showed the use of functions, loops, and ranges as two processes emerged (Figure 1, right).

## Discussion and implications

Thinking with the framework of body-material collaboration, we recognize that the Python code does not capture how Jasmine and the fiber craft materials came together to form a human-material collaboration. We identified three child-material collaborative processes that fostered the fiber crafts-based computation. First, Jasmine and the loom *simultaneously programmed and processed* the pattern instead of delegating tasks to the machine. For the lace pattern, the loom called for a shift in the computational process: Both sides needed to advance in parallel and, therefore, a change in programming was needed. Second, Jasmine *became a part of the emerging computation*. Through left-right movements, Jasmine’s arm plus the shuttle that held the “pixel-making” material (i.e., yarn) became the computational processing unit. Third, this *slowed down computing* and made the usually invisible computational processes visible. Together, these child-material collaborative processes highlight the active role of materials in what computation can become. Computation in fiber crafts seemed contingent on child-material collaborations. Leveraging these processes for computer science education could present a low-cost context for interrogating the role of humans in computation. Identifying contexts for exploring human-machine interactions such as fiber-based approaches to child-material computing, are of increasing usefulness for computer-supported collaborative learning as ubiquitously spreading computational algorithms alter learning processes and the role of people in relation to computation.

## References

- Peppler, K. (2013). STEAM-powered computing education: Using e-textiles to integrate the arts and STEM. *IEEE Computer*, September 2013, pp. 38-43.
- Buechley, L. (2006, October). A construction kit for electronic textiles. In *2006 10th IEEE international symposium on wearable computers* (pp. 83-90). IEEE.
- Davidson, J. & Ryberg, T. (2015). “This is the size of one meter”: Children’s bodily-material collaboration and understanding of scale around touchscreens. In *The Computer Supported Collaborative Learning (CSCL) Conference 2015* (Vol. 1, pp. 70-77). Gothenburg, Sweden: ISLS.
- Kafai, Y., Fields, D., & Searle, K. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review*, 84(4), 532-556.
- Plant, S. (1995). The future looms: Weaving, women, and cybernetics. *Body & Society*, 1(3-4), 45-64.

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# Dialogic Intervisualizing: Rethinking Text-Discourse-Learning Relations in Multimodal Problem-based Learning

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**Abstract:** Examining the nature of digital texts in the developing contexts of problem-based learning (PBL) constitutes an expansion in research on dialogic approaches to learning in technology-rich, inquiry-based designs. This study adopts Interactional Ethnography as an orienting theory to frame the purposeful tracing of the unfolding knowledge co-construction processes across a medical PBL cycle. We investigate how these processes are interactionally accomplished in and across intertextually tied events where devised, generated, accessed, curated and appropriated digital texts are connected in webs of meaning. The concepts of multimodality and intertextuality from literacy studies provide explanatory theories to investigate how digital texts in the developing dialogic space are consequential the learning process across the phases of a PBL cycle. We propose the concept of *dialogic intervisualizing* to theorize these new text-discourse relations in inquiry-based learning.

**Keywords:** Interactional ethnography, multimodality, problem-based learning; facilitation

## Background

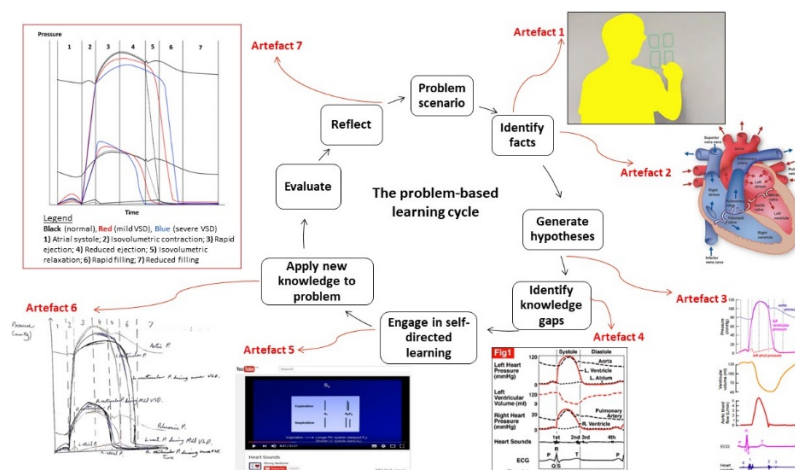
Given the socio-cognitive foundations of PBL with collaborative disciplinary knowledge co-construction occurring in small group dialogues, designing ethnographic, discourse-based studies to capture and analyze interaction-based learning processes in-situ is both logical and compelling. Attending to the processes of appropriation and development of curated and student-devised digital resources is critical because these resources provide access to, and structure information by embedding expert knowledge and skills in these virtual spaces (Savin-Baden, 2016); however, this is less explored. This study aims to trace participants' learning trajectories as facilitators and students engage in dialogic activity while utilizing multimodal resources.

## Approach

The study is theoretically grounded in Interactional Ethnography (IE) with learning socially-situated and discursively constructed across times, events and configurations of actors and artifacts (e.g., texts) (Green & Bridges, 2018). This perspective is particularly important in seeking to understand the dialogic relationship between social activity and collective-individual cognitive development (Derry et al, 2010). With specific reference to multimodal texts, we align with the notion of "intersemiotic relations" (Bateman (2014). One Year 2 medical student PBL group in the 6-year Bachelor of Medicine and Bachelor of Surgery (MBBS) program and their expert PBL facilitator (n = 12) form a *telling case*. The archived materials for analysis included video recordings of three face-to-face PBL tutorials (~ 2 hours each) and student learning materials collected across the problem cycle. Classroom videos were transcribed and PBL case materials (tutor and student guides; student generated materials) were collected. Recall interviews were recorded and transcribed and added to the archive. The team co-analyzed video recordings and transcripts to identify rich points associated with educational technologies and multimodal texts and to trace the consequential nature of these texts for medical student learning (Green & Bridges, 2018).

## Results and discussion

The 'rich point' (Agar, 2006) for tracing intervisual ties between texts was identified where a student (S11) was asked by a peer to draw a representation of the point he was seeking to explain. Figure 1 illustrates both the chronological relationship between texts and talk from Tutorial 1 and Student 11's (S11) initial whiteboard drawing attempt (Artefact 1) to the S11's final representation (Artefact 7) which was composed and circulated (unknown to the facilitator) after the final tutorial (Tutorial 3) and maps this to the phases of the PBL cycle of inquiry.



**Figure 1.** Dialogic intervisualizing across the PBL cycle.

Drawing on Interactional Ethnography, multimodality and intervisuality, we also expand the conceptualization of the role of visualizing (as a verb) in dialogic learning contexts such as PBL. Our argument is the ongoing process of student-led semiosis evident in the analysis above, whereby meaning-making is supported through the building of discourse ties between graphic representations as visual ‘texts’ and the actions proposed or made transparent by members in the PBL cycle (e.g., facilitator, students). The concept of *dialogic intervisualizing* recognizes the dynamism and centrality of new text types as contextualization cues to meaning and sociocultural processes. The concept also emphasizes not only student agency and autonomy in a fluid and dialogic learning process such as PBL but also the centrality of the expert facilitator in guiding the process of textual selection, curation, critique and final appropriation. We also propose that the concept of dialogic intervisualizing situates the event and textual processes, the developing composition and a meta-discursive set of orienting signals as well as processes of naming key phenomena.

## Conclusion

For this Interactional Ethnography, we have examined this process of facilitated textual production and interpretation within and across the dialogic learning space that is a PBL cycle in a process of dialogic intervisualizing. This analysis proposes theoretical insights through the proposed concept of dialogic intervisualizing which broadens the conceptualization of dialogic learning and social semiotic conceptions of intervisuality at their point of intersection in inquiry-based learning designs.

## References

- Agar, M. (2006). An ethnography by any other name... *Forum: Qualitative Social Research*, 7(4).
- Green, J.L & Bridges, S.M. (2018). Interactional Ethnography. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman & P. Reimann. (Eds). *International Handbook of the Learning Sciences*. NY: Routledge/Taylor & Francis.
- Bateman, J. (2014). *Text & Image: A Critical Introduction to the Visual/Verbal Divide*. London. NY: Routledge.
- Danish, J. A. (2013). Designing for Technology Enhanced Activity to Support Learning. *Journal of Emerging Learning Design* (1).
- Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., Rogers, H., Koschmann, T., Lemke, J. & Sherin, M. G. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences*, 19(1), 3-53.

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# Exploring the Potential of IVR Technology to Promote Collaborative Learning in Science Experiences

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**Abstract:** This poster explores how different types of virtual reality technology (VR) allow for various degrees of collaborative enactment within virtual environments. This two-staged study analyzed the engagement and reflections of 27 students with three forms of VR hardware. Findings from direct observations and students' perceptions suggest that the capabilities of high-end immersive virtual reality (IVR) can allow for more meaningful and natural forms of embodied interactions, locomotion, and verbal communication.

**Keywords:** Computer supported collaborative learning (CSCL), Virtual reality assisted education (VRAE), enactment in VR, embodiment in IVR, sensorimotor contingencies for virtual collaboration.

## Introduction

For years, studies have explored the potential of non-immersive virtual reality (NiVR) for training, skills development, and formal education (Jensen & Konradson, 2018; Wang, Wu, Wang, Chi, & Wang, 2018). As a platform, NiVR has reached a stable state of maturation; however, immersive virtual reality (IVR) is still in an early evolutionary state. With the advent of the first modern commercial headsets since 2014, companies like Google, HTC, Sony, and Oculus have contributed to creating a saturated and fragmented market by commercializing headsets with very distinct features that can afford users rather different experiences, all under the umbrella term of virtual reality (VR). This has become problematic not only for its rate of adoption, but also for its implementation in educational settings, and for educational research. Although there is little evidence supporting the notion that these new and varied versions of the technology can enhance instruction in any significant way compared to NiVR, the push from these companies has led to initiatives seeking to bring IVR into classrooms, i.e. Google Expeditions, Immersive VR Education, zSpace, and Avantis Education's ClassVR. Furthermore, these ventures follow the assumption that IVR headsets can inherently support learning due to their perceived qualities and fail to acknowledge that the findings from the empirical studies on the educational uses of NiVR do not necessarily carry over to IVR. Some researchers have tried to address this gap in the literature; however, there still is little consensus on the usefulness of IVR for educational purposes. Whilst some studies have shown positive results (Dede, Salzman, & Bowen Loftin, 1996; Ketelhut, Nelson, Clarke, & Dede, 2010; Webster, 2016), others present a less favorable vision on the educational advantage of IVR (Makransky, Terkildsen, & Mayer, 2017; Moro, Štromberga, & Stirling, 2017; Parong & Mayer, 2018).

## Methodology and analysis

This piece of research comprises a pilot study carried out in preparation for a larger project exploring how high-end IVR technology (1) affords sensorimotor experiences that could support learning through embodied interactions. During data collection, it became evident that the qualities that make high-end IVR technology more advanced allowed for deeper interactions and showed the potential to support collaborative activities.

This pilot study took place in a secondary school in London with a sample of 21 girls aged 11-13 and a separate sample of 6 adult participants at university level, its aim was to test different data collection instruments and to define the sensorimotor differences between low and high-end IVR, and NiVR. Due to limitations of time and number of headsets available, only a few students were able to use the VR technology directly. Those who were selected for participation were randomly allocated into three groups where they performed science related activities using a type of VR hardware and a piece of commercial software specifically designed for each platform: those in the control group used desktop-based VR technology, group 1 used Samsung's Gear VR headset, and group 2 and the adult sample used an HTC Vive headset. Data was collected through video recordings, an observation log, notes from interviews and discussions, and short pre and post-tests. Participants were briefed on the study asked to opt in through consent forms, additionally, parental consent was sought for underage students.

Thematic analysis was carried out on the notes made from unstructured interviews and on the embodied interactions observed on the video recordings. Coding was done in two stages (first deductively and then inductively).

## Discussion and findings

The experimental design of this pilot study brought about a few lessons going forward. Firstly, although some NiVR platforms are capable of embedded collaborative work, the version of the software used here relied on external collaborative activities. Students were able to perform the tasks in pairs and take turns and negotiate the steps to follow. Based on the notes and video recordings, it was observed that students not only became more engaged with the activities whilst working in pairs, but they were also more willing to explore the virtual spaces as they had to navigate them by taking into consideration the requests of their partner. In contrast, those who performed the activities on their own followed a more linear path which aligned to the directives in the environments. Although this outcome in the control group is worth exploring further, the conditions of the study groups led to more unexpected collaborative uses of the technology given the isolating nature of wearing a headset. On the one hand, the stereoscopic 3D view and first-person perspective of the technology used in both cases added to a more immersive experience, but on the other, the hardware used in the first group limited students to a fixed position which hindered exploration. Additionally, the pointer-like controller in this group did not allow for more natural and direct manipulation of objects and for the exploration of the space as was possible with the technology used in the second study group. Regardless of the constraints, students who were not using the technology at the time still engaged with their peers through voice commands after visualizing the virtual environment on a screen. Furthermore, the fact that the second group involved being able to manipulate objects and physically walk, allowed non-participants to spatially navigate the virtual space with the help of the screen and physically help their peers move and walk as they would a visually impaired person, although participants were perfectly capable of performing the activities themselves. This demonstrated not only the impact that collaboration can have in virtual spaces as pupils could discuss solutions and negotiate a common understanding of concepts, but more importantly, it showed the need for collaboration that students have for deeper engagement with the environment.

Ultimately, what this pilot study has done is raise a number of questions in relation to the use of VR as an instructional tool such as in what ways and to what depth are embodied interactions and locomotion involved in supporting learning through this medium, which learning domains have the potential to be more effectively supported by VR technology, and how can VR instruction shape distance learning and collaboration.

## Endnotes

- (1) High-end IVR refers to tethered headsets that require a powerful computer to operate. In contrast, low-end IVR describes untethered headsets with low computing power either embedded in the casing or based on a mobile phone.

## References

- Dede, C., Salzman, M. C., & Bowen Loftin, R. (1996). ScienceSpace: virtual realities for learning complex and abstract scientific concepts. In *Proceedings of the IEEE 1996 Virtual Reality Annual International Symposium* (pp. 246–252). IEEE.
- Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, 23(4), 1515–1529.
- Ketelhut, D. J., Nelson, B. C., Clarke, J., & Dede, C. (2010). A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Educational Technology*, 41(1), 56–68.
- Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2017). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*.
- Moro, C., Štromberga, Z., & Stirling, A. (2017). Virtualisation devices for student learning: Comparison between desktop-based (Oculus Rift) and mobile-based (Gear VR) virtual reality in medical and health science education. *Australasian Journal of Educational Technology*, 33(6), 1–10.
- Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology*, 110(6), 785–797.
- Wang, P., Wu, P., Wang, J., Chi, H.-L., & Wang, X. (2018). A Critical Review of the Use of Virtual Reality in Construction Engineering Education and Training. *International Journal of Environmental Research and Public Health*, 15(6), 1204.
- Webster, R. (2016). Declarative knowledge acquisition in immersive virtual learning environments. *Interactive Learning Environments*, 24(6), 1319–1333.

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# Using Computer-Supported Collaborative Learning (CSCL) for Global Curriculum Inquiry: A Case Study in Hong Kong

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**Abstract:** This poster aims at presenting the findings of a case study of a group of student teachers using online discussion as a form of Computer-Supported Collaborative Learning (CSCL) in doing inquiry projects in collaboration with prospective teachers from Spain and experienced teachers from Canada. Data was collected from individual and focus group interviews, as supplemented with online discussion threads. Findings evidenced the processes and potentials of global curriculum inquiry using online discussion in developing student teachers' global citizenship. Implications about the use of online discussion for supporting the development of global citizenship in teacher education as well as future research directions are then discussed.

## Introduction

There have been increasing attentions to the needs of educating global citizenship in teacher professional development in contributing to the sustainable development of the global world (Goodfellow, Lea, Gonzalez, & Mason, 2001). In this connection, the recent *Education for Sustainable Development and Global Citizenship in Education 2030* initiated by the UNESCO (UNESCO, 2017), developing global citizenship is one of the Sustainable Development Goals which calls for embedding global citizenship themes and concepts within all areas of learning and teaching. Different local and international scholars found that teachers' awareness of global citizenship are narrow and insufficiently prepared (Lee & Leung, 2006; Groves & O'Connor, 2017).

One of the potential ways in attaining the goal of developing student teachers' global citizenship is the use of Computer-Supported Collaborative Learning (CSCL) technologies, which can facilitate the socio-cognitive processes of learning (i.e. working in groups) through social interaction with the support of a computer or the internet that connects and engages people in sharing and creating knowledge through scaffolding dialogues across multi-cultural regions (Sorensen, 2008) whilst it. Evidence showed that the applications of CSCL (e.g. He & Huang, 2017) enable the effectiveness of learning and teaching. A few scholars (e.g. Sorensen, 2008) discussed and evidenced how CSCL technologies may help the development of global citizenship but these studies were not conducted in teacher education settings. Meanwhile, to our knowledge, how CSCL may help develop global citizenship of student teachers (teachers) is seldom explored and documented from an Asian perspective. Therefore, the aim of the case study is to explore how online discussion as a form of CSCL facilitate the development of student teachers' awareness of global citizenship through real experiences in interacting with others around the world, with the key research question, *How do student teachers perceive and experience the use of online discussion for developing global citizenship? What motivates student teachers to get engaged in online discussion with 'others'? What do they learn from 'others'?*.

## Context of the study

The case study was based on a global curricular inquiry project that occurred in a postgraduate diploma of education (PGDE) programme in a public university in Hong Kong. The overarching objectives of the project are: (a) to develop student teachers' awareness of global citizenship through engaging in online discussion with their "global peers" (i.e. a group of 18 student teachers from a university in Spain and two experienced teachers from Canada), and (b) to enable student teachers to interact with their "global peers" and engage in online dialogue around curricular issues. Participating student teachers worked in groups to initiate and compromise curriculum-related inquiry topics for collaborative discussion on an online discussion platform (i.e. Weebly – an online blogging system), where experienced teachers from Canada and student teachers from Spain engaged in the online discussion with the local Hong Kong student teachers. At the end of the online discussion, student teachers presented their findings and reflections based on the global curricular inquiry projects.

## Data collection and analysis

Using a qualitative approach, multiple sources of data were collected from a purposive sample of six informants (four females and two males). Data included individual and focus group interviews, as supplemented with discussion threads on the online discussion platform. During the process of interviewing, the researcher showed the online discussion platform for assisting participants to elicit thoughts and reflect upon experiences. Thematic analysis was done to search for the patterns and themes as emerged from the qualitative datasets.

## Key findings (1): Fostering deep learning processes

Interaction with peers locally and inter-culturally plays a vital role in driving the participants' motives in engaging in online discussion. For example, this student teacher mentioned,

I think Spanish students are really very serious in participating in the discussion. This really motivates us much more. This encourages us to think and respond to them as they are so devoted and responded to us, we also had to be whole-hearted and continue the discussion together. (Student K1, PGDE Year 1)

Apart from interactivity of online discussion, the quality of the interaction also helps ignite the participants' willingness to participate in the online discussion.

I think my motivation is based on Spanish students' responses because Spanish students responded to us in very details... very long and precise. ... if we can know how many students exist there, that will even be better. (Student I2, PGDE Year 1)

## Key finding (2): Reflecting on different learning issues

The participants realized that learning can be globally emerged and collaborative across different countries. They expressed that they knew more about the global world and discovered the differences in how to learn in difficult cultural contexts. One of the participants shared that,

They [Spanish students] were really serious. Theirs was very informative. ... At the end that was quite good, we understood what exactly Spanish were doing was quite different. ... for example, in our topic about tutorial class, because attending tutorial classes is very popular, so we would like to know about how Spanish side looks like. (Student K1, PGDE Year 1)

The kind of global learning apparently was beneficial to teacher preparation. One participant concluded her learning experience in this way, saying that,

When doing discussion, there are many insights, or seeing more things, and some viewpoints are different, then that actually can exchange different points of view, that's good for my own learning and I can get prepared for my future teaching career as I know more about what other countries are doing in curriculum and this experience makes me know how to use technologies for learning and teaching. (Student K2, PGDE Year 1)

## Conclusion and implications

This case study explored how the use of online discussion as a form of CSCL was perceived and experienced by student teachers to inquire curricular issues through collaborating with Spanish student teachers and Canadian teachers. Implications about the development of global curricular inquiry in teacher education as well as future research directions are discussed.

## References

- Goodfellow, R., Lea, M., Gonzalez, F., & Mason, R. (2001). Opportunity and equality: Intercultural and linguistic issues in global online learning. *Distance Education*, 22(1), 65-84.
- Groves, J. M., & O'Connor, P. (2017). Negotiating global citizenship, protecting privilege: western expatriates choosing local schools in Hong Kong. *British Journal of Sociology of Education*, 1-15.
- He, J., & Huang, X. (2017). Collaborative online teamwork: Exploring students' satisfaction and attitudes with Google Hangouts as a supplementary communication tool. *Journal of Research on Technology in Education*, 49(3-4), 149-160.
- Lee, W. O., & Leung, S. W. (2006). Global citizenship education in Hong Kong and Shanghai secondary schools: Ideals, realities and expectations. *Citizenship Teaching and Learning*, 2(2), 68-84.
- Sorensen, E. K. (2008). Design of dialogic eLearning-to-learn: meta-learning as pedagogical methodology. *International Journal of Web Based Communities*, 4(2), 244-252.
- UNESCO (2017). *Education for Sustainable Development and Global Citizenship in Education 2030 / SDG 4*. Retrieved on November 11, 2018 from: <https://bangkok.unesco.org/content/education-sustainable-development-and-global-citizenship-education-2030-sdg-4>.

# A Qualitative Analysis of Joint Visual Attention and Collaboration with High- and Low-Achieving Groups in Computer-Mediated Learning

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**Abstract:** While interest in using dual eye tracking sensors in computer-supported collaborative learning research continues to grow, it remains a challenge to know how to interpret the data these tools generate. This qualitative analysis leverages dual eye tracking data to offer Joint Visual Attention (JVA) graphs as a novel approach to depicting gaze synchronization, and presents a case study to provoke discussion around the opportunities to improve JVA graphs.

## Introduction

Measuring collaborative learning is a difficult task, as collaboration is a continuous and multi-dimensional process (Meier, Spada, & Rummel, 2007). In situations of collaborative learning, however, Joint Visual Attention (JVA)—the tendency for social partners to focus on a common reference and to monitor one another’s attention to an outside entity (Tomasello et al., 2005)—can act as a proxy for the quality of students’ collaboration (Schneider et al., 2018). Additionally, researchers can now leverage emerging technologies, such as mobile eye tracking devices, to more rigorously measure students’ levels of JVA. In this analysis, we leverage the massive datasets generated by mobile eye trackers to offer JVA graphs as an objective depiction of synchrony in students’ gaze behaviors. We conclude by coupling two JVA graphs with observational data from a case study of two groups—who are similar based on their JVA levels, but differ in collaboration quality and learning gains—to open opportunities to improve JVA graphs.

## Study design

This abstract focuses on the qualitative analysis of mobile eye tracking video footage collected from a subset of two dyad pairs, Groups 6 and 35 (N=4 out of 84), who participated in a previous empirical study (Schneider, accepted). Paired participants were asked to program a robot using a block-based programming language to navigate a series of increasingly difficult mazes in 30 minutes. The groups were selected based on two criteria: similarity in JVA levels and significant differences in learning gains scores compared to the whole study sample (n= 42 pairs). Group 6 had a learning gain score of 2 points and Group 35 had a learning gain score of 48 points, both on a 100-point scale.

## Methods

Participants wore mobile eye trackers, and an automated system determined the location and proximity of participants’ gazes. JVA graphs were generated for each dyad pair to depict the geometric proximity of participant gazes during the learning activity. Gaze proximity was counted as present whenever the distance between the two participants’ gaze points was below a certain threshold (Schneider, accepted). Rising JVA lines indicate gaze convergence and falling JVA lines indicate the opposite (see Figure 1). We generated a qualitative codebook to categorize collaborative learning processes associated with high and low levels of JVA depicted by the graph. Two researchers independently coded a sample, and a Cohen’s Kappa coefficient of 0.69 was reached indicating “good” agreement. Codes referenced in the case study below are illustrated by observational data in Table 1.

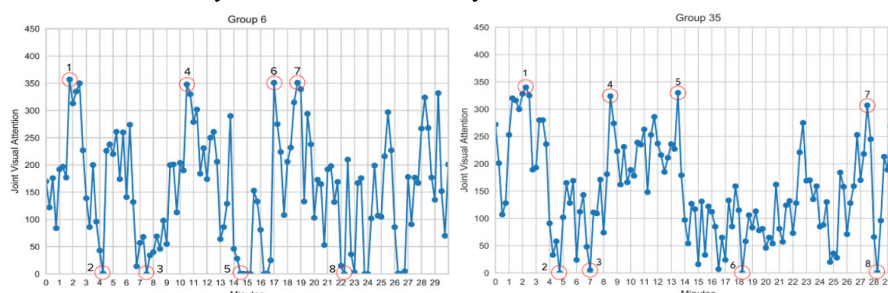


Figure 1. JVA graphs of two dyads during the 30-minute programming activity with examples of high and low JVA circled in red.

## Case Study

In this section we present a case study to illustrate that high and low JVA levels are not always predictive of collaboration quality, and to identify promising indicators of quality collaboration as it relates to JVA.

**Table 1: Qualitative observations (left) and quotes (right) showing differences in collaborative processes at high JVA (top row) and low JVA (bottom row) between Group 6 (low-achieving) and Group 35 (high-achieving)**

Group 6 (low learning gains)	Group 35 (high learning gains)
<p><i>High JVA: Gaze Following / Unbalanced Participation</i>  <i>&lt;L tries to solve a sensor value problem&gt;</i>            Then for about 40 seconds there is complete silence. Though it seems as though she is struggling to find an answer to the sensor value question, Left does not ask Right, nor does Right volunteer any suggestions.</p>	<p><i>High JVA: Coordinated Gaze / Thinking Aloud</i>  <i>&lt;R thinks aloud, builds common ground&gt;</i>            R: "It seems like the 'else' is probably forward. And [every time] we turn we want to have this (points to block) repeat. I forgot about that."  <i>&lt;without prompt, L agrees with R's ideas&gt;</i>            L: "Yeah, to go straight again."</p>
<p><i>Low JVA: Looking at Different Places / Unbalanced Participation</i>            The participant on the left picks up the cord to guide the robot. Left stands up to run code on robot. Right remains seated. It appears Right can neither see the robot, nor is trying to see the robot move. Meanwhile, Left watches the robot as it moves, and as she controls it.</p>	<p><i>Low JVA: Looking at Different Places / Thinking Aloud</i>  <i>&lt;Dyad decides to use sensors to make the robot run&gt;</i>            R: "So we know now how to make it go straight and hit a wall. The question is, 'we need to know whether it goes right or left'. So, then, we might want to work with these sensors to determine what's on each side."  <i>&lt;R points to the sensors on the left and right sides of the robot&gt;</i>            L: "Okay..."</p>

*Analysis.* Based on Table 1, we see at high JVA Group 6's collaborative learning processes (CLP) are characterized by gaze following and unbalanced participation where one participant actively works with the robot and the other is passive. Meanwhile, Group 35's CLP are characterized by thinking aloud and coordinated gaze where students share gazes due to verbal communication that helps them maintain their approach to achieve a shared goal and build common ground. At low JVA, Group 6 looks at different places during moments of unbalanced participation, while Group 35 engages in thinking aloud. This shows low JVA can also be an indicator of high-quality collaboration. Additionally, Group 6 spends most of their time in silence, while Group 35 often shows verbal activity. This observation suggests that thinking aloud is associated with a quality of collaboration that leads to high learning gains, while a tendency to engage in unbalanced participation is associated with a quality of collaboration that leads to low learning gains.

## Conclusion

The JVA graph is an objective tool that provides a way for people to see different levels of synchronized gaze and rigorously measure students' JVA. Key indicators of quality of collaboration highlighted in the case study present an opportunity to discuss ways to improve JVA graphs, and even ideate new, compound visual representations that include key indicators of quality of collaboration and learning gains such as verbal activity, movement, and other multi-modal data streams.

## References

- Meier, A., Spada, H., & Rummel, N. (2007). A rating scheme for assessing the quality of computer-supported collaboration processes. *International Journal of Computer-Supported Collaborative Learning*, 2(1), 63–86.
- Schneider, B., Sharma, K., Cuendet, S., (2018). Leveraging mobile eye-trackers to capture joint visual attention in co-located collaborative learning groups. *International Journal of Computer-Supported Collaborative Learning*, 13: 241.
- Schneider, B.(accepted). Unpacking Collaborative Learning Processes during Hands-on Activities using Mobile Eye-Tracking. In *the 13th International Conference on Computer Supported Collaborative Learning*.
- Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, 28(05).

# Interactive Visualizations to Enhance Social Learning Practices in MOOC Platforms

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**Abstract:** In MOOCs, social learning theory is challenged to perform at scale, but platforms do not have specific functionality which affords scalability. This study examines a design-based research intervention in the learning platform: The Comment Discovery Tool. Results from the initial iteration of this tool suggest positive impact, but further work is suggested to develop MOOC pedagogy in line with novel toolsets.

## Introduction

MOOCs typically have a thousand or more enrolled learners. Kizilcec et al. (2013) demonstrate that contribution in forums is strongly linked with ‘completing’ learners, and suggests that platform designers should build features that promote pro-social behaviour as this encourages learning. Previous research (Tubman, Oztok, & Benachour, 2016) discovered that conversations in the FutureLearn MOOC platform consistently decrease dramatically after the first reply, regardless of course size or subject matter. This suggests that the platform and sociomaterial factors are foundational to the pedagogy of MOOCs. This study re-imagines the social learning features through the design paradigm of ‘stigmergy’. Stigmergy is defined as “communication through signs left in the environment” (Dron, 2006; Elliott, 2016). This paper seeks to find answers to the following questions about a bespoke platform intervention: Does the platform intervention have a statistically significant impact on the length and unique members of conversations? Does the platform intervention affect the types of conversations on the platform?

We propose a taxonomy of ‘conversation types’ based on unique participants: a social dimension based on turn taking and the length attribute of a conversation to quantify the impact of our intervention. Our research extends Chua et al.’s (2017) comment categories from single post onto the whole conversation. This paper analyses the first iteration of a platform design intervention: an interactive ‘word cloud’ we call ‘Comment Discovery Tool’ (CDT). The tool functions by visualising all the comments into a ‘word cloud’, taking the top 200 words used. Learners can click several words which filters comments and redraws the cloud. The intention is that learners will be drawn to words through their implicit meaning. The tool also encourages a sense of ‘play’ and an appreciation of which concepts ‘go together’.

## Methodology

This study examines the FutureLearn MOOC platform, which is distinctive in that it follows the Conversational Framework and has a ‘comments’ thread on each individual page so conversations can be free-flowing around the immediate content. This study takes a mixed-methods, design-based research approach investigating the impact of a platform plugin embedded into 8 out of a total of 35 courses. The results from this study are from the first iteration of the design intervention.

## Results

257239 conversations were analysed. An ANOVA analysis showed that the unique learners variable was significant,  $F(1, 257239)=496.265, p=0.00$ , and also that the conversation length variable was significant,  $F(1, 257239)=601.703, p=0.00$ . Cohen’s *d* scores were also calculated for a measurement of impact, and generated a score of 0.15 for unique learners, 0.12 for conversation length. This suggests the CDT has had a small but noticeable impact across the courses in DBR phase 1.

304 people responded fully to a 15-question survey. There was a positive correlation between valuing social interaction and all the questions relating to learning; social learners see the value in the CDT, and are inclined to comment more themselves. These are all important factors in the theoretical understanding of sociocultural learning (discovery, diversity and participation). However, there was a smaller impact in terms of discovery of new people, which may indicate that learners are more inclined to use the tool in order to connect ideas, so for vicarious learning. More experienced learners (who had participated in more than 1 other course) were more inclined to use the CDT multiple times, so familiarity with the platform is correlated with disposition to try out novel approaches.

Table 1: Descriptive statistics

	Courses (n=35)	N	M	SD
Unique Learners	no CDT	225618	1.33	0.80
	CDT	31621	1.46	0.91
Conversation Length	no CDT	225618	1.48	1.43
	CDT	31621	1.67	1.70

## Discussion

A DBR approach is taken in this research with a social constructivist theoretical framework. The primary finding is that the intervention does appear to have an impact on the social dimensions, and this is shown both quantitatively and qualitatively, so we believe this meets the challenge by Kizilcec et al. for effective pro-social platform tools. Some learners comments that they were unsure how to use the tool suggesting the scaffolding could be improved to make the affordances more transparent. Others suggested that some words in the CDT were not very meaningful, so didn't add value to the activity. There is another side to this insight: individual words can be computationally operationalised, but it does not change the pedagogy or the culture of participation (Fischer, 2011). A potential development could encourage learners to hashtag their comments so an emergent folksonomy of more specific and meaningful terms can emerge, which follows the 'stigmergic' design principles.

## Conclusion

We believe that visualising participation into meaningful units, and according to learner preference adds something new to the pedagogy of scale. We have extended the FutureLearn platform design in terms of visualising 'trends' in the user generated comments and believe that this development could be further improved by embracing hashtags, folksonomies and developing the stigmergic design paradigm. Further research should examine in more depth using an interview methodology what specific impacts the CDT activity is having on learning in order to develop and embed it more effectively into pedagogy suited for MOOCs.

## References

- Chua, S.-M., Tagg, C., Sharples, M., & Rienties, B. (2017). Discussion Analytics: Identifying Conversations and Social Learners in FutureLearn MOOCs. *MOOC Analytics: Live Dashboards, Post-Hoc Analytics and the Long-Term Effects*, 36–62.
- Dron, J. (2006). The way of the termite: a theoretically grounded approach to the design of e-learning environments. *International Journal of Web Based Communities*, 2(1), 3. <https://doi.org/10.1504/IJWBC.2006.008611>
- Elliott, M. (2016). Stigmergic collaboration: A framework for understanding and designing mass collaboration. In *Mass collaboration and education* (pp. 65–84). Springer.
- Fischer, G. (2011). Understanding, fostering, and supporting cultures of participation. *Interactions*, 18(3), 42–53.
- Kizilcec, R. F., Piech, C., & Schneider, E. (2013). Deconstructing disengagement: analyzing learner subpopulations in massive open online courses. In *Proceedings of the third international conference on learning analytics and knowledge* (pp. 170–179). ACM.
- Tubman, P., Oztok, M., & Benachour, P. (2016). Being social or social learning: A sociocultural analysis of the FutureLearn MOOC platform. Presented at the The 16th IEEE International Conference on Advanced Learning Technologies, Austin, Texas: IEEE.

# Revision Analysis of Students' Position-Time Graphs

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**Abstract:** This research investigates the types of revisions students make to position-time graphs they construct. In our online graphing unit, students construct position-time graphs and then revise their graphs after receiving various forms of feedback. We examine how and why students attempt to revise their graphs, finding that students continue to have difficulty with constructing and revising position-time graphs. We then suggest areas for support in the future design of guidance for graph construction.

## Objectives

Interpreting and constructing data visualizations is a skill necessary for scientific literacy since it allows for the elucidation of patterns and underlying processes and helps to reveal correlations between events (Friel et al., 2001; Wu & Krajcik, 2006). Construction and revision of graphs are important practices, however middle school students are rarely asked to interpret, let alone construct, graphs in science classes (Boote, 2012). Position-time graphs are particularly difficult for students, and many students interpret graphs as pictorial representations of an event rather than a relationship between the two variables on the axes (Brasell, 1987). This study looks at types of revisions students make to their position-time graphs after completion of our online graphing unit in order to determine where further guidance is needed.

This study employs a Web-based Inquiry Science Environment (WISE) unit, titled Graphing Stories, which was designed according to the Knowledge Integration (KI) framework, a constructivist framework that involves eliciting and building off of students' prior knowledge (Linn & Eylon, 2011). Students' issues with interpreting graphs often come from a difficulty in connecting the significance of graphical features, such as scale, slope, and direction of lines, to the thing they represent in reality. The KI framework encourages making these connections in our curriculum by eliciting students' prediction graphs (their initial ideas), giving them guidance that helps them to distinguish between ideas, and then prompting them to revise.

## Methods

Two teachers from one middle school (62% non-white, 22% free/reduced lunch, 12% ELL) participated in this study, with a total of 10 classes of 8<sup>th</sup> grade students (N=231). Students completed the 5-day Graphing Stories unit during 50 minute class periods. Students worked in collaborative workgroups assigned by their teachers, mostly pairs with a few students working individually. Students completed the pretest one day before beginning the unit, and the posttest one day after completing the unit. Both pre and posttest were completed individually.

The online Graphing Stories unit is designed as an introduction to interpreting and constructing data visualizations, addressing several NGSS science and engineering practices (NGSS Lead States, 2013). The curriculum focuses mainly on constructing and interpreting position-time graphs, and includes animations that match up to student-constructed graphs to give visual feedback. Students construct graphs with various graphing tools, and have several opportunities to revise their graphs after receiving various forms of feedback. For this study, we focus on the types of revisions students made on a posttest item that asks them to construct a position time graph and then revise their graph after receiving guidance. The prompt states: "Karim wanted to bike up a big hill in his neighborhood. He went slowly up the steep hill, then really fast on the way down the other side. Use the graph below to sketch his ride. Think about the different speeds he went during his ride." Students then examine and evaluate graphs created by two fictional students before revising their own graph. After making revisions, students are prompted to explain what they changed about their graph and why.

## Results

Students' graph revisions for the assessment item were categorized into six different groups based on aspects of the graph that they changed (Figure 1). Only 15% of students (N=35) correctly drew the graph, and had no need to revise. Of those that did not correctly draw the graph, many (N=85, 36%) chose not to revise their graph, generally citing that they believe they were already correct despite their graphs going back to the starting position. About 20% of students (N=48) revised the slope of their graph, either correcting the speed or making difference between the two speeds more apparent. Many students needed to revise the direction of their line, but failed to recognize their error, keeping their "graph-as-picture" representation.

Category (with student explanation)	Initial Graph	Revised Graph
<b>Slope: N=48 (20.8%)</b> I changed when Kareem went up because he must have went slower going uphill and faster going down.		
<b>Direction: N=24 (10.4%)</b> I Change the graph so that it represents the distance is the y axis. I made these changes because my graph used to say he went back to the same place, I want it to show that he went somewhere.		
<b>Slope and Direction: N=5 (2.2%)</b> I change the two points because the graph before shows him goes up hill very fast and down hill very fast		
<b>Arbitrary: N=34 (14.7%)</b> I got rid of the small space of time where he isn't moving at the top of the hill.		
<b>No Revision, Incorrect: N=85 (36.8%)</b> <b>Correct, (no revision): N=35 (15.1%)</b>		

Figure 1. Graph revision categories with student examples about the reasoning behind their change and percentages (left column); one example for each category showing initial graph (center) and revised graph (right).

## Significance of study

Graphing is an important skill, but students are rarely asked to construct, let alone revise, graphs. These results show that students need further guidance to recognize position-time graphs as a relationship between these two variables rather than a drawing of what is happening. Students also need practice evaluating their own work for correctness, in light of new information they have learned. In developing guidance, we should specifically target the relationship between line direction and position as a concept to emphasize.

## References

- Boote, S. (2012). Assessing and understanding line graph interpretations Using a scoring rubric of organized cited factors. *Journal of Science Teacher Education*, 1–22. doi:10.1007/s10972-012-9318-8
- Brasell, H. (1987). The effect of real-time laboratory graphing on learning graphic representations of distance and velocity. *Journal of Research in Science Teaching*, 24(4), 385-395.
- Friel, S. N., Curcio, F. R., & Bright, G. W. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications. *Journal for Research in Mathematics Education*, 32(2), 124–158. doi:10.2307/749671
- Linn, M., & Eylon, B.-S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. New York: Routledge.
- Wu, H.-K., & Krajcik, J. S. (2006). Inscriptional practices in two inquiry-based classrooms: A case study of seventh graders' use of data tables and graphs. *Journal of Research in Science Teaching*, 43(1), 63–95.



# Research as Learning from Youth: Leveraging Collaborative Digital Tools to Position Youth as Experts on Themselves

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**Abstract:** This paper explores collaboration in a co-research team including teen interns and traditionally-credentialed adult researchers. Through collective redesign of roles and methods, the team leveraged common cloud-based collaboration and productivity tools to support positioning teen interns as expert researchers on themselves. Digital youth practices and formal research conventions were hybridized into a new set of “syncretic” research practices.

## Introduction

CSCL research draws from a diversity of approaches, spanning a wide continuum of methodologies and theoretical underpinnings (Jeong and Hmelo-Silver, 2010). In most CSCL research, the theoretical approach, research methods, and analysis are designed and undertaken by traditionally-credentialed adult researchers. Building upon work that researches “with” participants, instead of “on” participants (Bang and Vossoughi, 2016; Gutiérrez and Jurow, 2016; Kirshner, 2015), our work seeks to reimagine the traditional assignment of power and expertise in research relationships, while leveraging common collaborative digital tools for learners (university researchers) to collaborate with experts (youth interns). This paper represents the collective research and writing of a co-research team comprised of members traditionally positioned as both “participants” and “researchers.” To clarify and delineate roles, the use of “we” in this paper represents the voice of the traditionally-credentialed adult researchers, except for youth-written sections indicated by *italics*.

## Background, theoretical, and experiential approach

This project is part of a larger US NSF-funded cyberlearning research project seeking to create authentic contexts for young adults’ engagement in artifact-oriented, technology-based, science-data journalism. The specific context explored for this paper was an out-of-school, paid summer internship for 15 high school students at a Midwestern University. Youth interns (1) designed science data infographics for publication; and (2) conducted self and peer research as co-researchers within the multi-institutional partnership. This self and peer research served as the primary data collection for the internship, and youth co-researchers maintain refusal and co-authorship rights to research products directly derived from their work. Adult co-researchers served as internship program facilitators and as data managers and archivists of the youth-generated data and analysis.

### Theoretical approach of adult co-researchers

We approach learning and identity development from a sociocultural perspective, drawing on communities of practice (Wenger, 1998), notions of mediated action (Wertsch, 1998), and trajectories of identification (Wenger, 1998). We approach research as a form of learning, as CSCL when mediated through digital tools, wherein we foster youth agency and position ourselves as novices apprenticing to the domain, community, and practices of youth. Research as learning with youth is supported by symmetrical dialogue between youth and adults, fosters social relationships among the entire research team, and makes intangible cultural tools more observable (Tabak & Baumgartner, 2004). Youth have “funds of knowledge” that they have accumulated over time (González, Moll, & Amanti, 2005), and we position these funds as valuable expertise and students as brokers of this expertise.

### Experiential approach of youth co-researchers

We believe that learning happens every day, all the time, in and out of school. We learn from friends, family, media, experiences, and, yes, school. The knowledge that “counts” for teenagers is usually the kind given to us by adults, and we are judged by how well we can repeat it. However, we are far more complex than our collective tests, report cards, and ACT scores could ever indicate. In schools, youth culture is seldom treated as important—in fact, it is often devalued as “distracting” and “off topic,” and we are told that it has no place in learning. As teenagers, we are constantly positioned as “who we will become” after some magical undefined period of

“adulthood” suddenly grants us the wisdom implied in the statement “when you’re older, you’ll understand.” Adults normally expect us to accept their words as “expertise,” unquestioned by our own experiences and knowledge. We find it puzzling that research that tries to understand our thinking process ignores so much of it.

## Syncretic practices

During the summer internship, youth and adult co-researchers collaboratively designed and refined a set of “syncretic” research practices (Gutiérrez and Jurow, 2016), merging everyday youth communicative practices (the way interns naturally annotated media, wrote about themselves, used humor and sarcasm) and professional practices (found in research discourse and action). Youth interns communicated with peers and the adult research team, documented, annotated and reflected on daily activities, thinking processes, struggles and problem-solving strategies throughout the summer. This began with individual self-structured research logs and culminated in “Self-Case Videos,” narrated slideshows drawn from individual and collective datasets. Figure 1 details how everyday digital youth communication practices merged with formal research conventions in syncretic research practices. At left are the formal research conventions and practices, and at right are the youth practices and conventions with small visual examples. The middle column indicates the syncretic practices that emerged.

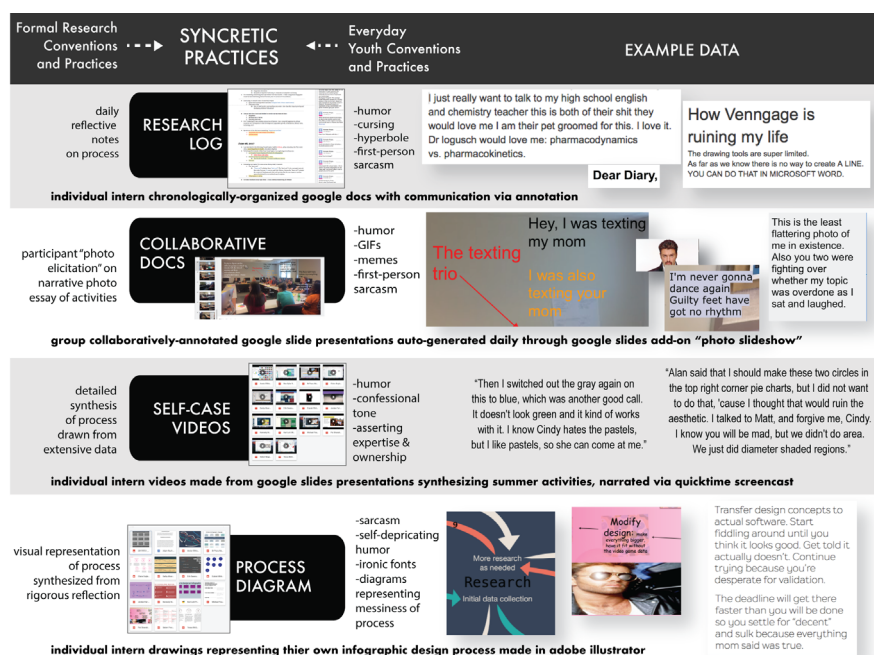


Figure 1. Syncretic Research Practices.

## References

- Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and Instruction, 34*(3), 173–193.
- boyd, d. m. (2008). *Taken out of context: American teen sociality in networked publics*. Berkeley: University of California Press.
- González, N., Moll, L. C., & Amanti, C. (2005). *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. New York: Routledge.
- Gutiérrez, K. D., & Jurow, A. S. (2016). Social design experiments: Toward equity by design. *Journal of the Learning Sciences, 25*(4), 565–598.
- Jeong, H., & Hmelo-Silver, C. E. (2010, June). An overview of CSCL methodologies. In *Proceedings of the 9th International Conference of the Learning Sciences-Volume 1* (pp. 921-928). Chicago: ISLS.
- Kirshner, B. (2015). *Youth activism in an era of education inequality*. New York: NYU Press.
- Lesko, N. (1996). Denaturalizing adolescence: The politics of contemporary representations. *Youth & Society, 28*(2), 139-161.
- Tabak, I., & Baumgartner, E. (2004). The teacher as partner: Exploring participant structures, symmetry, and identity work in scaffolding. *Cognition and Instruction, 22*(4), 393–429.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.
- Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

# **Mezclado: History of our Neighborhoods in Augmented Reality**

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**Abstract:** We held two years of community meetings where we iteratively designed and prototyped a community augmented reality app. We aim to reimagine two neighbourhoods to overcome stigmatization and change the perspectives. This design objective motivates our augmented reality history app.

## **Introduction**

Experiences outside the classroom inform what individuals believe about the past (Wineburg, 2001). Over the last two years, we engaged our communities in a process of history making through the design and testing of an augmented reality (AR) experience. Our stated mission is 1) to counteract the effects of community and racial stigmatization by demonstrating the positive assets of the communities to residents and to others from outside the neighborhoods; and 2) to build ongoing collaboration between cultural and ethnic groups that are too often separated, toward the increased mutual understanding, respect, and support that will contribute to long-term constructive social change.

## **Origin of the project**

Nine African American and Latinx graduates of the nine-month Multicultural Leadership Academy hosted by the Latino Policy Forum conceived the project. The Academy focused on creating collaborative relationships between African Americans and Latinx to overcome significant historical divisions between the groups and create a positive force for social change. After graduating, the team conceived of this project, and obtained the support of the Field Museum, which had been a technical advisor to the Academy, and the Chicago Park District, which is sponsoring a project to engage communities in the stewardship of natural areas in urban parks.

## **Frames and discourse**

When children make games, as in Vygotsky's (1978) depiction, they assign new meanings to common objects. For example, behind the couch becomes the robbers' den. The broomstick becomes the cowboy's horse. Through these sign manipulations, we map meanings of one social setting onto another imagined place. This remapping is the heart of creating an augmented reality, when applying the lens of figured worlds (Holland et al., 1998). New digital artifacts are placed into space to remap their meanings for audiences. The process has a dissociative element. People learn to "detach themselves" (Holland et al., 1998, p. 50) from their experienced physical surroundings and enter this imagined world. In this world, people use collectively developed signs and symbols (Vygotsky, 1978). For example, a prop as simple as a stick might launch a child into a world as a cow wrangler riding horseback. In our implementation, I argue that the community remixes digital artifacts and imaginatively uses visual primitives. In other words, we symbolically remap our spaces to create an augmented space to tell the story of our neighborhoods.

## **Augmented reality**

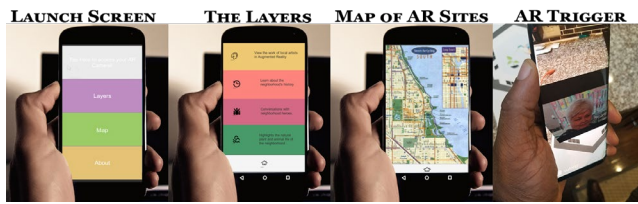
Augmented reality is an emerging technology that creates an enhanced image or environment on electronic devices (smartphones, tablets, or goggles) by overlaying computer-generated images, sounds, and text on a real-world environment (New Media Consortium, 2014). The technology has been used in informal learning environments (Yoon, S., Anderson, E., Lin, J., & Elinich, K, 2017), including historical AR education (Harley, et al., 2018). We are prototyping an AR "app" that enables visitors to experience and interact with stories of history, cultural milestones, natural features, civic activism, and artistic inspiration not visible in the real landscape.

## **Research question**

Our question is, how can an AR app allow for new kinds of historical practices that can empower communities both by creating artifacts to reshape perceptions, and by using created artifacts to reflect on community space?

## **Results: Design based trajectory to date**

The app brought into the discussions "new narratives" around how connecting murals through the app can support deeper connections to community resources, and how AR triggers can challenge existing deficit beliefs about the community. The app contains five layers: history, art, environment, heroes, and English as a second language.



**Figure 1.** The launch screen, description of the five layers and map that shows where AR sites are located.

These layers interact, such that users can choose what they see at each site, while also seeing the overlapping frames that inform each other in the space. We have finished the second prototype with these layers. The user can explore the information provided in their chosen topic. When the user activates an AR trigger, shown on the right side of Figure 1, the trigger displays video and audio to discuss the history of the site.

In our second prototype, we framed our neighborhoods through semiotic remapping. When users arrive at AR sites, they hold up their phone to see the augmented elements appear on the phone screen. These elements overlay the image as seen through the camera. The elements can be video, audio, or 3D avatars of historical figures. These elements reframe the space, from one of every day to one with history built in.

In one section of the experience, we have users interact with an AR trigger that superimposes a video on the narrator's old street in Bronzeville. In a discussion of this experience one viewer changed his understanding how the place had changed. He discussed the history, but also created a new understanding. He saw that people created a place name to overcome a negative historical narrative. The connection of the video appearing in the place affected his understanding of both. This is the hope of *mezclado*, where imaginative pivots in lived space can shift our understanding of space. In this way we can mix reality in a way that reflects the lived reality of a place to more fully respect the process that brought us to our current neighborhoods.

## Augmented murals for deeper connection

Mural artists contribute to the contested history of neighborhoods. AR creates deeper links between the resources in our community, the narratives that shape our understandings, and the wider audience who might just pass by these aspects that define our past. We understand the history of a place differently after inserting AR into everyday experiences. With augmented reality we seek *Mezclado*. The artist's vision of linking the art on the street to online media for history is the work of our project. The artists connect the visual elements of the mural to the information about where it came from as a way to share history. The process of bringing together multiple signs and symbols re-imagines spaces and their history.

## Conclusion

We constructed two prototypes in two years and will continue to iterate our augmented reality experience. In our design based research, we see the possibility of meeting our goals to ameliorate the effects of community and racial stigma, and to increase collaboration between marginalized groups. This process contributes to how historical content is consumed and understood, deconstructed and re-imagined.

## References

- Harley, J. M., Lajoie, S. P., Tressel, T., & Jarrell, A. (2018). Fostering positive emotions and history knowledge with location-based augmented reality and tour-guide prompts. *Learning and Instruction*.
- Holland D., Lachicotte W. Jr., Skinner D., & Cain C. (1998). *Identity and agency in cultural Worlds*. Cambridge: Harvard University Press.
- New Media Consortium. (2014). *NMC Horizon Report: 2014 K-12 Edition*. Austin, Texas: The New Media Consortium.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher mental process*. ed. and trans. M. Cole, V. John-Steiner, S. Scribner & E. Souberman. Harvard University Press (original work published 1930–1935).
- Wineburg, S., Mosborg, S., & Porat, D. (2001). What can Forrest Gump tell us about students' historical understanding? *Social Education*, 65(1), 55-55.
- Yoon, S., Anderson, E., Lin, J., & Elinich, K. (2017). How augmented reality enables conceptual understanding of challenging science content. *Journal of Educational Technology & Society*, 20(1), 156.

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# Studying Computational Thinking Practices Through Collaborative Design Activities with Scratch

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**Abstract:** Previous studies have focused on examining individuals' computational thinking (CT) practices in varied learning contexts. This study aimed to expand the current framework of CT by investigating how CT is practiced through collaborative design activities with Scratch. We analyzed students' CT practices as a group in different design stages. By identifying the patterns of CT practices which emerged through collaborative design activities, this study informed how CT is socially practiced in small groups.

## Introduction

The notion of computational thinking (CT) is becoming increasingly important for all citizens in the digital age. Wing (2006) argues that computational thinking will be a fundamental skill by the middle of the 21st century, just like reading, writing, and arithmetic. CT entails a series of problem-solving processes, such as recognizing patterns, and systematically breaking down a problem, and then composing an algorithmic solution. Recent studies have begun to develop operational definitions or frameworks in order to make the concept of CT accessible to educators (e.g., Grover et al. 2014). Brennan and Resnick (2012) propose a new framework for studying computational thinking from three dimensions to provide a comprehensive understanding of CT. Particularly, CT practices involve 4 aspects: (1) experimenting and iterating, (2) testing and debugging, (3) reusing and remixing, and (4) abstracting and modularizing. They argue that the development of computational thinking is an interactive and reflective process in which learners create, revise, and share their creations during the learning process. Learners develop their CT through the processes of making and cultivating their knowledge based on their experiences.

Collaborative design activities are defined to be a knowledge creation process which involves students actively communicating and working together to create a shared view of joint design ideas and decisions (Hennessy & Murphy, 1999). Learning through collaborative design process has been proven to deepen students' content knowledge through practices and advance their problem-solving skills to solve complex and multifaceted problems (Hakkarainen et al., 2013). Many studies have focused on studying individuals' CT practices and development in varied learning contexts (e.g., Weintrop et al., 2016). However, little attention has been paid to computational thinking practice in a collaborative learning environment, focusing on how CT is socially situated and practiced through interaction (e.g., Chowdhury, 2015). In this study, we applied Brennan and Resnick (2012)'s CT framework to examine students' CT practices through collaborative design activities with Scratch, which involves planning and coding stages to extend the implication and understanding of CT.

## Methods

We conducted the pilot study in the after-school program in a suburban school district in a midwestern U.S. state, Indiana. The data were collected in two two-hour sessions in which nine 6<sup>th</sup> to 8<sup>th</sup> graders in three groups used Scratch to remix and design a game project collaboratively. Students had varied programming backgrounds and the groups were a mixture of novice to experienced students. The sessions were video-recorded and transcribed to examine students' computational thinking practices through collaborative design activities with Scratch. Scratch (<https://scratch.mit.edu/>) is a block-based programming language and is designed to enable users to learn computational concepts, while also including problem solving, creative learning, and systemic reasoning (Resnick et al., 2009). During the collaborative design processes, students used 3D printed Scratch blocks, papers, and pens to brainstorm and plan their project ideas and design elements (e.g., backdrops, game components) (planning stage), and then they moved to Scratch to implement their design (coding stage).

We used small group as the unit of analysis to examine students' CT practices through collaborative design activities. We applied Brennan and Resnick (2012)'s CT framework to investigate students' CT practices. The data were analyzed based on a qualitative coding process and coded with small segments to identify CT practices within the group. Additionally, in efforts to examine CT practices during collaborative design activities, we utilized iterative content coding to identify the patterns of CT practices throughout the design stages.

## Findings

Preliminary coding results showed that patterns of CT practiced emerged through the collaborative design processes. For example, all three groups showed a higher number of experimenting and iterating in the planning stage while they brainstormed the project. Particularly, we found that CT practices demonstrated different levels of complexity in different design stages (planning and coding). All three groups showed experimenting and iterating in both planning and coding stages; however, compared to the experimenting and iterating practices in the planning stage, students showed a deeper level of experimenting and iterating in the coding stage (see examples below). In the planning stage, students identified concepts of their project and developed a script to implement the design. In the coding stage, they were able to experiment and iterate their design by identifying the variables of the script and developing a plan to modify the variables. These two stages involved different levels of CT practice regarding experimenting and iterating. Examples below showed the excerpts which students applied experimenting and iterating in two design stages (planning and coding). The group was designing a maze game in which they tried to add moving obstacles (birds) to increase the difficulty of the game.

**Planning stage (off-screen, working with 3D-printed blocks, papers, and pens):**

- P1 Sarah: Okay, so we can start from here (point on the paper), so they can go either this way or that way  
P2 Zach: I think we can put a lot of birds (*Authors' Note (AN)*): *moving obstacles*) here...  
P3 Lisa: Here, in the middle.  
P4 Zach: Or here, something like that.  
P5 Sarah: Like make it (*one of obstacles*) disappears.  
P6 Zach: Or make it move slower. Maybe birds over there can move really fast...

**Coding stage (on-screen, working with Scratch):**

- C1 Zach: I think I will set it (*start point of the maze*) as 0 and we want to move it here. When the player hits the bird, he will go back to the original location, so that's the location I want. This is the end point. End point is...  
C2 Lisa: 212 and -25.  
C3 Zach: So you will move from left to right, and I want it move back to...  
C4 Sarah: -25  
C5 Zach: Something. They will move. That's really fast (check the sprite variable). So I want to change the time (*variable*) to make it slower.  
C6 Sarah: That makes sense.

## Discussion

The pilot study serves as a springboard to explore how computational thinking is practiced through collaborative design activities. This study was part of a larger study. The preliminary results supported that patterns of CT practices were emerged across two design stages. Particularly, students demonstrated different levels of CT practices in different design stages which inferred that different collaborative design activities might facilitate different level of CT practices. The results show great promise for future research to further investigate how different collaborative design activities promote different aspects and levels of CT practices, and to what extent that the design of these activities may advance collaborative CT practices.

## References

- Brennan, K., & Resnick, M. (2012, April). New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the American Educational Research Association, Vancouver, Canada* (Vol. 1, p. 25).
- Chowdhury, B., Bart, A. C., & Kafura, D. (2018, February). Analysis of Collaborative Learning in a Computational Thinking Class. In *Proceedings of the 49th ACM Technical Symposium on Computer Science Education* (pp. 143-148). ACM.
- Grover, S., Cooper, S., & Pea, R. (2014, June). Assessing computational learning in K-12. In *Proceedings of the 2014 conference on Innovation & technology in computer science education* (pp. 57-62). ACM.
- Hennessy, S., & Murphy, P. (1999). The potential for collaborative problem solving in design and technology. *International journal of technology and design education*, 9(1), 1-36.
- Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, 25(1), 127-147.
- Webb, N. M. (2013). Information Processing Approaches to Collaborative Learning, in In C. E. Hmelo-Silver, C. A. Chinn, C. Chan, & A. M. O'Donnell (Eds.), *The international handbook of collaborative learning* (pp. 19-40). New York: Routledge.

# Computer-Supported Collaborative Learning and Learning Sciences Research in EducMap

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**Abstract:** This study examined the positions of Learning Sciences (LS) and Computer-Supported Collaborative Learning (CSCL) research in educational research using EducMap, a map of global educational research. LS/CSCL research has a presence in about one third of educational research, a substantial presence given its relatively short history.

## Introduction

Learning Sciences (LS) and Computer-Supported Collaborative Learning (CSCL) seek to advance sciences and practices of learning. They have a relatively short history compared to educational research at large, but have been actively expanding its impact and relevance. In this paper, we examined the place of LS and CSCL in educational research using EducMap, a map of bibliographical clusters in educational research.

## Methods

EducMap was constructed using a bibliographic coupling technique analysis. Educational research papers were extracted from Scopus and were linked when they share at least two references. This resulted in a map of 19 research clusters that differ in their core references (Jeong, Lund, Grauwin, & Jensen, in preparation). LS and CSCL core papers were identified based on the papers listed in syllabi and webinar sections of the NAPLES site and recent reviews on CSCL. Removing overlapping papers, the LS core paper list contains 452 papers and the CSCL core paper list contains 251 papers in total (Jeong & Kim, 2018). We located clusters in which these LS and CSCL core papers appear in one of the key places of the cluster (e.g., the top 15 most cited references or in the top 10 more representative or most cited papers within the cluster). We identified these cluster as LS and/or CSCL clusters, but note that this does neither mean that the respective fields “own” the clusters nor the absence of another field. They are only one of the many key references associated with the clusters. EducMap is available for three time periods (i.e., ‘2000-2004’, ‘2005-2009’, ‘2010-2014’) at the moment, but the current paper reports on the second period in which CSCL was being established as a field with the first publication of *ijCSCL* in 2006.

## Results

Of the 19 clusters in EducMap, seven clusters were identified as LS, two of which were also identified as CSCL (Figure 1). LS/CSCL research has a presence in about one third of the clusters in this period, a substantial presence given its relatively short history. What are the clusters of research in which LS or CSCL core papers have a presence? The biggest LS cluster is the Learning Systems cluster. Papers in this cluster address a diverse set of issues from language learning, professional development, and/or identities, and yet are closely connected by a set of shared references. References about socio-cultural perspectives (e.g., Lave & Wenger, 1991) were visible, suggesting that sociocultural theory is serving as a theoretical background to papers in this cluster. The next biggest LS cluster is the Motivation cluster. It mainly consists of papers that addressed goal orientation, development of interests, among other things, and tend to ground their research on theories of social learning and motivation (e.g., Bandura, 1997; Dweck & Leggett, 1988). The School Building cluster, the next biggest LS cluster, tends to consist of papers about inquiry learning, scientific argumentation, and technology, among other things. Consensus documents such as National Science Education Standards were highly cited in this cluster. The rest of the LS clusters appear to be about medical education with an emphasis on problem-based learning (PBL) and teacher training.

Two clusters, Cognitive Systems and Internet, were also identified as CSCL clusters, that is, both LS and CSCL core papers appeared in these clusters. The Cognitive Systems cluster is interested in CSCW and learning systems with emphasis on animated models, computer-based instruction and expertise-reversal effects. References related to cognitive load theory and multimedia learning were highly cited in this cluster. As for the Internet cluster, research addresses topics related to computer-mediated communication, asynchronous online discussions, as well as content analysis methods. Papers related to communication theories (Short, Williams, & Christie, 1976) and content analysis were highly cited in this cluster, suggesting a close link between content analysis methods and online communication.



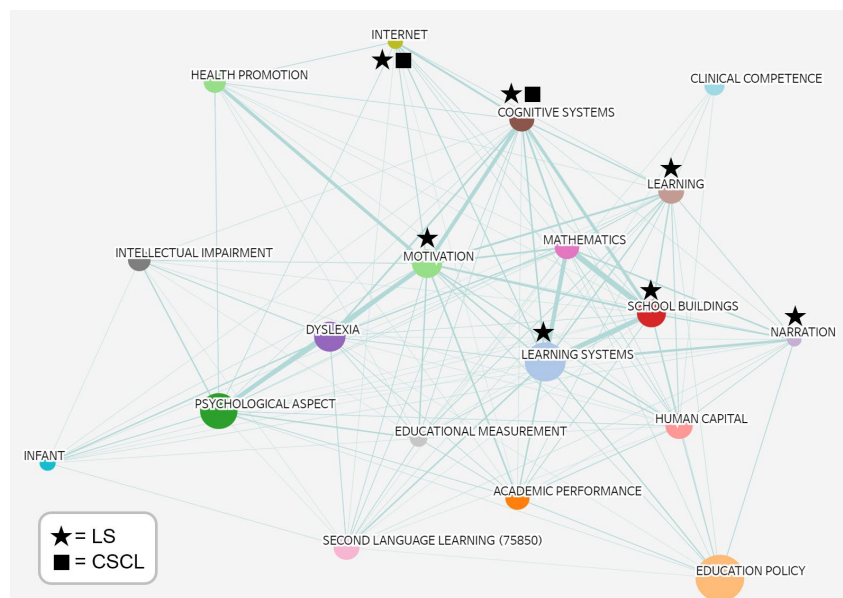


Figure 1. LS and CSCL clusters on EducMap during 2005-2009.

## Discussions

The results showed that seven out of the 19 research clusters in educational research were classified as LS and/or CSCL clusters during 2005-2009. LS/CSCL research has a strong presence in clusters that emphasize sociocultural theory, science education, motivation, and teacher training. A strong presence in such clusters are aligned with the missions of the fields, and are encouraging. At the same time, LS/CSCL research was not clearly visible in other clusters. LS/CSCL research does not need to have strong presence in all educational research, but a lack of presence in clusters that emphasize educational policy, and disciplinary learning other than science education is somewhat unexpected because these are issues that LS/CSCL consider important. The LS/CSCL research community needs to make more concerted efforts to reach out and make connections in these research areas. This study is the first application of biographical coupling to LS/CSCL research. Cautions are needed in interpreting the results, but the results provided insights about the positions of LS and CSCL research in educational research as a whole. We hope this study sparks lively reflections and discussions about where future research efforts need to be directed to fulfill the missions of learning sciences and computer-supported collaborative learning.

## References

- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.
- Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological review*, 95(2), 256.
- Jeong, H., & Kim, J. (2018). Core research publications of Learning Sciences and Computer-Supported Collaborative Learning. In Ogata, H. et al. (Eds.) *Extended Summary Proceedings: 26th International Conference on Computers in Education* (pp.1-3). Philippines: APSCE.
- Jeong, H., Lund, K., & Grauwlin, S. (in preparation). Knowledge bases of educational research.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation* (Vol. 521423740). Cambridge: Cambridge university press.
- Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. John Wiley and Sons: London.

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# Using a Resource Activation Lens to Understand Classroom Enactments of Computationally-Based Science Curricula

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**Abstract:** In this study, we examine how teachers use existing resources to enhance their teaching practices in a computationally-based science curriculum. We used a theoretical framework that examined how two teachers differentially activated material, cultural, social, and symbolic resources in different teaching contexts. This led to differing instantiations of their curricula and ultimately differing student learning outcomes. We discuss implications for this research in terms of the qualities of implementation that need to be emphasized in professional development activities.

## Introduction and theoretical considerations

Studies on reforming science teaching in urban schools stress the need to design high-quality computationally-based curricula (Denning, 2017). Due to a lack of administrative support to teach inquiry-based science, teachers in urban schools need to have opportunities to acquire support elsewhere (Barton & Berchini, 2013; Furman et al., 2012). Furthermore, despite the importance of collaboration between teachers for lesson planning and delivery, teachers in urban schools often become isolated (Vangrieken et al., 2015) and are not able to find experts to support curricular reform efforts (Fischer et al., 2017). In previous research, we have written about the need to use social capital strategies to support teachers to adopt new curricula in urban contexts. Social capital is the garnering of resources from one's network, which is distinct from human capital that consists of the knowledge and skills each individual possesses. Using resource activation framework (Rivera Maulucci, 2010), we describe two cases in which the teachers show differential activation methods and abilities and the aspects of the teaching that more or less supported this activation. This study is guided by the following questions: (1) To what extent does activation happen? (2) Are there additional resources that need to be activated? and (3) What are the implications for activation of resources for professional development (PD)?

Rivera Maulucci (2010) describes a science teaching framework based on the activation of material, cultural, social, and symbolic resources in urban schools. In science teaching contexts, *activating material resources* could look like a teacher finding a short news clip to facilitate students' discussion about the application of science in the real world. *Activating cultural resources* could be a teacher participating in PD and adapting their lesson plans to their district's science vision. Whether and how the development of social networks and collaboration are encouraged in the teaching system falls under the category of social resources. A teacher's symbolic resources might be activated when the teacher is afforded some autonomy to design lessons using new pedagogy.

## Methods and context

Two high school science teachers, Emily and James, were voluntarily recruited in their second year of teaching for this study. Both teachers were trained in the same pre-service program in which the principal investigator taught and interacted with the teachers in course work. Emily taught ninth-grade biology in an independent school that was comprised of 25% underrepresented minority students and 47% low income. James taught ninth-grade chemistry in an urban public school that was comprised of 99% underrepresented minority students and 100% low income. Both teachers attended a two-week long PD workshop during the spring semester of 2017. As part of a larger design-based exploratory research study, the PD workshop was designed to help teachers develop mobile curricula for students to take scientific action in their community through an app programming tool called App Inventor. The workshop entailed content-based modules focusing on the App Inventor programming tool (week 1), and opportunity to design their own app projects and to construct curricula (week 2). Emily developed an eight-day lesson plan within an ecology unit to teach concepts related to the health of environmental streams, including analyzing and collecting data to make decisions about the water quality of their local stream. James developed five-day lesson plans for a water cycle unit to teach essential characteristics of the water cycle as part of environmental chemistry, including the investigation of water problems with drought or floods in their neighborhood and making apps to address water overabundance or shortage.

To answer our research questions, we collected data from four sources: (i) teacher's post-implementation interviews with 19 overarching questions to probe their experience and perspectives on the success of their implementation; (ii) classroom observations including classroom context, reports of the instruction and activities taking place, and their interactions with resources; (iii) lesson plans and worksheets that contained detailed information about the design of the curricula and classroom activities; (iv) students' app projects that contained additional information about how they applied what they had learned from the computational activities. We used a multiple case study methodology (Yin, 2017) to provide a rich description of our participant's resource activation. Since the study was exploratory and design-based, all data sources were qualitatively assessed and discussed by the project team.

## Findings

### Differences in activating material and cultural resources

The data from our study also revealed that teachers activated material resources to enhance cultural resources in their classrooms in different ways and with varying degrees of difficulty. For Emily, her very clear understanding of how she intended for the apps (material resource) to support content knowledge (cultural resource) influenced what she perceived as challenges and how she needed to activate support. The biggest challenge for Emily was finding out the best ways to teach App Inventor to students along different developmental paths so that they individually would have enough understanding of programming to complete the science activity she planned. After Emily revisited the PD materials, she created her own instructional materials to integrate. For example, after assessing the available PD resources, she found a recycling app, which is adapted from Hello Purr. Emily asked students questions about the purpose of each block in the app to familiarize them with the engineering design process. Then, she asked students to remix the app using at least two of the suggestions from the PD website. From the data, James showed a weaker understanding of how building and using apps could support his science instruction goals. His idea was to have students work in groups to create apps that addressed some problems related to water. That could mean tracking the users' water usage, educating the users about water crises around the world, or animating the water cycle. However, the actual implementation did not go as planned. On Day 1, James introduced the sample rock-scissors-paper (RSP) app and students followed James step by step. On Day 2, James distributed handouts that included different ideas that allowed students to remix the RSP app individually. On Days 3 through 5, students were asked to develop an app using the worksheets where they could write their app idea and draw a prototype. Unlike Emily, James was most interested in figuring out what to teach with App Inventor rather than how this material resource could be used to support students' content learning of the water cycle. Somewhere in the implementation of his lessons, James forgot his pedagogical goals (cultural resource), which led to computation focus-teaching in his classroom. This lack of contextualized resources for James to activate cultural resources precluded him from seeking and learning more about available and applicable science topics or ways to teach them like Emily did. Both teachers thought of ways to utilize PD resources to support student learning during their unit implementations; however, James's inability to situate the programming in his science curriculum limited the time to teach the science content.

## References

- Barton, A. C. & Berchini, C. (2013). Becoming an insider: Teaching science in urban settings. *Theory Into Practice*, 52(1), 21-27.
- Denning, P. J. (2017). Computational thinking in science. *American Scientist*, 105(1), 13-17.
- Furman, M., Barton, A. C., & Muir, B. (2012). Learning to teach science in urban schools by becoming a researcher of one's own beginning practice. *Cultural Studies of Science Education*, 7(1), 153-174.
- Vangrieken, K., Dochy, F., Raes, E., & Kyndt, E. (2015). Teacher collaboration: A systematic review. *Educational Research Review*, 15, 17-40.
- Fischer, C., Fishman, B., Dede, C., Eisenkraft, A., Frumin, K., Foster, B., & McCoy, A. (2018). Investigating relationships between school context, teacher professional development, teaching practices, and student achievement in response to a nationwide science reform. *Teaching and Teacher Education*, 72, 107-121.
- Rivera Maulucci, M. S. (2010). Resisting the marginalization of science in an urban school: Coactivating social, cultural, material, and strategic resources. *Journal of Research in Science Teaching*, 47(7), 840-860.
- Yoon, S. A., Yom, J. K., Yang, Z., & Liu, L. (2017). The effects of teachers' social and human capital on urban science reform initiatives: Considerations for professional development. *Teachers College Record*, 119(4), n4.
- Yin, R. K. (2017). *Case study research and applications: Design and methods*. Sage publications.

# Assessing Collaborative Online Inquiry and Social Deliberation in Digital Environments

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**Abstract:** We describe efforts to design and validate a digitally-based assessment of collaborative online inquiry and social deliberation using a digital virtual world platform with embedded supports for real-time collaboration. Cognitive validity studies were conducted to examine the collaborative prompts and the overall task, with 21 dyads participating in either Face-to-Face (FTF; n=5) or Computer-Mediated (CM; n=16) conditions. Quantitative results suggest the task captured variation in dyads' inquiry performances and processes.

## Assessment of 21<sup>st</sup> century skills: Online inquiry and collaboration

Critical thinking, complex problem solving, and collaboration are required 21<sup>st</sup> century skills for success in college and the workforce. Current large-scale assessments in the United States do not fully represent the range of 21<sup>st</sup> century skills associated with the complexities of digital literacy and information-based problem solving in collaborative, networked environments; thus, there has been increasing interest in the development of assessments that capture valid evidence of these constructs. This project aimed to develop and validate an assessment of students' collaborative online inquiry and social deliberation skills, using a digital environment for collaboration.

### Small-scale cognitive validity study

We developed an assessment of online inquiry skills in a collaborative context by adapting an existing individual scenario-based virtual world assessment task for use with dyads. Evidence-centered design (ECD) principles (Mislevy, Almond, & Lukas, 2003) were applied to expand our online inquiry construct definitions, evidence collection, and task designs to incorporate collaborative work (Coiro, Sparks & Kulikowich, 2018). This included adding explicit prompts to collaborate, delivered through a digital environment designed to support real-time remote collaboration (Hao et al., 2017). We conducted several small-scale studies to examine the utility and validity of the collaborative prompts and the collaborative task, with 21 dyads participating in either Face-to-Face (FTF) or Computer-Mediated (CM) conditions. We collected multiple sources of evidence of students' inquiry proficiency, including item responses, moment-to-moment actions (recorded in log files), and students' real-time conversational dialogue (audio/video, text-based chat) as they worked collaboratively to complete the online inquiry task. Here, we present preliminary quantitative evidence of task performance.

## Methods

### Participants

Participants were rising or current 9<sup>th</sup> and 10<sup>th</sup> grade students (mean age=14.8 years, range: 14-16) in the Northeastern U.S. Altogether 21 dyads (42 individuals; 27 females, 15 males) participated across four rounds of data collection, in FTF (n=5) and CM (n=16) conditions, with CM groups being divided across data collection phases, including play testing (n=5), in-school tryouts (n=6), and laboratory-based tryouts (n=4).

### Collaborative virtual world task

The collaborative scenario-based virtual world research task engaged dyads in locating, evaluating, reading, and synthesizing information from multiple sources by incorporating evidence from those sources into an overall response to an inquiry question (i.e., whether or not an artifact should be placed in a museum based on its historical accuracy). The task has three phases (see Coiro et al., 2018): *Setup* (scenario and task introduction), *Free Roam* (exploring, gathering and evaluating available resources), and *Conclusion* (apply information from collected sources to construct an overall response). Dyads also completed an *Oral Presentation Task* summarizing their overall conclusions and using information from key resources to support their reasoning. Responses and actions in the task were scored based on ECD documentation (e.g., credit for correct answers or for actions that move students closer to a correct solution to the inquiry task), yielding a total of 87 points, with subscores computed by

task phase (Setup = 12 points, Free Roam = 51 points, Conclusion = 24 points) and by inquiry construct (Planning = 6 points, Locating = 22 points, Evaluating = 35 points, Synthesizing = 24 points).

## Preliminary results

### Quantitative analysis

Mean scores for the total task, task phase (Setup, Free Roam, and Conclusion), as well as proportion correct for each inquiry subskill ( $P+$ , i.e., raw score divided by maximum points per subskill of Plan, Locate, Evaluate, and Synthesize) and total score are presented (see Table 1). Performance varied across the dyads, with scores in the Free Roam phase (i.e., locating and evaluating tasks) showing greatest variability. Conclusion Phase/Synthesis subscores also varied, in part because some dyads did not finish. Altogether 17 of 21 dyads completed the main task, and 12 of 21 completed the culminating oral presentation task. The task captured variability in inquiry scores.

Table 1: Mean Scores (Standard Deviations in Parentheses) and Subscores by Task Phase and Inquiry Subskill

Condition	N	Total Scores (max=87)	Setup (max=12)	Free Roam (max=51)	Con-clusion (max=24)	Total Score ( $P+$ )	Plan ( $P+$ )	Locate ( $P+$ )	Evaluate ( $P+$ )	Synthesize ( $P+$ )
FTF- Playtest	5	54.30 (7.18)	9.00 (0.79)	26.00 (7.72)	19.30 (1.89)	.62 (.08)	.83 (.12)	.59 (.17)	.49 (.14)	.80 (.08)
CM- Playtest	6	49.67 (9.30)	9.58 (0.80)	24.92 (5.48)	15.17 (6.64)	.57 (.11)	.86 (.13)	.54 (.18)	.50 (.08)	.63 (.28)
CM- School	6	43.83 (11.47)	9.00 (1.48)	23.67 (4.63)	13.40 (4.60)	.50 (.13)	.86 (.07)	.58 (.11)	.42 (.09)	.56 (.19)
CM-Lab	4	57.25 (4.99)	9.63 (1.11)	27.50 (4.14)	20.13 (2.43)	.66 (.06)	.79 (.21)	.60 (.10)	.55 (.09)	.84 (.10)
<b>Total</b>	<b>21</b>	<b>50.55</b> (9.74)	<b>9.29</b> (1.06)	<b>25.31</b> (5.41)	<b>16.75</b> (5.06)	<b>.58</b> (.11)	<b>.84</b> (.12)	<b>.58</b> (.14)	<b>.48</b> (.10)	<b>.70</b> (.21)

Note:  $P+$ : proportion correct, or the dyads' earned score divided by the maximum possible points for each skill.

## Discussion

Preliminary analysis of quantitative scores, capturing dyad's performance with collaborative online inquiry and social deliberation, revealed that the scenario-based virtual world task seems to elicit a range of performances from student dyads. Performance was best on planning and synthesis tasks, with moderate performance on evaluate and locate tasks. All dyads experienced more difficulty with locating and evaluating tasks, and several lost points due to inefficient or ineffective allocation of time across multiple resources in the task, such that some failed to finish in the allotted 2.5 hour timeframe. Overall, however, the preliminary results indicate that the inquiry task was feasible for students to use and presented an appropriate level of challenge. Relationships among collaborative processes, dyad characteristics, and the quantitative scores reported above will also be discussed during the poster presentation, with implications for future research on collaborative assessments of online inquiry and social deliberation, as relevant to the CSCL community and to the design of collaborative assessments.

## References

- Coiro, J., Sparks, J.R., & Kulikowich, J.M. (2018). Assessing online reading comprehension, collaborative inquiry and social deliberation across multiple sources and perspectives. In J.L.G. Braasch, I. Bråten, & M.T. McCrudden (Eds.), *Handbook of Multiple Source Use* (pp. 485-517). Routledge.
- Hao, J., Liu, L., von Davier, A.A., Lederer, N., Zapata-Rivera, D., Jakl, P., & Bakkenson, M. (2017). EPCAL: ETS Platform for Collaborative Assessment and Learning. *ETS Research Report Series* (RR-17-49), 1-14. doi:10.1002/ets2.12181
- Mislevy, R. J., Almond, R. G., & Lukas, J. F. (2003). A brief introduction to evidence-centered design. *Research Report 16-2003*. Educational Testing Service: Princeton, NJ.

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# Learning with Multiple Representations and Student Engagement in Secondary Education: A Preliminary Review of Literature

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**Abstract:** Research on learning with multiple representations and the need to develop students' representational competence has increased in recent years. However, studies rarely address instructional approaches to develop students' skills of learning with these resources. It is also the case that the nature of student engagement when they use representations in their learning is rarely examined. We report preliminary findings of a systematic review on the nature of student engagement when using multiple representations. Our analysis resulted in 4 categories of student engagement revealing various levels of learner agency. Results provide insight for research and practice in designing and understanding learning with multiple representations.

The ability to learn with multiple representations (MR) is an essential skill for secondary school students. In the context of science education, learning involves not only understanding concepts and scientific facts but also using the various representational tools and inscriptions that are needed to engage in the processes of scientific inquiry (Gilbert, 2008; Lemke, 1998). Lemke (1998) argued that textual descriptions are not sufficient to learn about science, engage in scientific inquiry and represent scientific understanding of a phenomenon. However, instructional approaches to develop learners' abilities to use multiple representations are limited. Furthermore, despite the complimentary nature of research on multiple representations and student engagement (Gebre, 2018), the two research foci progressed independently. This paper presents a preliminary systematic review of existing literature with the purpose of examining the nature and purpose of student engagement in learning with MR.

## Multiple representations and student engagement

Different researchers use different concepts to refer to the use of representations in learning such as "multiple representations" and "representational competence". In this paper, we build on Gebre and Polman's (2016) distinction and use "multiple representations" to refer to the various visual tools (e.g., graphs, drawings, images, text) students use in their learning. "Representational competence" refers to the abilities of the learners to understand, critique and learn with multiple representations (Gebre & Polman, 2016; diSessa & Sherin, 2000). The importance of multiple representations as tools of learning and communication has been highlighted in recent literature (Gilbert, 2008; Namdar & Shen, 2016; Wu & Puntambekar, 2012). For example, Namdar & Shen (2016) argued that the use of multiple representations in learning supports the development of argumentation in science education. However, instructional approaches for representational skills are rare (Wu & Puntambekar, 2012).

Defining student engagement as the nature, extent and quality of students' interaction with the learning context including materials, tools, activities and other people (Azevedo, 2006), we focus on two aspects of engagement: cognitive and agentic engagement. Cognitive engagement is students' involvement in deep learning strategies, complex cognitive activities and active learning processes. It relates to the nature of learning activities and the extent to which the activities are instrumental in fostering learners' abilities to deal with complex problems. Agentic engagement refers to the extent of learners' involvement in making constructive contributions to the flow of learning and instruction including, their agency to make decisions/choices as well as personalizing the learning experience to their needs and contexts (Reeve and Tseng, 2011). Cognitive and agentic engagement are important because studies showed that high engagement has been related to students' involvement in framing learning activities and processes (Schmidt et al., 2018). This study answers the question, "What is the nature of student engagement in learning with multiple representations?"

## Methods

We conducted a concurrent abstract search of three databases (ERIC, EBSCOhost and PsycInfo) using terms 'representation' OR 'visual' OR 'drawing' AND 'learning' OR 'achievement' OR 'outcome' AND 'high school' OR 'secondary school'. We used four inclusion/exclusion criteria: a) secondary education, b) MR as a main focus of the study and/or intervention, c) learners' direct interaction with representations and d) assessment of outcomes or satisfaction. Thirty-four articles were selected for further analysis or data extraction (27 in STEM areas, 5 language and arts and 2 in geography). Data extraction involved reading the methodology section of the studies and open-coding the nature of student engagement or interaction (when they use MR) with the purpose of understanding what learners were doing or required to do in the instructional process as reported in the studies.

## Results

Of the total 34 studies, only 16 (47%) involved the use of computers as tools of learning and representation (12 STEM, 3 language and arts and 1 geography). Only fifteen studies involved collaboration or group work among learners the remaining 19 studies focused on individual learning. However, collaboration did not depend on computer use (6 studies used collaboration without computers), nor did the use of computers guarantee collaboration among learners (7 studies involved collaboration with no computer use).

Our preliminary analysis resulted in four categories representing the variation in student engagement while using representations: learning from (N=14), manipulating (N=8), representing ideas or processes (N=11) and constructing complex representations (N=4). Note that the total of coded segments adds up to 37 this is because three studies involved more than one activity related to use of multiple representations.

“Learning from” involved the use of expert-generated representations by students in the learning process. What is expected of the learners is to understand, interpret, discuss or write about the representation. For example, Homer & Plass (2010) examined students’ learning from simulation diagrams with narration and iconic representations. “Manipulating” involved students in choosing variables and/or values to change in a given model or representation and observe the effects of their manipulation. Five of the eight studies coded as manipulation involved the use of computer in learning. “Representing” involved creating visual images, pictures or drawing to represent a specific idea or data. For example, Smajdek and Selan (2016) required students to create a drawing representing their understanding of a text (provided by teachers) within five minutes of reading. In most cases, teachers provide the task (sometimes including the variables involved). For example, a teacher can ask her students to represent a car in acceleration and students draw their understanding of a speeding car. Finally, “constructing” related to complex representations which involved defining the problem and variables, using evidence or data to support claims, organizing the data and constructing representations. McDermott & Hand (2013) engaged students in producing visualization-embedded writing in a chemistry class with subsequent creation of checklist to assess the quality of “embeddedness” in science communication (p. 226). Similarly, Gebre & Polman (2016) used multiple representations to foster young adults’ science literacy.

## Discussion

Multiple representations can serve both as learning and communication tools for students to understand phenomenon and express their understanding. However, the manner MR are deployed in learning design determines their role in fostering student-centered and complex learning. Learner agency and complex cognitive activities increase as the nature of student engagement progresses from “learning from” to “constructing” representations. However, the findings imply that learning design with MR has a long way to go in terms of addressing learner agency and attending to the tenets of student-centered approaches to instruction.

## References

- Azevedo, F. S. (2006). Personal excursions: Investigating the dynamics of student engagement. *International Journal of Computers for Mathematical Learning*, 11, 57-98. DOI 10.1007/s10758-006-0007-6
- Gebre, E. (2018). Learning with multiple representations: Infographics as cognitive tools for authentic learning in science literacy. *Canadian Journal of Learning and Technology*, 44(1), 1–24.
- Gebre, E., & Polman, J. L. (2016). Developing young adults' representational competence through infographic-based science news reporting. *International Journal of Science Education*, 38(18), 2667–2687.
- diSessa, A. A., & Sherin, B. L. (2000). Meta-representation: An introduction. *The Journal of Mathematical Behavior*, 19(4), 385–398. doi:10.1016/S0732-3123(01)00051-7
- Gilbert, J. (2008). Visualization: An emergent field of practice and enquiry in science education. In J. Gilbert, M. Reiner, & M. Nakhleh (Eds.), *Visualization: Theory & practice in science education* (pp. 3–24). Springer.
- Lemke, J. (1998). Multimedia literacy demands of scientific curriculum. *Linguistics & Education*, 10(3), 247–271.
- Namdar, B., & Shen, J. (2016). Intersection of argumentation and the use of multiple representations in the context of socio-scientific issues. *International Journal of Science Education*, 38(7), 1100-1132.
- Reeve, J. & Tseng, C. (2011). Agency as a fourth aspect of students’ engagement during learning activities. *Contemporary Educational Psychology*, 36, 257-267. doi:10.1016/j.cedpsych.2011.05.002
- Schmidt, J. A., Rosenberg, J. M. & Beymer, P. N. (2018). A Person-in-Context Approach to Student Engagement in Science: *Examining Learning Activities and Choice*, 55(1), 19-43. DOI:10.1002/tea.21409
- Smajdek, A. & Selan, J. (2016). The impact of active visualisation of high school students on the ability to memorise verbal definitions. *CEPS Journal* 6 (4), 163-186
- Wu, H. K., & Puntambekar, S. (2012). Pedagogical affordances of multiple external representations in scientific processes. *Journal of Science Education and Technology*, 21(6), 754-767.

# An Exploratory Study of Automated Clustering of Themes to Identify Conceptual Threads in Knowledge Building Discourse

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**Abstract:** In this study, we adopted Jaccard index and tf-idf without stop words to automatically cluster the ideas students discussed in on an online knowledge building platform called Knowledge Forum. We visualized the clusters, provided keywords that most represent the context of each cluster and compared the generated themes with manual coding themes. The results suggest that most of the generated themes were consistent with human coding results.

## Introduction

Knowledge Building advocates that students take collective responsibility for continually improving ideas and pursuing more coherent explanations as a community (Scardamalia & Bereiter, 2014). During Knowledge Building, students generate diverse ideas, build onto each other's ideas, and introduce new ideas to their community both face to face and in Knowledge Forum—a software environment developed to support Knowledge Building practice (Scardamalia, 2004). Developing an understanding of the themes that a class works on is the starting point of understanding the frontier of community knowledge.

Methods to identify meaningful semantic themes have been a focal area of research in CSCL (e.g., Suthers, Lund, Rosé, Teplovs, & Law 2013). In this study, we suggest that text classification approaches, which extract and represent important information from documents, have the potential to help identify broad themes in online discussions (Mu, Stegmann, Mayfield, Rosé, & Fischer, 2012). The Jaccard index also referred to as Intersection over Union, has been widely used for comparing the similarity between samples in automatic classification, citation analysis, information retrieval and so forth (Hamers et al., 1989). To help capture conceptual threads in students' Knowledge Forum discussions, we developed a note clustering tool adopting the Jaccard index. This tool creates automated visualizations of sentences with overlapping keywords as clusters, and we created a conceptual label for each thematic cluster. In detail, we explored whether automatically generated themes were consistent with human coding results of conceptual threads in the student discourse.

## Methods

The dataset analyzed in this study consists of 298 Knowledge Forum notes generated by grade 1 students (11 boys, 11 girls). Over the span of three months, students engaged in Knowledge Building discourse about the water cycle. Two researchers coded the Knowledge Forum notes into 15 conceptual threads (i.e., a group of notes which aim to address the same thematic issue). The manually coded conceptual threads were compared with the automated clusters generated by the note clustering tool used in this study.

The text classification processes mainly consist of five steps: 1) We manually spell-checked all the Knowledge Forum notes given the difficulty of automatically correcting the notes written by junior students. 2) We segmented the notes into sentences based on punctuations via the NLTK sentence tokenizer (Bird, Klein, & Loper, 2009). Then symbols, stop-words, and small sub-words were removed from the sentences (Patel, & Shah, 2013). Also, since most notes students wrote were related to water, we removed “water” from the analysis to achieve a clearer picture of other themes. 3) The lowest frequency for a word to be included into the analysis is two since a keyword needs to appear at least twice to form a connection with other sentences. 4) We connected similar sentences together to form a network using Jaccard index. The metric we used for similarity threshold is representing the number of intersection keywords across sentences out of all words used in the union of keywords between any two sentences. We set 3/5 as the threshold. 5) We performed clustering on the network formed. We use the Louvain Method (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008) for clustering nodes into what are known as communities in the network sciences literature.

We visualized the networks formed under this procedure using visNetwork, a package in R. The notes are represented using red dots and were connected using red lines. In order to summarize the context of each cluster, we extracted the top words used by notes within each cluster using the tf-idf method which highlights top words used by the cluster and removes highly frequent words used across the whole dataset. Each cluster summary was marked using a blue dot, and the size of the blue dot indicates the popularity of the cluster – the more sentences (red lines) in a cluster, the bigger the dot (as shown in Figure 1).

## Results

393 sentence units were segmented out of the dataset, and 136 keywords were kept in analysis. Figure 1 shows 16 clusters were formed by the tool. The two researchers identified 15 conceptual threads. Here, we qualitatively matched the two sources of clusters—the ones displayed outside of round brackets were generated by the tools while the ones inside the brackets were identified by the researchers: *water evaporates when it is hot (why does water evaporate, why can't you see water vapour)*; *evaporation makes clouds and rain (how does water vapour go back into water, rain, why does the earth need clouds/water)*; *clouds block vapor (where does water vapour go if there are no clouds)*; *clouds are light so they float (how does water vapour float, clouds' weight, how can water be so light)*; *the atmosphere stops clouds to go to space (the atmosphere)*; *the color of clouds (clouds' colour)*; *water freezes when the weather is cold (ice)*; and *meteorites hit the earth (where did water come from, can you make water)*. All the human coded themes were extracted by the note clustering tool except “groundwater.” Possible reasons for why this theme was not picked up were that students did not use enough overlapping keywords when discussing this topic or the proportions of overlapping words they used in sentences did not meet the chosen threshold.

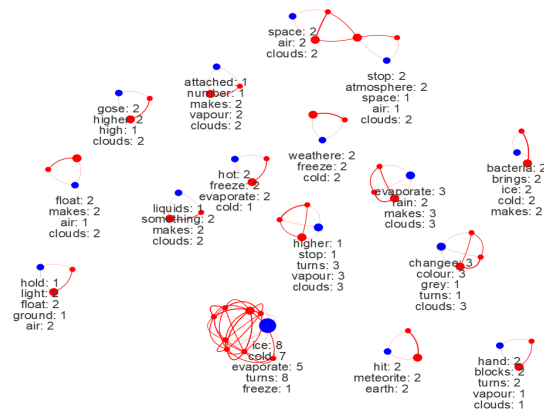


Figure 1. Automated clusters generated by the note clustering tool.

## Discussions and conclusion

We see this method as an option to speed up the manual process of connecting notes together. We imagine people applying this network method to a raw dataset to jump-start the connection process for students, summary process for teachers and analysis process for researchers. We noticed that clusters may represent the same theme due to different keywords used, different ways students wrote their ideas, and different combinations of ideas. For instance, the two cluster context summaries “ice, cold, evaporate, turns, freeze” and “whether, freeze, cold” are both related to the theme of “ice.” We also noted that the assumption of intersection of words misses out on words that are synonyms, such as “cold” and “freezing.” Ideally, we would consider these words to be the same unit and hence count it in our intersection, and only count once in our union. We are working on a method currently for this as future work.

## References

- Bird, S., Klein, E., & Loper, E. (2009). *Natural language processing with Python: analyzing text with the natural language toolkit*. " O'Reilly Media, Inc."
- Blondel, V. D., Guillaume, J. L., Lambiotte, R., & Lefebvre, E. (2008). Fast unfolding of communities in large networks. *Journal of statistical mechanics: theory and experiment*, 2008(10), P10008.
- Hamers, L. et al. (1989). Similarity measures in scientometric research: The Jaccard index versus Salton's cosine formula. *Information Processing and Management*, 25(3), 315-18.
- Mu, J., Stegmann, K., Mayfield, E., Rosé, C., & Fischer, F. (2012). The ACODEA framework: Developing segmentation and classification schemes for fully automatic analysis of online discussions. *International journal of computer-supported collaborative learning*, 7(2), 285-305.
- Patel, B., & Shah, D. (2013, March). Significance of stop word elimination in meta search engine. In *Intelligent Systems and Signal Processing (ISSP)*, 2013 International Conference on (pp. 52-55). IEEE.
- Scardamalia, M. (2004). CSILE/Knowledge forum®. *Education and technology: An encyclopedia*, 183-192.
- Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (2nd ed.), pp. 397-417. New York: Cambridge University Press.
- Suthers, D. D., Lund, K., Rosé, C. P., Teplovs, C., & Law, N. (2013). *Productive multivocality in the analysis of group interactions*. Springer US.



# Exploring Students' Self-Assessment on Collaborative Process, Calibration, and Metacognition in an Online Discussion Environment

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**Abstract:** Students need to accurately assess their performance on collaborative sense-making before employing strategies and making changes to improve their collaborative learning processes. In this study, one group of three undergraduate students who took part in five synchronous discussion in an online text-based learning environment was focused on as a case. The patterns of self-assessment, their calibration of understanding of learning goals, and inaccurate understandings were analyzed and discussed.

Collaborative skills are gaining prominence as the workplace becomes increasingly dependent on groups to solve complex, cross-disciplinary problems. According to Stahl (2017), group practices provide group members with opportunities that individual work cannot provide, where they can share knowledge and develop intersubjective sense-making. One critical competence that learners need to have to achieve better learning outcome is regulation. Learners with better self-regulated learning skills perform better academically (Azevedo, 2009). In collaborative learning activities, groups with higher regulation show less conflict and more productive processes. Self-assessment on both content knowledge and collaborative sense-making processes is critical to group success. In this study, we investigate the co-occurrence of students' self-assessment and their metacognitive reflection and aim to investigate the interplay between accuracy in individual self-assessments and group calibration as teams engage in metacognitive reflections over the five sessions in one semester.

Self-assessment is critical to students' self-regulated learning and also their lifelong learning (Harris & Brown, 2013). To improve accuracy of self-assessment, students' self-calibration of their decisions on performance over time and over different learning goals is needed. However, students' calibration is affected again by various factors, including students' actual performance level, feedback provided by instructors, and the degree of their sophistication in epistemological beliefs (Dunning, Heath, & Suls, 2004). We see calibration as a process of change that happens when students are engaged in metacognitive activities and adjusting their understanding of the assessing criteria, and argue that the process of calibration is enhanced when students are actively engaged in metacognitive activities both individually and as a group. To better understand the nested relation between self-assessment, calibration, and metacognition, we ask the following questions: 1. How does the group's average scoring accuracy of collaborative process change over time? 2. How does individual students calibrate their understanding of criteria over time as they engage in metacognitive activities? 3. What are the most commonly mistaken criteria?

## Methods

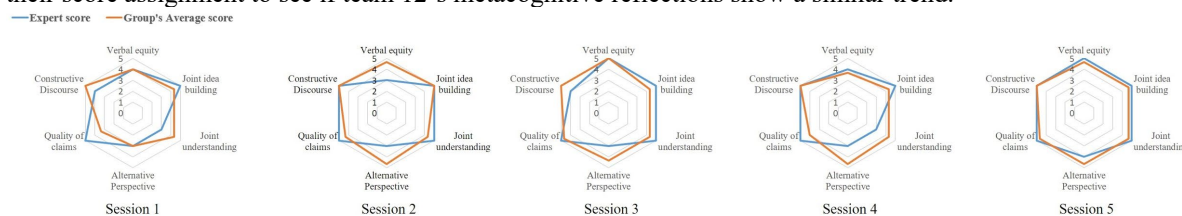
The study took place in a 15-week university level introductory online course in College of Information Sciences and Technology in a university in the Northeast United States in Spring 2016. We selected one team (Team 12) of three as a case. Same with other teams, team 12 answered questions about course materials before participating in online synchronous discussions in weeks four, six, eight, ten, and twelve. The online text-based discussion environment is called CREATE (*Collaborative Regulation, Enhanced Analysis, and Thinking Environment Prototype*). After answering reading questions, teams first plan their discussion. When they meet online, they discuss the course materials for around 90 minutes, move to the self-reflect session where they self-assess the discussion quality, and close with a group discussion on their individual reflections. Students use the same rubric for self-assessment with the one used by expert to assess group discussion quality. The rubric is a 5-point rating scales on six items (i.e. verbal equity, developing joint understanding, joint idea building, exploring alternative perspective, quality of claims, and constructive discourse; see more in Table 1 in Borge, Ong, & Rosé, 2018).

To answer the first question, we examined the students' group average scores as compared to expert scores. For expert scores, six items were averaged to produce an overall quality of collaborative communication competence. For students' group average score, after averaging each individual's quality of collaborative communication competence score, the quality scores from each student were then averaged to present group's overall average scores. To answer the second and third research questions, we analyzed the data of individual students self-reflections where they gave self-assessing scores and justification score on the item. Code "Match"

was assigned to students' justification that included direct or indirect explanation of item. Cases when students provided description of any other item, indicating misunderstanding or confusion about assessment criteria, were coded "Mismatch." "Other" refers to cases when students provided unrelated or general justification, or the justification was missing.

## Findings

Figure 1 of the radar plots of score changes (Blue: Expert score, Red: Groups' average score) shows an increased accuracy in terms of the group's self-assessment. However, we need to examine students' self-reflections about their score assignment to see if team 12's metacognitive reflections show a similar trend.



**Figure 1.** Quality of discussion assessed by expert and team 12 from session 1 through session 5.

Analysis of the individual reflections across five time points, the percentage of Match justification tend to improve, from 50% at session 1 to 61.54% at session 5. Percentage for students' Mismatch justification identified noticeably decreased as time goes by, from 27.78% at session 1 to 7.69% at session 5. However, the percentage for Other category varied from 21.88% to 36.36%.

A further focus on Mismatch reflections revealed that when students were asked to assess joint idea building, students frequently included the quality of claim (19.4%); when assessing alternative perspective, the most frequently confused criteria was identified to be joint idea building (18.2%); and when assessing verbal equity, quality of claims were identified in students' justification (11.8%).

## Discussion and conclusion

The present study examined students' self-assessments on collaborative processes as they engaged in group discussions, and how the nested calibration and metacognition is related to the accuracy of self-assessment. As shown in the findings, students improved in accuracy of assessing their discussion quality as their scores were better aligned with expert scores by session 5. Team 12 also showed calibration in their understanding of the rubric. The shown calibration in metacognitive activities matches the improved accuracy of the group's self-assessments, indicating that having students to reflect on their discussions for the self-assessment scores directly engages students in metacognitive processes, which contributes to both students' metacognitive competence and self-assessment accuracy.

Nevertheless, further work is needed to reflect all 12 teams' calibration accuracy over time on collaborative sense-making. With data from more groups, we would be in a better position to understand the complex interplay between calibration and metacognition, and how this interplay is related to self-assessment. Also, quality of claims are the most frequently confused item, meaning when asked to assess other items, students included criteria of quality of claims in their justification. This indicates the necessity of follow-up analyses about students' understanding in association with criteria, which may be expected to give an implication for the design of learning systems. Providing more explanations or visualizations as scaffolding in the activity that fade as students are more familiar with the environment is one way to address this problem.

## References

- Azevedo, R. (2009). Theoretical, conceptual, methodological, and instructional issues in research on metacognition and self-regulated learning: A discussion. *Metacognition and Learning, 4*, 87-95.
- Borge, M., Ong, Y. S., & Rosé, C. P. (2018). Learning to monitor and regulate collective thinking processes. *International Journal of Computer-Supported Collaborative Learning, 13*(1), 61-92.
- Dunning, D., Heath, C., & Suls, J. M. (2004). Flawed self-assessment: Implications for health, education, and the workplace. *Psychological Science in the Public Interest, 5*(3), 69-106.
- Harris, L. R., & Brown, G. T. (2013). Opportunities and obstacles to consider when using peer-and self-assessment to improve student learning: Case studies into teachers' implementation. *Teaching and Teacher Education, 36*, 101-111.
- Stahl, G. (2017). Group practices: A new way of viewing CSCL. *International Journal of Computer-Supported Collaborative Learning, 12*(1), 113-126.

# Intelligent Cognitive Assistants to Support Orchestration in CSCL

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**Abstract:** This design paper proposes an intelligent cognitive assistant framework that utilizes AI-based multimodal learning analytics for developing a teacher dashboard. Using six data streams, we suggest this design can extend teacher’s instructional capacity in technology-rich collaborative inquiry-focused science classrooms. We discuss how this tool can support teacher’s orchestration in relation to relevant learning practices in complex problem-solving activities in a CSCL environment.

## Introduction

Teacher orchestration is critical for supporting CSCL. It is defined as productively coordinating supportive interventions across many learning activities occurring at multiple social levels (Dillenbourg et al., 2009). Because it requires teachers to instantly facilitate a range of activities and resources at the same time, teacher orchestration is considered to be an exceptionally complex task (Prieto et al., 2018). Teacher professional development (PD) can be a promising solution; however, it often takes teachers away from the classroom. Traditional PD formats do not provide the most relevant and contingent support when teachers need it most (Jenkins & Agamba, 2013). Thus, we propose how an intelligent cognitive assistant in a teacher dashboard can provide just-in-time guidance. Employing learning analytics affords teachers opportunities to track students learning activities and extend their instructional capacity to provide contingent and adaptive teaching (Ferguson, 2012). In this poster, we outline the design principles of the *Intelligent Augmented Cognition for Teaching (I-ACT)* framework that uses AI-based multimodal learning analytics for developing a teacher dashboard.

## Using multimodal learning analytics for the design of I-ACT cognitive assistant

In inquiry-based CSCL environments, a core competency of effective teachers is classroom orchestration which ranges from engaging learners as both individuals and groups, establishing learning priorities, assembling instructional resources, supporting complex thinking, and enabling students to build connections between ideas (Prieto et al., 2017). In the collaborative learning environment, teachers are often asked to conduct multiple forms of learning activities which pose considerable orchestration load (Prieto et al., 2017). Tools for learning analytics seek to use data from learners and the classroom and promote awareness and reflection through collecting, analyzing, and synthesizing multiple data sources into visualizations (Ferguson, 2012). Several dashboards have focused on classroom orchestration and support for teachers to support collaborating groups such as TinkerBoard (Son, 2012) and Collaid (Maldonado et al., 2012). Typically, in these dashboards, activity information is visualized on a large display to capture learner performance and to deliver insight into collaboration among students using audio, physical, and positioning traces of student activity. Emphasis is placed on providing real time data visualizations including social interaction, time spent, or artifacts produced to enable teachers to detect when to intervene.

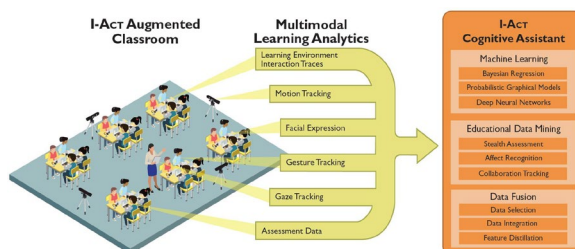


Figure 1. I-ACT Teacher augmentation in the classroom.

The I-ACT cognitive assistant will be designed to directly support K-12 science teachers by providing context-sensitive guidance. It will be driven by AI-based multimodal learning analytics (see Figure 1) from six data streams: learning environment interaction traces, motion tracking, facial expression tracking, gesture tracking, gaze tracking, and assessment data. First, I-ACT science classrooms will track students’ problem-solving

interaction data. I-ACT will track not only the location and movement of teachers and students in the classroom but also students' facial expressions, gestures, and gaze to supply a rich set of learner information. Additionally, I-ACT cognitive assistants will collect assessment data during the course of students' problem solving. Collectively, the multimodal learning analytics will guide teachers in effectively orchestrating science inquiry with a data-rich picture of student problem-based learning (PBL) and collaboration. During class, the I-ACT cognitive assistants will provide real-time recommendations and guidance to teachers to reduce orchestration load so that they can effectively scaffold learners throughout the full teaching workflow in science PBL through their laptop or tablet. For example, the I-ACT cognitive assistant will alert teachers to tell which students need assistance with the highest priority, what types of problem-solving and collaboration support strategies might be most effective, and when they need to pause activities to provide a mini lecture, either to particular students, to specific groups of students, or the whole class.

More specifically, I-ACT will reduce orchestration load across three phases of implementation: (1) prospective guidance, (2) concurrent guidance, and (3) retrospective guidance post-implementation. In prospective pedagogical guidance stage, I-ACT will provide "forward guidance" to plan successful classes and anticipate triggers that might lead to failure. The assistant will proactively suggest strategies and anticipate potential obstacles to manage orchestration load. Next, in the concurrent pedagogical guidance stage, I-ACT will help teachers with facilitation such as initiating inquiry, scaffolding problem-solving process, and pushing for deep knowledge construction. Classroom implementation of technology-rich inquiry puts an extremely high orchestration load on teacher performance so the assistant will be beneficial for teachers during this stage. Lastly, in retrospective pedagogical guidance stage, I-ACT will guide teachers in reflecting on their orchestration moves and help them make successful ones continue. It is a critical step to provide reflection space to make sense of what went well, what did not, and why, because what teachers encounter in the classroom is new. Further, the I-ACT cognitive assistants' prospective, concurrent, and retrospective guidance will be improved with the same multimodal data that was collected during class time in a tight feedback loop. This poster will present a design case of middle school students participating in a life science unit in which they learn about ecosystems. We test our design as students collaboratively engage with a problem scenario centered on an aquatic ecosystem that has become polluted as a result of human activity using the Crystal Island narrative game (Rowe et al., 2011), which generates highly granular problem-solving logs during three stages of orchestration.

## Conclusion

Although there has been a lot of research and development of learning analytics tools and resources over the last decade, much of the existing research and practical tools has not fully supported enabling and transforming teaching and learning practice, which is, in part, due to the lack of meaningfully developing these metrics in relation to relevant learning practices. I-ACT cognitive assistant will demonstrate a promising design case that can help teachers extend their teaching capacity to provide contingent and adaptive scaffolding in technology-rich inquiry teaching environment, where learning technologies support both student collaboration learning and PBL.

## References

- Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In *Technology-enhanced learning* (pp. 3-19). Springer, Dordrecht.
- Prieto, L. P., Sharma, K., Kidzinski, Ł., Rodríguez-Triana, M. J., & Dillenbourg, P. (2018). Multimodal teaching analytics: Automated extraction of orchestration graphs from wearable sensor data. *Journal of computer assisted learning*, 34(2), 193-203.
- Jenkins, S., & Agamba, J. J. (2013). The missing link in the CCSS initiative: Professional development for implementation. *Academy of Educational Leadership Journal*, 17(2).
- Ferguson, R. (2012). Learning analytics: drivers, developments and challenges. *International Journal of Technology Enhanced Learning*, 4(5/6), 304-317.
- Son, L. H. (2012) Supporting reflection and classroom orchestration with tangible tabletops. PhD Thesis.
- Maldonado, R. M., Kay, J., Yacef, K., & Schwendimann, B. (2012, June). An interactive teacher's dashboard for monitoring groups in a multi-tabletop learning environment. In *International Conference on Intelligent Tutoring Systems* (pp. 482-492). Springer, Berlin, Heidelberg.
- Rowe, J. P., Shores, L. R., Mott, B. W., & Lester, J. C. (2011). Integrating learning, problem solving, and engagement in narrative-centered learning environments. *International Journal of Artificial Intelligence in Education*, 21(1-2), 115-133.

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# Mediating Collaboration in History with Network Analysis

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**Abstract:** This poster discusses a promising collaboration platform to encourage students in co-constructing historical knowledge through a network visualization tool. The tool uniquely mediated collaboration at both the small and large group level in a big lecture format undergraduate history class. The findings demonstrated the tool mediated a specific sequence of collaborating processes at both levels and students' ability to see the historical relationships.

## Introduction

Novice history learners struggle to consume lengthy historical texts because they tend to see such texts as an established list of facts to memorize rather than as an interpretive argument supported by evidence (Wineburg, 1991). It is particularly challenging for them to grasp the connections between the many participants and events within the text. Given the length and scope of many historical texts, students can benefit from collaborating to divide the text into more digestible components, and then working together to construct an argument based on the entirety of the corpus. However, framing history as an interpretive account through collaborative effort is unusual in undergraduate history classrooms because the large lecture format that is common to many undergraduate survey classes makes it challenging to coordinate students' activities. In this poster, we suggest that network visualization tools can offer a promising collaboration platform to encourage co-construction of the connections within historical texts. The aim of this study is to provide a deeper understanding of how a network analysis tool called Net.Create (see Figure 1) might function to mediate students' collaboration at both the small group and whole class (i.e., large group) level as they explore the details of a history text through network creation and analysis.



Figure 1. Net.Create interface and students' constructed network.

## Net.Create as a tool for supporting collaborative learning

From the lens of sociocultural theory, learning, thinking, and acting are mediated or transformed by tools and signs (Roth & Lee, 2007). The study of mediated action is concerned with both individual's active use of cultural tools and the mediator's influence on individual's use. Therefore, mediators both shape and are shaped by the individual (Danish, 2014). In this study, we positioned Net.Create as a mediating tool to scaffold student collaboration across the small and large group level and to provide a meaningful joint task that affords discussion. Net.Create is a network analysis tool that supports student entry of information about relationships among person, group, event, or place in historical texts into a database of connections that is then visualized live as each new entry is added. Network analysis can represent the connections within historical texts by collecting and visualizing data as a set of elements (nodes) and connections between the elements (edges), and the history students can build and use the aggregated information from each node and edge connections to interpret history. The specific features in the tool can scaffold the collaborating process by mediating students' conversation while students determine which historical piece can be recorded as a node and categorize it into person, group, event, or place. Next, the edge entry prompts scaffold students to look at the relationship between nodes, select the directionality of the edge, and provide a citation. As nodes or edges are recorded, they are instantly visualized in the whole class network. By using this tool, small groups of students engage with the historical significance for each detail while reading the part of the text and collaboratively co-construct the historical connections among many possible entries and can simultaneously see and reflect on the whole class network. The process of dividing a long historical source into smaller sections and offering those sections for small-group data entry is a good model for other networks outside of history where simultaneous or team-based network data entry is needed, focusing on network interactions.

## Methods

This study used the Net.Create tool during two 50-minute class sessions in a classroom of 73 students taking a survey history course at a midwestern United States university. Students were divided into groups of 2-3 students. The classroom was a large lecture hall where seats were arranged in tiers. Each group had at least one shared laptop to collaboratively use the tool. A total of 8 groups voluntarily participated in the data collection including video, pre/posttest, and software log data. Each group was assigned to a different chapter from a text about Alexander the Great and asked to make entries with using the Net.Create tool. We selected Alexander the Great because it was the most complex, lengthy source in a course on ancient history taught by history instructor who had agreed to participate in the study. At the end of each class, students were asked to interpret Alexander's leadership style. To analyze the data, we employed discourse analysis (Potter, 2003) to discover a pattern of interaction in the classroom.

## Findings

Our analysis showed that the Net.Create tool shaped students' particular collaborating sequence in working with the historical text. To begin the activity, students as a group first read the text and started to think and discuss about what would be a reasonable item to record as a node before entering nodes and edges (e.g., So, do we put either of that down (pointing the screen), should we put Ammon, should we put Homer). While entering them, the prompts in the tool to add nodes and edges led the students to engage the text in a more interpretive way and pushed them to look for connections. For example, when students were asked to categorize their entry by person, group, event, or place, they discussed about selecting the most reasonable argument as a group based on what they read (e.g., So I know we mentioned the dream in an event description, but should we make the dream into an event on its own?) Then, they seamlessly started to look for another node to connect through an edge (e.g., And then, you've gotta add an edge). These patterns of discourse prevailed across the data set. Also, the Net.Create tool uniquely mediated student collaboration in interpreting the historical text at both small and large group level. As soon as a small group of students entered nodes and edges in the tool, they were instantly able to observe how their group's entry was visually connected to the whole group network. This feature of the tool afforded students a way to visualize how they were contributing to the whole network and realize how each node was related in the bigger history context (e.g., Whoa! This is so cool! We should keep going! We need to contribute). Later in the class, the instructor was actively utilizing the co-constructed whole network for a whole class discussion (e.g., What do you guys see here? Which nodes aren't connected?)

## Discussion and conclusion

These findings suggest that the Net.Create tool mediated how students collaborated at both the small and large group level to engage with a new-to-them historical monograph in a manner that helped them begin to situate ideas within the text. First, in order to create a network, students had to identify nodes and edges within the text, which led them to have productive conversations about the important people, places, and events in the text. Second, as students used Net.Create to connect nodes via edges, the tool mediated their ability to see the historical relationships and made it salient when nodes were connected to primary network or not. Third, the tool leveraged the larger community to support students in making sense of an entirely new text in a limited time. Lastly, the network served as a reference point for the whole class discussion, leveraging the work of small collaboration groups to support whole class connections. By dividing up a large, unfamiliar text into smaller pieces and assigning those to small collaborating groups whose work fed back into a whole-class network, the large lecture format that typically limits collaboration options became a positive feature of the activity. These results provide evidence that Net.Create demonstrated promise in supporting students in co-constructing historical knowledge.

## References

- Danish, J. A. (2014). Applying an activity theory lens to designing instruction for learning about the structure, behavior, and function of a honeybee system. *Journal of the Learning Sciences*, 23(2), 100-148.
- Potter, J. (2003). Discourse analysis and discursive psychology. *Qualitative research in psychology: Expanding perspectives in methodology and design*, 73-94.
- Roth, W. M., & Lee, Y. J. (2007). "Vygotsky's neglected legacy": Cultural-historical activity theory. *Review of educational research*, 77(2), 186-232.
- Wineburg, S. S. (1991). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of educational Psychology*, 83(1), 73.

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# Evaluating the Impact of a Smart Greenhouse Intervention on Interest and Identity Using a New Framework

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**Abstract:** A mixed methods study of a 14-day computational-thinking-and-computer-science-infused environmental science intervention observed 193 middle schoolers to engage behaviorally. Based on self-reports and observations, some students increased coding and computer science (CCS) interest and negotiated CCS identity. New criteria for the study and evaluation of identity development, strongly related to interest development, may provide a useful framework for other interventions intended to broaden computational participation.

Infusing computational thinking (CT) in science classrooms benefits from fostering a lasting, positive CCS identity, particularly for students from non-dominant populations (Kafai, 2016). This 14-day, CT-infused intervention was designed to teach CCS content and support student CCS interest and identity. Content included students building automated tabletop greenhouses capable of small-scale urban farming. In pairs or trios, students wrote MicroPython code for a Wio Link ESP8266 board which they connected to actuators, sensors, and displays, applying new CT and CCS skills to collecting data and controlling environmental variables for their basil, cilantro, or lettuce plants. Such content related to identity in that, “[p]rogramming is not an abstract discipline, but a way to ‘make’ and ‘be’ in the digital world” (Kafai, 2016, p. 27).

## Theoretical frameworks

Hidi and Renninger (2006) inductively found interest to develop over four fluid phases. In Phases 1 and 2, individuals attend to content fleetingly, whereas in Phases 3 and 4, students show “enduring predisposition to re-engage content” (p.111). *Interest* intersects with *identity* where these constructs share markers. *Identity resources*, in signaling to students who they are and can be, are the main mechanism by which identities become available in science-learning environments (Pinkard et al., 2017). Nasir and Cooks (2009) describe three interrelated types of identity resources – *material*, *relational*, and *ideational* – upon which three new criteria for development of students’ CCS identity were based. Criterion 1 was the provision to students of the three types of identity resources: *material resources* of the curriculum on the design of an automated greenhouse and investigation of scientific questions, *relational resources* of student-teacher relationships and teacher-assigned work groups, and *ideational resources* of teachers’ beliefs affording space for students to exchange ideas. Table 1 details what students could do with the design affordances from Criterion 1 to develop their CCS identities.

Table 1: Framework for Identifying Student Usage of Identity Resources, Including Phases of Interest, Abridged

	Material Resources	Relational Resources	Ideational Resources
Criterion 2 (C2): Use of identity resources	Students first engage with curriculum, re-engage (Phase 2). May repurpose curriculum.	Students develop extended work partnerships with teachers and each other.	Students position selves in CCS (Phase 3), & negotiate CCS identity.
Criterion 3 (C3): Sustained use of identity resources	Students re-purpose curriculum, applying it to other contexts, e.g., at home (Phase 4).	Students have long term relationships and networks in CCS (Phase 4).	Students have lasting, “sticky,” ideas about who they are in CCS (Phase 4).

Note: “Phase” refers to the four phases of interest found in Hidi and Renninger (2006).

*Material Resources* (C2, C3) describe how a student might, over time, shift her relationship to CCS content through curriculum materials. A student may start out with perfunctory behavioral engagement (C2) but as she develops expertise, she may also begin to deepen her interest. When a student realizes she is re-engaging content independently (C3 and interest Phases 3-4), knowing that she has turned to the same content repeatedly in the past supports her believing that she would continue to do so in the future, helping her to further identify with CCS. *Ideational Resources* similarly progress from less likely to re-engage without support (C2) to highly likely to re-engage (C3), in this case with ideas about CCS content as well as who one is in relation to CCS (e.g., beliefs, goals, and hopes about oneself in CCS). *Relational Resources*, which may be the most impactful, as disciplinary relationships are crucial to defining one’s disciplinary identity (Pinkard et al., 2017), progress from structured, compulsory participation with others (C2) to voluntary and externally-affirmed participation (C3).



## Research questions and study design

Our research questions were whether changes occurred in students' (1) CCS Interest, or (2) CCS Identity. In an explanatory design, data from surveys (pre, post), interviews (pre, post, five-month follow-up), and observations provided evidence to use Table 1 as a rubric to answer the research questions. From 193 students ( $m=95$ ,  $f=94$ , non-binary=4; Latinx=88, White=70, other=35), 16 focal-group students were selected for deeper scrutiny based on differences in pre-interviews and -surveys on CCS confidence, proficiency, and prior experience as well as long-term scales on *CCS Identity* ( $items=12$ ,  $\alpha=.88$ ), and *CCS Interest* ( $items=12$ ,  $\alpha=.92$ ).

## Results and implications

Before the intervention, Latinx students reported less frequency of prior experience than White/other ethnicity students [65% vs. 85%,  $F(1, 118) = 1.412$ ,  $p = .027$ ]. Long-term *CCS Interest* and *CCS Identity* scale scores did not change statistically significantly (for all students, by gender, or by ethnicity/race), but did show gains in reliability. Shorter-term, qualitative results supported interest and identity development.

One student's experience in the greenhouse intervention exemplified different criteria for identity development being met or considered. Gal (names are pseudonyms) began with no prior CCS experience, low interest, and a stereotypical, male-gendered idea of coders as "some weirdo sitting in a room typing on his computer." During the unit, Gal *used* relational identity resources (C2) when she coached a worried friend, Mae. In turn, Mae *used* relational identity resources when she encouraged Gal's interest in coding a robotic arm. Gal then *used* the material identity resources (C2) of robotic equipment when she independently re-engaged with coding in experimentation with the robotic arm. The coaching opportunity may have helped Gal to develop the ideational identity resource (C2) of understanding that CCS takes "determination, perseverance, and optimism." Gal's attainment of Criterion 2 for all identity resources supported the conclusion that her CCS identity developed during the intervention, as did her interest. In the post interview, Gal had a new, non-gendered conception of coders as scientists who make "gadgets" for useful automation. She pondered a later scientific investigation with her partner (C3, Material and Relational Identity Resources), but, five months later, had not done it. Gal still considered herself highly interested but felt a bit "less" CCS identity than after the unit, perhaps due to a lack of opportunity to re-engage in any CCS projects that could have re-triggered interest.

Our analysis of the 16-student focal group found that the combination of *presence* (C1) and *use* (C2) of identity resources shifted students' ideas about what mattered in the content and who they were in relation to it. All students achieved piqued interest; none were indifferent. Some were observed using ideational identity resources when they proposed, defended, and revised ideas on greenhouse design. We believed that the use of relational identity resources had potential for lasting impact when students felt safe enough to critique and build upon each other's ideas, particularly when their partners were also their friends, a relationship that would outlast the unit. Students adopted ideas about what is valued (e.g., in greenhouse design) as well as enacted practices (e.g., idea-generation, critique) to decide who one is and can be in CCS. The quality and quantity of the interest that students discussed in their follow-up interviews suggested that the spaces where students applied CCS to the greenhouse problem, in being pushed into public view as a site for active negotiation, aided in identity development (Nasir & Cooks, 2006; Pinkard et al., 2017). Aligned with Gal's outcome, other students attributed drops in interest and identity to not having more CCS activities to do after the curriculum unit had ended.

This work went beyond an existence proof that CT can be embedded into mainstream science classes, towards organizing an understanding of identity resources, strongly related to interest, to support students' developing CCS identities. We believe that this intervention showed potential for impacting students' CCS interest and CCS identity development, specifically through the provision, engagement, and re-engagement with high-quality material, relational, and ideational resources. We believe that in the future, using these newly-developed criteria not just for evaluation, but also as targets or goals for curriculum design, would help to create curricula that support the development of students' CCS interest and CCS identity.

## References

- Hidi, S., & Renninger, K. A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist*, 41(2), 111-127. doi:10.1207/s15326985ep4102\_4
- Kafai, Y. B. (2016). From computational thinking to computational participation in K--12 education. *Communications of the ACM*, 59(8), 26-27.
- Nasir, N. i. S., & Cooks, J. (2009). Becoming a hurdler: How learning settings afford identities. *Anthropology & Education Quarterly*, 40, 41-61.
- Pinkard, N., Erete, S., Martin, C. K., & McKinney de Royston, M. (2017). Digital Youth Divas: Exploring narrative-driven curriculum to spark middle school girls' interest in computational activities. *Journal of the Learning Sciences*, 26(3), 477-516.



# When Words Are Not Enough: What Student Gestures and Embodied Responses Tell Us About Understanding Science Through Dance

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**Abstract:** First and second grade students in a technology-based immersive learning environment collaboratively created and performed dances as an embodied form of sensemaking to reinforce scientific learning. Providing verbal and gestural feedback on a dance synthesized embodied, enactive, and cognitive practices. Students watching dances used gesture where their vocabulary was no longer adequate to describe their scientific understanding. We argue that legitimizing multimodal forms of expression expands on students' collaborative reasoning tools.

## Introduction

First and second grade students at the [School] participated in a seven-day unit of study exploring states of matter using technology, play, and embodied forms of inquiry and representation. The final day asked students to create and perform dances showing a designated state change (e.g. liquid to gas), while their peers watched the performance and tried to guess which state change they performed. The dances were used and viewed as cultural artifacts that supported and deepened science learning and inquiry. Building on research that recognizes the role the body plays in sense-making and the role of gesture in social interactions (Goodwin, 2018; Goldin-Meadow, 2004), this poster positions dance as part of an embodied science learning approach that expands students' available reasoning tools. We claim students presented understandings of micro- and macro-level phenomena in their dances, and relied upon gesture and embodiment to fully express their understanding of complex science ideas during discussions.

## Methods

iSTEP—interactive Science through Technology Enhanced Play—is a multi-year design-based research study (Design Based Research Collective, 2003) exploring scientific inquiry through embodied play. We used inductive methods and interaction analysis (Jordan & Henderson, 1995) to analyze video data from two classrooms of 25 6-8 year-olds, working with two teachers. Students engaged with ideas of water particles on a macro level (e.g. water vapor is gas), and on a micro level (e.g. particles in a gas move quickly). A researcher led the final day, where students choreographed dances demonstrating a state change in groups, performed them, and gave and received feedback on their dances as a means of integrating their understanding of how both micro (particles) and macro (observable) levels engage concurrently.

## Findings and analysis

Dance challenged students to engage in reasoning strategies in both choreography and as while viewing their peers' dances. First, we present students demonstrating simultaneous understanding of macro and micro particulate behavior physically through dance. Students collaboratively engaged in multimodal forms of expression to simultaneously represent particulate behavior as water particles in liquid, and as water (Figure 1).






**Figure 1.** Students simultaneously represent macro and micro particulate matter of liquid with their bodies.

Students represented water at a macro level by using “curvy” lines in their bodies including a rounded spine and articulations of the wrist and arms. Students showed the micro-level by demonstrating the spacing (close together) and movement (slow) of liquid water particles. This dance presented their understanding of the particulate behavior of water laminated (Goodwin, 2018) upon their understanding from lived-experience of macro-water behavior. We see these movements explored during choreographing and performing a dance as supporting

sensemaking at both micro- and macro-levels through dance and conversation. We suspect that their exposure to MR technology and invitation to choreograph a dance supported their ability to move freely and present their understanding of the states of matter with their bodies across both levels. A complex task was accomplished because dance and the body were accessible as reasoning tools to support sensemaking and representation.

We also analyze student observers engaging with multimodal forms of expression to support understanding content knowledge in response to their peers' performances. It is important to note that even though some students had not yet presented their dance, all students had already choreographed and practiced their dances. After watching a group perform, the audience members guessed that liquid was represented in the dance (Figure 2).

2A.		<p>Researcher: What did you see that made you think maybe it was liquid? What did you see.          Taylor: Uhm, like at first they were gas...and then solid, and then liquid, and then GAS!  <i>(Taylor's left hand extending quickly out in front of him while saying GAS!)</i>          Researcher: Oh, so GAS! you said really, it sounded really fast to me.</p>
2B.		<p>Rosie: GAS! <i>(Rosie's left hand extends quickly out in front of her while saying GAS! Repeating the same gesture from Taylor)</i></p>
2C.		<p>Clementine: <i>Shifts her weight to get up on her knees, and says to her neighbor, "I think gas was like, GAS! (same the arm gesture as Taylor and Rosie), "GAS!" (repeating the same arm gesture) "GAS!" (with both arms extending from the core to distal reach) "GAS! GAS! GAS! GAS!"</i>  <i>Each time she is using her gesture with quick, direct flicking motion with her arms, radiating from her core to the reaches of her arms, with a neck and head flick.</i></p>

**Figure 2.** Students discuss a group's dance.

When prompted to describe why he thought the dancers were evoking liquid, a student stated, "Uhm, liquid because they were going slow when they got there, was kinda like a wave." At this point, Rosie said, bu-bu-bu-bu-shhhhhh (wave noise with wave arm movement; Figure 2B), and Clementine said, "that reminded me of a wave...good..." and generated her own wave movement with her arms (Figure 2C). In this moment, students articulated scientific concepts with a combination of words and gestures, communicating with more rigor than they had previously managed with words alone. We argue that these physical embodiments are different than gestures studied previously (Goldin-Meadow, 2004) in that students engaged in this process are utilizing multimodal forms of expression and representation informed by their own experiences of choreographing dances, engaging with the mixed reality visualization, and grappling with the scientific content verbally with peers in small and large group discussions.

## Discussion and Implications

The instances presented in which student movements simultaneously instantiated micro and macro levels of systemic behavior indicated that talking about scientific phenomena was challenging, but the body could accomplish simultaneous, laminated, multi-leveled movements where linear words currently fail them. Current literature positions embodiment as a tool for sensemaking (Wilson, 2002), and gestures as important in communication and meaning making by emphasizing as well as building new meaning (Goodwin, 2018). Here we argue that choreographing, performing, and watching classmates perform dances demonstrating scientific concepts supported understanding of the science curriculum by privileging both linguistic and embodied sense-making. The data we present show evidence of the body leading the sense-making process in rigorous scientific inquiry. In future work, we want to explore how this process leads to deeper scientific inquiry that supports the development of representational knowledge, embodied sense-making, and understanding science through dance.

## References

- Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 5-8.
- Goldin-Meadow, S. (2004). Gesture's Role in the Learning Process. *Theory Into Practice*, 43(4), 314-321.
- Goodwin, C. (2018). *Co-operative action*. New York, NY: Cambridge University Press.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, 4(1), 39-103.
- Wilson, M. (2002). Theoretical and review articles: Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9 (4), 625-636.

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# Using Sentence Embeddings to Automatically Extract Cohesion and Alignment Metrics in Problem-Solving Tasks

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**Abstract:** We introduce an automated approach that builds on sentence embeddings, a novel natural language processing technique that extracts meaning from sentences, to create two quantitative measures that serve as proxies of collaborative learning. Cohesion is extracted as adjacent utterance similarity and represents the amount of overlap between contiguous conversational turns. Alignment is extracted as a similarity between a focus utterance and a reference text and represents the degree to which a conversation utterance aligns with the task. These two dimensions divide the quality of conversation in four quadrants.

## Introduction

Pre- and post-collaboration scores measure the effect of collaboration on students' learning in a distal manner. For in-vivo measures of collaboration, however, researchers investigate the interaction among participants while they solve a problem as a group. The challenge is that metrics that assess a group's collaboration quality are hard to come by manually. In particular, producing hand codes of a group's collaboration requires sizable human resources. To tackle this issue, various studies have investigated the use of automated approaches to help researchers and instructors reduce the costs of hand coding collaboration transcripts (Mu, Stegmann, Mayfield, Rosé, & Fischer, 2012). Natural language processing (NLP) techniques offer solutions to automatically extract viable measures of collaboration. Some automatically extracted features can predict the quality of a collaborative activity by analyzing linguistic properties of the transcript (Andrade, Georgen, & Stucker, 2017). Various studies have explored computational techniques to extract the cohesion of a conversation (Luna Bazaldua et al., 2015). Cohesion refers to the similarity of adjacent utterances, and it measures the semantic alignment between interlocutors (Graesser, McNamara, Louwerse, & Cai, 2004). Cohesion is indicative of the development and maintenance of shared understanding, which has been shown to be a good predictor of learning in groups (Roschelle, 1992). Other studies have used similar techniques to extract a group's alignment with the task (Andrade et al., 2017). Task alignment is related to how similar a participants' discourse is to the disciplinary ways of talk—i.e., how discipline experts talk. Previous research has shown that task alignment is correlated to course grades (Barron, 2003). Our goal is to investigate the value of a new computational approach that potentially improves the measures of cohesion and task alignment as proxies of a group's collaboration quality. We ask: how is collaborative learning related to patterns of conversational cohesion and task alignment?

## Measuring cohesion and task alignment

The development of word embeddings has facilitated the geometrical representation of words. Mathematically, a word embedding is a function that maps a word to a vector of numbers within a multidimensional space (Schnabel, Labutov, Mimno, & Joachims, 2015). For instance, word embeddings capture semantic similarities that can reproduce linguistic analogies such as "Insect is to Ant as Fruit is to Apple" in a geometrical space. This geometrical space allows for algebraic expressions such as:  $\text{Insect} - \text{Ant} + \text{Apple} = \text{Fruit}$ . Recently, Google released a Universal Sentence Encoder for sentence embedding (Cer et al., 2018). Instead of mapping single words, sentence embedding provides a mapping between a span of text and a vector of numbers. Cosine similarity examines the semantic similarity between two sentence embeddings. Computing a group's conversation cohesion is an iterative process in which a similarity value between adjacent utterances is calculated. Computing task alignment is an iterative process in which each utterance is compared to a reference text. In this case, the reference text is an expert's way of solving the problem. This comparison uses the cosine similarity between the focal text (a student's utterance) and the reference text (expert written solution).

## Collaboration quadrants and predicting learning gains

Since cohesion and alignment values are captured at each communicative exchange, we hypothesize that there is a time dependency between these two dimensions of collaboration. A conceptual space with four quadrants represents the intersection between levels of high and low values in each dimension. For instance, there are moments in the conversation students have high levels of cohesion (their talk builds upon each other) as well as

high levels of task alignment (their talk mostly refers to the problem at hand). On the other hand, there are moments when their conversation has high cohesion but low alignment (great off-task talk); low cohesion but high alignment (e.g., their on-task but do not seem to take up each other's ideas); and low cohesion and low alignment.

## Results

Table 1 shows brief excerpts illustrating what these collaboration quadrants look like in practice. These excerpts were taken from a transcript, during those conversational exchanges our algorithm pointed out towards the corresponding quadrant. A quick appraisal of quadrants seems to validate the qualitative differences at these conversational moments.

Table 1: Collaboration Quadrants

	High Cohesion	Low Cohesion
High Alignment	S17: It is impossible for DC to flow across a capacitor. S06: And AC is like the sin wave right. Yeah AC is a sin wave. Wait let me zoom in even more on this. Well I mean there is some oscillation, so it is in between 3.5 and 4. So maybe it is not actually I mean it looks like AC.	S17: Oh, yep ok there we go. s06: Or test point 1. S17: Oh, you want to try it at 1. s06: And then connect this to ground and this timing control thing is so annoying.
Low Alignment	S1: So how can we prove that it is going to light up twice. S2: Isn't that just because in that one second period it is going to light up twice. S1: Yeah but how do we prove this on circuit wizard. S2: I'm not too sure about that one. S1: Here let's try this. Shucks. Let's throw in a circuit board or something.	S1: Trying to remember where that was. We did that in that last. S2: It is in. You find it. I can't see it. Go to the bottom. Virtual instruments oscilloscope. S3: Channel one is for the positive. Oh, come on.

## Discussion and conclusion

The use of sentence embeddings allows for the geometrical representation of the meaning of whole sentences, which can be transferred to the encoding of utterances from collaborative transcripts. Our results show that these two measures of collaboration, automatically extracted from the transcripts, are highly correlated to learning gains. The development of cohesion and alignment values during a conversation create a quadrant space that informs the quality of the talk. Some of these quadrants are productive and some are not. For instance, successful groups spend more time in a kind of conversation that has high cohesion and high collaboration. Not so successful groups tend to spend more time in quadrants where there is low cohesion and low alignment.

## References

- Andrade, A., Georgen, C., & Stucker, M. (2017). Exploring a Text-Mining Approach as Rapid Prototyping Tool for Formative Assessments in Inquiry-Based Online Learning. In B. Smith, M. Borge, E. Mercier, & K. Y. Lim (Eds.), *Making a Difference: Prioritizing Equity and Access in CSCL* (Vol. 1, pp. 151-158). Philadelphia, PA: International Society of the Learning Sciences.
- Barron, B. (2003). When smart groups fail. *The journal of the learning sciences*, 12(3), 307-359.
- Cer, D., Yang, Y., Kong, S.-y., Hua, N., Limtiaco, N., John, R. S., . . . Tar, C. (2018). Universal sentence encoder. *arXiv preprint arXiv:1803.11175*.
- Graesser, A. C., McNamara, D. S., Louwerse, M. M., & Cai, Z. (2004). Coh-Metrix: Analysis of text on cohesion and language. *Behavior research methods, instruments, & computers*, 36(2), 193-202.
- Luna Bazaldua, D. A., Hao, J., Khan, S., Liu, L., von Davier, A. A., & Wang, Z. (2015). *On convergence of cognitive and non-cognitive behavior in collaborative activity*. Paper presented at the Proceedings of the 8th International Conference on Educational Data Mining Conference.
- Mu, J., Stegmann, K., Mayfield, E., Rosé, C., & Fischer, F. (2012). The ACODEA framework: Developing segmentation and classification schemes for fully automatic analysis of online discussions. *International journal of computer-supported collaborative learning*, 7(2), 285-305.
- Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *The journal of the learning sciences*, 2(3), 235-276.
- Schnabel, T., Labutov, I., Mimno, D., & Joachims, T. (2015). *Evaluation methods for unsupervised word embeddings*. Paper presented at the Proceedings of the 2015 Conference on Empirical Methods in Natural Language Processing.

# Gaming the Schoolyard: Promoting High School Students' Collaborative Learning through Geolocative Mobile Game Design

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**Abstract:** Geolocative augmented reality game design offers students a potentially rich collaborative learning experience connected to their local school's physical and cultural environment. This qualitative study describes a pilot implementation of a collaborative geolocative mobile game design curriculum within a high school computer science classroom setting, considered through the lens of embodied and enactive learning, and suggests ways in which teacher facilitation strategies can support utilizing this approach in a classroom setting.

## Background

Geolocative mobile augmented reality (AR) games situate gameplay within a real-world context. As the player moves around the physical environment, their location-aware mobile device senses their position, triggering in-game content (e.g., interactions with virtual characters). Students can learn from and engage with a physical setting via location-based AR games in scenarios ranging from investigating a fictionalized toxic spill (Klopfer & Squire, 2008) to exploring the illegal wildlife trade in a zoo-based whodunit (Perry & Nellis, 2012).

Constructionism suggests deep learning can stem from making and sharing personally meaningful digital artifacts (Jonassen, Howland, Moore & Marra, 2003), including location-based AR games (Klopfer & Sheldon, 2010; Perry, Coulter, Rubio, & Holden, 2015; Vogel & Perry, 2018). When working collaboratively (Resnick, 1996), students can externalize and refine their ideas with one another, and divide tasks enabling more complex designs. Making an AR game involves a range of skills, including manipulating maps, thinking in geospatial terms, creating visual designs, coding, writing, playtesting and iteration (Vogel & Perry, 2018). This pilot study examines one high school class that utilized an AR game design curriculum, examining how embodied and enacted learning intersected with the unique affordances of geolocative game design.

## Implementation of collaborative AR game design curriculum

### Methods, sample and data collection

In Spring 2018, researchers collaborated with a high school computer science teacher who assigned a three-week class project in which students used TaleBlazer, a free AR creation platform, to make a geolocative game on their school's campus. The 10 students in grades 9-12 were divided into three working groups. Participation in the research study was voluntary and uncompensated. Each group was tasked with designing and implementing a location-based AR game for school's lower school students. The teacher challenged his students to create an AR game artifact that, "takes place outside [anywhere on the school's large campus], uses the physical environment, tells a powerful story, [and] uses game mechanics in some way." Researchers gathered qualitative data, including interviews with the instructor and participating students, three sessions of class observation field notes, digital game artifacts, and draft game design notes. Researchers analyzed data looking for ways in which embodied and enacted learning appeared to impact students' experience, ways in which the teacher scaffolded student work, and opportunities to improve future iterations of the tools and curriculum.

### AR game design through the lens of embodied and enacted learning

*Embodied learning* considers the role of the learner's physical body as integral to the learning experience. Location-based AR games require players to move through the real world as the game unfolds. *AR game designers* therefore consider ways in which their game design decisions (e.g., where they position their virtual characters) impact their players (how far players walk, how quickly they move, etc.). Youth game designers were sometimes surprised to see how the physicality of the experiences played out. During a playtest, one group of game designers observed young game players joyfully counting the number of stairs (a clue in the game) by running up and down the stairs while counting, rather than just standing and pointing. For the game designers, this observation reinforced the ways in which the potential for physicality in the game could be engaging for the learners. The *teacher* also reminded student game designers of the ways in which players (in this case younger students at the middle school) would be physically affected by the choices they made (e.g., they might get tired). He also noted that due to the affordance of the AR editor's primarily a top-down view of the Google map, designers did not anticipate the time and effort to move through the game space and sometimes "put down the dots" without fully considering implications of distance between game hot spots, backtracking, etc.

*Enacted learning* refers to interactions between the individual and their environment that promote learning. For location-based AR games, the game space integrates with the larger social, physical, and cultural context. Moreover, AR games frequently ask players to examine, observe or infer something about the real world to progress in the game. *AR game designers* are tasked with considering where, when, and how to ask players to interact with the real world in their game designs. Even though most students were very familiar with their school environment, nevertheless the *teacher* provided time for students to walk the grounds, pick their game's specific locations and artifacts, and determine ways in which they would ask the player to engage with the environment. Midway through the process, the teacher raised concerns that students were not yet able to develop a robust game concept beyond a superficial "tour" as a way to create a location-based game.

[The students] needed to do some research to come up with some ideas around their theme... Their original idea was to do a tour of campus, but unless they could find something specific to say about their theme regarding each of the buildings, I think it'll be hard to be comprehensive enough. It might be kinda of a pain to force [building name] to match [famous alumnus of the school] in some way, you know... (interview, April 8, 2018)

Later, the teacher noted that by considering the role of a narrative, students began to think holistically about their game, and more thoughtfully integrate locations, commenting, "I think when we first started talking about it was just a series of locations, and now they're starting to put the pieces together... so I'm happy about that."

## Discussion and conclusions

Two key challenges emerged with the AR game design curriculum. First, students unfamiliar with this genre of enacted learning – in which the physical context of the game plays a significant role – were put into the role of designer. Sample games did not demonstrate enough complexity and variety, leaving students ill equipped to envision more creative, complex game mechanics and defaulting to closely mimic the models and/or initial suggestions of the teacher, which was problematic. Student designers would likely benefit from additional varied sample games (including previous year's student projects) helping students to envision a wider possibility space of projects. Second, the top-down map view tools themselves had unintended consequences by not providing students, who typically do not consider embodied learning constraints and impacts, with a sense of spatial scale, leaving them unable to anticipate player fatigue or feasibility of completing the game within the allotted time. Early prototyping, and potential changes to the tool (e.g., distance calculators) might potentially help designers quickly uncover such flaws. As educators consider implementing AR game design curricula, the novelty of students' considerations of enacted and embodied learning ought to be scaffolded both technologically and pedagogically for student designers to successfully work within this genre.

## References

- Jonassen, D.H., Howland, J.L., Moore, J.L., & Marra, R.M. (2003). Learning to solve problems with technology: A constructivist perspective. Merrill Prentice Hall, Upper Saddle River, New Jersey.
- Klopfer, E., & Sheldon, J. (2010). Augmenting your own reality: Student authoring of science-based augmented reality games. *New directions for youth development*, 2010(128), 85-94.
- Klopfer, E., & Squire, K. (2008). Environmental Detectives—the development of an augmented reality platform for environmental simulations. *Educational Technology Research and Development*, 56(2), 203-228.
- Perry, J., Coulter, B., Rubio, J. & Holden, C. (2015). How I Learned to Stop Worrying and Love Youth Game Creation. *Games+Learning+Society*, Madison, WI.
- Perry, J., & Nellis, R. (2012). *Augmented Learning: Evaluating Mobile Location-Based Games at the Zoo*. ISTE, San Diego, CA.
- Resnick, M. (1996, July). Distributed constructionism. In *Proceedings of the 1996 international conference on learning sciences* (pp. 280-284). International Society of the Learning Sciences.
- Vogel, S., & Perry, J. (2018). We got this: Toward a facilitator-youth "apprenticeship" approach to supporting collaboration and design challenges in youth-designed mobile location-based games. In D. Herro, S. Arafeh, R. Ling & C. Holden (Eds.), *Mobile learning: Perspectives on practice and policy* (Digital Media and Learning), (pp. 143-168). Charlotte, North Carolina: Information Age Publishing, Inc.

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# Designing Learning Analytics for Teacher Learning: An Analytics-Supported Teacher Professional Development (ASTPD) Approach

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**Abstract:** Researchers have recently emphasized the contribution of learning analytics interventions to the advancement of theory. We propose an analytics-supported teacher professional development (ASTPD) approach and evaluated the impact of the ASTPD approach on teacher learning and reflection about their dialogic instruction. The results show that integrating learning analytics and TPD drawing on educational theories and the TPD context had an impact on the participating teachers' dialogic practice as well as their student learning outcomes.

## Introduction

While the recent years have witnessed an increased interest in the use of data to inform educational decision-making, relatively less attention has been paid to the role of theory in designing learning analytics interventions (Knight & Shum, 2017; Wise & Shaffer, 2015). In this paper we propose an analytics-supported teacher professional development (ASTPD) approach, which aims at leveraging learning analytics to facilitate teachers' reflection about their classroom practice. The ASTPD transforms the prevalent video-based TPD activities around the temporal and sequential lesson observations into analytics- and visualization- supported TPD activities, which is likely to increase the efficiency and effectiveness of TPD.

## The present study

The ASTPD approach is informed by the sociocultural (Vygotsky, 1978) and situated learning theories (Brown, Collins, & Duguid, 1989). The theories highlight the importance of situating teacher learning in artifacts of practices and mediating teacher learning through productive and meaningful talk, tasks, and tools leveraged by participants' collaborative interpretation and communication of data-based evidence. The ASTPD approach employs learning analytics technologies to provide teachers with the analytics and data in form of visualisation of their own classroom data for using in TPD tasks and activities.

Based on the ASTPD approach, Chen, Clarke, and Resnick (2015) developed a teaching analytics tool, Classroom Discourse Analyzer (CDA) to facilitate in-service teachers' reflection on teacher-students classroom talk interactions in audio- and video- recorded classroom lessons. The authors have upgraded the CDA tool to a web-based version, CDA 2.0, a web platform that presents formative feedback in the formats of interactive graphics, videos and transcripts, not only about the classroom process, but also about data summaries of individual and group classroom interactions. In this study, we report the use of CDA 2.0 in a TPD program. CDA is aimed to leverage learning analytics technologies to ease teachers' search, access, extract, and focus of information in video-based observation of their own and others' teaching, as well as to improve their individual, collaborative, and repeated learning effects. Specifically, CDA provides process- and product- oriented learning analytics support for one important aspect of teacher learning objective, teachers' ability to use of academically productive talk to engage students into deep thinking and reasoning, drawing upon the Accountable Talk theories (Chen et al., 2018; Resnick, Michaels, & O'Connor, 2010).

## Data sources

In this paper, we report on the effects of conducting ASTPD sessions for secondary mathematics teachers' learning about dialogic instruction across four semesters in two school years. There were in total 46 sixth- and seventh-grade participating teachers in the same school district. Twenty-four teachers were randomly assigned to the ASTPD treatment group who attended six ASTPD sessions across two years to learn and reflect on their classroom talk in addition to workshop learning, and 22 teachers to the comparison group who only learned about Accountable Talk through the same workshops. No statistical differences of the two groups were found regarding teacher gender, age, years of teaching, and their educational level.

## Results and discussion

### Teacher Accountable Talk moves

The quality of teacher talk in the two groups was further compared based on teacher's average frequency of accountable talk moves used in one class including *revoice*, *say more*, *press for reasoning*, *challenge*, *restate*, *add on*, *agree/disagree* and *explain others*. The eight talk moves were grouped by four goals (Resnick et al., 2010). First, teachers help individual students share, expand and clarify their own thinking through *say more* and *revoice*. Second, teachers help students listen carefully to one another through asking students to repeat or rephrase other's viewpoints (*restate*). Third, teachers help students deepen their reasoning through *pressing for reasoning* and *challenge*. Lastly, teachers help students think with others through *agree/disagree*, *add on*, and *explain others*. Except for the second goal (teacher talk moves that help students listen carefully to one another), differences on the other three goals between two groups all reached statistical significance in ANCOVAs, suggesting that the ASTPD intervention improved teachers' enactment of productive talk moves in the classroom.

### Student average words per turn and achievement

Students in the experimental group spoke more words per turn by the end of the project than the beginning, while numbers of student words per turn in the comparison group were similar in both the pre- and post-test. Students of both groups were instructed to complete a pre-test and a post-test, with different but comparable items. An independent t-test showed that the treatment group and comparison group had a difference regarding the gain scores from pre to post test.

### Teacher perceived affordances of the ASTPD approach

We identified four ways in which the ASTPD approach has supported the teachers' learning to enact productive dialogue practices, including: (1) focusing teachers' attention on certain dialogue practices for targeted improvement, (2) raising teachers' awareness of their dialogue practices through quantifying the dialogue practices, (3) deepening teacher reflection on practices through comparison with others' dialogue practices and (4) supporting noticing and reflection on the changes in dialogue practices by continued feedback on changes.

## Conclusion and implications

It is conjectured that this new TPD model will maximize the benefits of classroom data in widening teachers' space of reflection. It balances teachers' autonomy to focus on different areas of their own concern while focusing their attention on salient features relevant to dialogue practices and hence creating a space for personalized learning. The paper has significant contributions to the thinking modes related to effective teacher learning and PD facilitated by learning analytics. The ASTPD approach has raised our awareness on the relation between learning and reflection, as well as the emphasis on the relevance of using the teachers' own classroom data in their professional learning community to inform their future practice.

## References

- Brown, J. S., Collins, A. M., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.
- Chen, G., Chan, C. K. K., Yu, J., Hu, L., Clarke, S. N., & Resnick, L. (2018). The impact of video-based and data-supported professional development on classroom dynamics. In Proceedings of the 13th International Conference of the Learning Sciences (ICLS 2018).
- Chen, G., Clarke, S. N., & Resnick, L. B. (2015). Classroom discourse analyzer (CDA): A discourse analytic tool for teachers. *Technology, Instruction, Cognition and Learning*, 10(2), 85-105.
- Knight, S., & Shum, S. B. (2017). *Theory and Learning Analytics*. In C. Lang, G. Siemens, A. Wise, & D. Gašević (Eds.), *The Handbook of Learning Analytics* (pp. 17-22). Society for Learning Analytics Research.
- Resnick, L. B., Michaels, S., & O'Connor, C. (2010). How (well structured) talk builds the mind. In D. Preiss & R. Sternberg (Eds.), *Innovations in educational psychology* (pp. 163-194). New York, NY: Springer.
- Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.
- Wise, A. F., & Shaffer, D. W. (2015). Why Theory Matters More than Ever in the Age of Big Data. *Journal of Learning Analytics*, 2(2), 5-13.

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# Balancing the Scales: Implications of Model Size for Mathematical Engagement

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**Abstract:** We discuss a constructionism-based geometry curriculum in which middle school students built models of tents, first at a full, large-size scale, and then at a small scale. We build on *body syntonicity* to analyze how students learn through relating abstract knowledge to the knowledge of their bodies. Using video data, we analyze the affordances and constraints for students' mathematical engagement in creating models. We conclude with brief implications for mathematics education and for CSCL research.

## Introduction and background: Mathematical modeling and scale

Given the value of geometry learning for both educational and industrial applications, it is necessary to design pedagogical practices that support such learning in ways that are meaningful for adolescents (Ma, 2016). While math educational researchers have studied the use of a variety of tools and manipulatives including project-based math curricula (e.g., Galindo & Lee, 2018), it is not yet clear whether students working with differently sized artifacts has unique affordances for their understanding of geometry. Thus, we sought to understand a) what mathematical practices were made visible in students' engagement with model-making activities, and b) what were the particular affordances for mathematical engagement in building large-scale and small-scale models?

In this poster, we present initial findings from a project-based geometry curriculum implemented by middle school teachers, in which students designed and built tents at two scales. Our analysis is based on constructionism (Papert, 1980), in which learning is presumed to happen most effectively when learners create personally meaningful objects in social contexts. Furthermore, Papert (1980) argued that anything can be learned if it is coherent, 'in tune,' or compatible with the learner's knowledge of their own bodies (i.e., body knowledge). This is what Papert calls "*body syntonicity*" (1980, p. 68). For example, the abstract notion of the *height* of a triangle is in tune or related to the learners' knowledge about the height of their own bodies. Our analysis, guided by the concept of body syntonicity, showed that students engaged their bodies and target math concepts differently across the two scale tents. This points to implications for the design of collaborative learning environments, including how to structure the scaling up and down of model making within collaborative and project-based learning (PBL) curriculum.

## Methods

This poster draws on data collected during a PBL math course that took place in a chartered public middle school with 72 students. The course was structured for students to design and build tents at two different scales: (1) large-scale structures that could fit a group of eight students and (2) small-scale models. The large-scale tent was built before the smaller, model-scale one, contrary to common practices where the model or prototype is built before a full-scale version. We focus on one small group of eight students as they worked across large- and small-scale structures, video-recording their work for qualitative analysis throughout the unit. We iteratively coded the videos to identify moments when students employed geometry concepts and practices based on state standards (e.g., triangle attributes, scale drawing, angle computation, Pythagorean theorem). Following the concept of body syntonicity and using interaction analysis (Jordan & Henderson, 1995), we zoomed in on particular episodes that involved geometry concepts and analyzed how student groups engaged differently with the math, tools, and materials in each small- and large-scale tent.

## Findings

During the building of the large-scale tent, the focal students used their bodies as resources while engaging with math. They first marked the location of the five vertices of their pentagon-shaped floor plan, starting with the center point (C, see Figure 1). One youth, Tom, suggested they use some nearby PVC pipes as rulers because the metric tape was not available. The flexible pipes were long enough for the students to lay them flat on the grass and then lower their own bodies to the ground to visually place the pipes as a way to ensure a straight line between two points. With a protractor from point C, students measured 72 degrees between two imaginary lines (CB and

CD). However, the combination of makeshift rulers and a measurement error caused by using a small protractor when trying to identify point D led to them placing the flag for the third vertice outside the pentagon (Figure 1, left, point E). Thus, the segment BE ended up longer than the expected 8 feet (BD). As the students worked again to locate the right location for point D, Tom lay down, using himself as a ‘ruler’ to estimate the height of the triangle (distance CF) that needed to be 5.5 feet long (Figure 1, center).



Figure 1. Tom discovered segment BE is too long (left). Tom estimates the height (center). Area diagram (right).

Moreover, the use of the two different scales impacted tool selection, a notable difference in the division of labor, as well as the size and behavior of the materials due to their weight. For instance, in the large-scale tent, multiple students had to help each other as they placed the roof and used heavy tools when placing the wooden stakes to support the walls (Figure 2a). In the small-scale model, one student could cut and sew the canvas roof panels or use simpler tools such as glue guns to install the tent walls (Figure 2b). In fact, group work and collaborations were impeded more in the small-scale work than in the large building project.



Figure 2a. Large-scale tents afforded collaboration.

Figure 2b. Small-scale tents afforded one-person tasks.

## Discussion

The order of first engaging with large-scale models before working on a smaller scale seemed to support students not only in repeated use of particular geometric concepts and practices, but also in allowing them to engage differently. For instance, students used their whole bodies to experience actual heights and lengths when lying down as “rulers” or simply by moving around and inside the tents (or watching others doing it). Students did not rely solely on “imagining” how long 5.5 feet looks, they collaboratively created non-standard units of measurement that anchored concepts to the world and to themselves. This points to important insights for the design of collaborative learning environments for geometry learning: Scaling-up before scaling-down may deepen mathematical collaborative engagement. It also points to ways that future computer-supported programs for digital model-making, simulation, and mixed reality might consider matters of scale. As for size changes, we need to pay attention to the impact on the type and use of the tools, the division of labor, and to the sensory information provided by the physical materials.

## References

- Galindo, E., & Lee, J. (Eds.). (2018). *Rigor, relevance, and relationships: Making mathematics come alive with Project-Based Learning* (1 Ed.). Reston, VA: National Council of Teachers of Mathematics.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39-103.
- Ma, J. Y. (2016). Designing disruptions for productive hybridity: The case of walking scale geometry. *Journal of the Learning Sciences*, 25(3), 335-371.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

# Knowledge Building in Robotics for Math Education

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**Abstract:** When integrating robotics into teaching activities, most educators employ Competition-Based Learning (CBL) approach. However, CBL may diminish robotics potential, because competitions may discourage active construction of knowledge and the development of talent by isolating students. In this study, we aim to employ knowledge building pedagogy and technology and explore if and how knowledge building creates an innovation network in robotics.

## Introduction

It has been claimed in some studies (e.g., Giannakopoulos, 2009) that Competition Based Learning (CBL) is the most effective way to integrate robotics into subjects such as math and physics. In CBL, students build and program their robots in order to accomplish challenges, beat others and get credit (Kanda, Shimada, & Koizumi, 2012). Although the concept of competition in education is supported by several studies, there are several concerns in regards to competitions in education. One concern is that during competitive activities, communication and helping others is usually minimized because students usually perceive their goals as only being reached if other students fail to achieve their goals (Johnson, Johnson, & Smith, 1991). In fact, the growing emphasis on the final products of competitive activities sometimes leads students to disregard other goals such as groups' interactions, collaboration and a shared vision (Cohen, Brody, & Sapon-Shevin, 2004). One potential solution for this concern is to teach robotics employing collaborative approaches. In this study, we employ knowledge building pedagogy and technology and explore whether knowledge building pedagogy and technology has the potential to create an innovation network in robotics?

## Theoretical framework

The 12 Knowledge Building principles frame Knowledge Building as an idea-centered pedagogy with students as epistemic agents, creating knowledge through engaging in complex socio-cognitive interactions in which students create *community knowledge* (Scardamalia & Bereiter, 2006). In this study, we employ Innovation network framework (Gloor, 2006) to explore how students collaborate with each other, and whether an innovation network is formed. Gloor identified three forms of network engagement: (1) Collaborative Innovation Network (COIN)- at the core is a team of self-organized and intrinsically self-motivated people who have a collective vision; (2) Collaborative Learning Network (CLN)- people with shared interests join the core community to discuss new ideas, learn, and apply innovations; (3) Collaborative Interest Network (CIN)- people at the periphery, often lurkers, seemingly share interests but do not contribute content. We may think of these different networks as concentric circles, with a ripple effect from innovative core to the periphery.

## Method and plan of analysis

This study explores knowledge work in a Grade 5 class. A total of 24 Grade 5 students attended this study and explored Mathematics topics (e.g., proportion, measurement, patterning) using robotics, employing Knowledge Building pedagogy and technology. Students used Knowledge Forum to share their ideas, ask questions, and discuss their problems with all other students in the community. In order to address the research question, we employed social network analysis to explore whether the three networks identified by Gloor (2006) is formed. The notes posted by students in Knowledge Forum is collected, and the network of writers (who communicated with whom) is created. The measures that are used in this study are betweenness centrality and density. As Gloor (2006) described, a central cluster of people in the network with high density and low betweenness centrality forms a COIN. On the other hand, CLNs and CINs have higher betweenness Centrality and lower density, because "external members are connected only to core team members but not among themselves" (Gloor, 2006, p. 150). Other statistic measures like note reading is used to examine which students form the CLN and which the CIN.

## Data analysis and preliminary results

Figure 1.a shows students' contributions network. According to Gloor (2006), a highly connected cluster of people is a strong indicator of the emergence of an innovation team. Considering this criterion, a potential COIN team is identified and shown in Figure 1.b

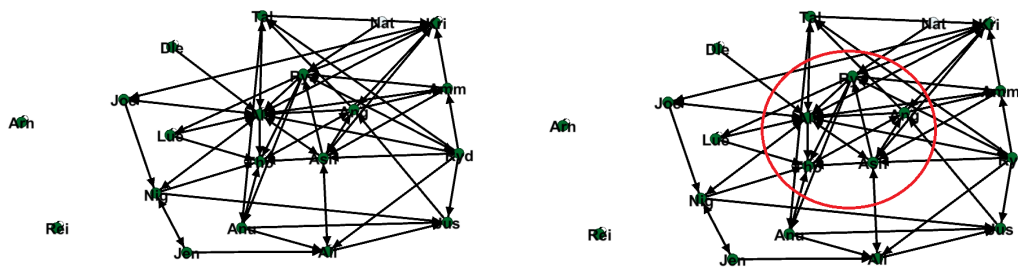


Figure 1. a. Students' contributions network, b. the potential COIN network.

According to Figure 1.b, Alt, Tho, Ash, Ang, Rya are the potential COIN members. To verify the COIN members have been correctly identified, Gloor suggested a COIN network has a high group density and low group betweenness centrality. The results of the SNA show that while the density of the whole network is 0.253, the density of the identified COIN is 1.5, which is in line with Gloor's statement. Also, the group betweenness centrality, as calculated according to Freeman's index, is 0.027536, which is considered low. Therefore, the results of the SNA show the network consists of Alt, Rya, Ash, Ang, and Tho has a high density and low group betweenness centrality, which confirms the emergence of a COIN.

On the other hand, Gloor stated that the CLN and CIN have low density and high group betweenness centrality. The density of the remaining network (i.e., the whole network, excluding the COIN members) calculated as 0.11, and the group betweenness centrality equals to 0.052809. The calculated measures confirm the remaining students form a CLN and a CIN. As stated by Gloor, the CLN members not only -like experts- actively share knowledge but also -like students- actively seek knowledge (Gloor, 2006). On the other hand, while a minority of people in a CIN share knowledge, the majority of them are silent knowledge seekers (lurkers) who do not usually contribute any content (Gloor, 2006). Therefore, students who have posted a reasonable number of notes (i.e., above the average) and have been actively reading notes (i.e. reading the notes more than the average) form the CLN. Using log data and considering the criteria described above, Ryd, Kri, Ali, and Tal form the CLN network. Therefore, the other 14 students form the CIN network. To verify this finding with social network analysis, we have separated the CLN and CIN networks to calculate network density and the group betweenness centrality for each network. The network density of the identified CLN is 0.417 and its Group betweenness centrality equals to 0.046087. On the other hand, the network density of the identified CIN is 0.082 and its betweenness centrality is 0.136361. The results show that both these networks have lower density and higher GBC compare to the COIN, which confirm the CLN and CIN are correctly identified.

## Conclusion and discussion

This study was the first attempt to employ knowledge building pedagogy and technology in robotics. The preliminary results show that employing knowledge building pedagogy in robotics creates a community knowledge in which an innovation network is formed. However, not only the emergence of the COIN is important, but also the movement of individuals between networks is important; it is important to have a community in which there are not insiders and outsiders but one where everyone can move between roles of doer, explainer, and critic. For future direction, we aim to conduct such analyses over time and explore how student collaboration patterns change over time, and whether students move from one network to the other two networks.

## References

- Cohen, E.G., Brody, C., & Sapon-Shevin, M. (Eds.) (2004). *Teaching cooperative learning: The challenge for teacher education*. Albany, NY: Suny Press.
- Giannakopoulos, N. (2009, September). *Experiences from WRO 2009 competition and verifications about the robotics incorporation in the school*. Paper presented at the Lessons Learnt from the TERECOP Project and New Pathways into Educational Robotics across Europe, Athens, Greece.
- Gloor, P. (2006). *Swarm creativity: Competitive advantage through collaborative innovation networks*. NY: Oxford University Press.
- Johnson, D., Johnson, R., & Smith, K. (1991). *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction.
- Kanda, T., Shimada, M., & Koizumi, S. (2012). Children learning with a social robot. In the *Proceedings of the 7<sup>th</sup> annual ACM/IEEE Intl Conference on Human-Robot Interaction* (pp. 351–358). ACM, NY, NY.
- Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 97-115). Cambridge University Press.

# Microblogging for Joint Construction of Meaning in the Classroom

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**Abstract:** In this study we present a digital microblogging tool called Talkwall with the aim to contribute to research focusing on how digital technology can facilitate student participation, dialogue, and learning in the classroom. By analyzing classroom interactions, we show how Talkwall supported joint meaning making in a whole-class setting.

## Introduction

Research on classroom dialogues shows that much variation in classroom dialogues exists worldwide (Alexander, 2008). The reason is that teaching often comes with established norms for classroom interactions, and if teachers use questions to keep topics closed down instead of opening them up, this may limit student engagement and the educational potential of talk. Generally, dialogue is considered productive for learning if the classroom is a place of purposeful inquiry in which students can express ideas, listen to each other, consider alternative perspectives, and share and build on each other's ideas (Alexander, 2008; Littleton & Mercer, 2013).

A growing body of research finds that digital technology may facilitate dialogic teaching in the classroom (Major et al., 2018). This research indicates that sharing objects on interactive whiteboards provides opportunities for shared attention and joint reference in whole-class teaching. The shared objects also provide opportunities for participation, as students can interact with and manipulate them, as well as save them for further discussions later. Furthermore, microblogging (e.g., Twitter) also seems to support joint construction of meaning in the classroom. The short-message format (e.g., tweets) seems productive for mobilizing and eliciting students' understanding of a topic, starting conversations or bringing new information into conversations. Talkwall is a microblogging tool that aims to support participation and dialogue in the classroom (Rasmussen & Hagen, 2015). In this study, we focus on how Talkwall can support joint construction of meaning through whole-class teaching and discussions.

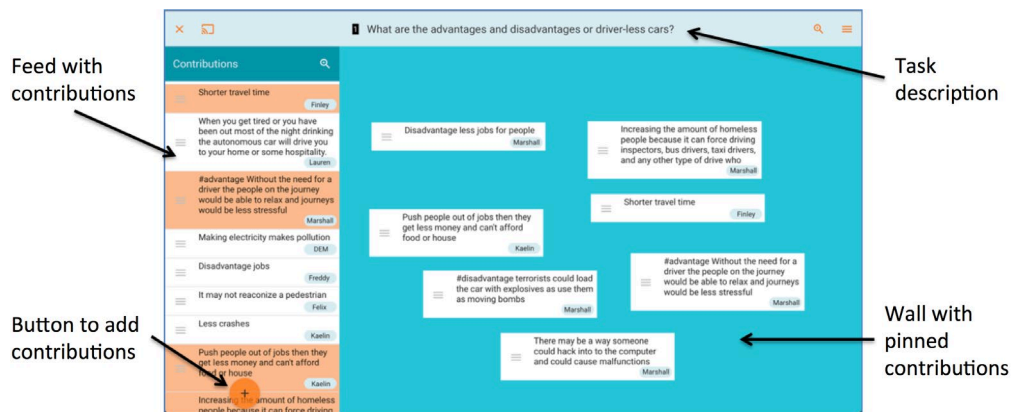


Figure 1. A screenshot of Talkwall with descriptions.

## Talkwall

Talkwall is a browser-based tool comprising a task description on top, a feed on the left, and a wall (Figure 1). The teacher posts tasks that are displayed centrally. Each task has one feed and one wall. To contribute an answer to a task, the student clicks the "+" symbol at the bottom of the screen to open a message box, in which students can enter their text. The contribution is then submitted to the feed with no limits as to how many contributions students can add to the feed. In Talkwall, participation and dialogue are supported mainly through three mechanisms: short textual contributions, the feed, and the wall. The short-communication format's intent lies in the premise that microblogging is so commonplace, it may encourage students to participate, and the format can be read quickly to exchange ideas and elicit possible discussions (Rasmussen & Hagen, 2015). For the teacher, the feed is intended to provide an overview not only in terms of participation, but also in how students formulate their ideas. For students, the feed is meant for them to both acquire and build on their peers' ideas. The teacher may highlight certain contributions in the feed to share interesting ideas concerning the task

that students are working on currently. Contributions in the feed also can be pinned to the wall to promote interesting contributions, arrange them, and synthesize their information through dialogue.

## Setting and method

In this study, we used data from a lower secondary school in Norway, where we conducted video observations of a social sciences class of approximately 26 students (13-14 years old, seated in groups of three and four) during the winter of 2017. The teacher had more than 20 years of experience and described herself as having ordinary knowledge of ICT. She is one of several teachers who participated in the "Digitalised Dialogues Across the Curriculum" project (DiDiAC) funded by the Research Council of Norway [FINNUT/Project No: 254761], which aims to develop and enhance classroom dialogue by using Talkwall. A rich data set was collected, comprising field notes, video recordings, interviews, and log data. The video recordings from whole-class sessions comprise the core data, and analyses of verbatim transcriptions of video recordings are used to provide concrete descriptions of social interactions. In this study we take a sociocultural perspective, and to understand what is going on, we apply Linell's (2009) concept of "joint construction". This analytic concept refers to the collective construction of discourse and meaning mediated by tools.

## A teacher's work with students' views in a whole-class setting

In what follows, we provide an example of a typical discourse from a one-hour lesson. The theme is the Industrial Revolution. The teacher first introduced the lesson's goals, and some central concepts. She then introduced a task called "odd one out," in which each group of students was presented with a set of four pictures and corresponding words describing the pictures. Each group's task in Talkwall was to decide which picture in its set did not fit the Industrial Revolution period and why. Each group used a tablet to write their answer in Talkwall. When all groups were done with the task the teacher used her tablet to pin each group's contribution one at a time. Each pinned contribution was projected onto a large screen in front of the classroom so that it could be discussed in a whole-class setting. The following excerpt begins just as the teacher has pinned Group B's contribution to the wall.

1. Teacher: Group B. Horses, coal, factories, machines. Horses. Please, explain (5.0)
2. Ann: Uhm, horses are out because they were used before the industrial revolution
3. Teacher: Okay? Yes. So horses were the only ones used before the industrial revolution? Is there anyone else that has thoughts about this? (2.0) (*Tom from another group raises his hand*) Yes, Tom?
4. Tom: Weren't machines used before the industrial revolution?

From this exchange a few aspects become apparent. First, Talkwall supports mobilizing and eliciting of students' ideas, as the contributions make the students' opinions visible (line 1). The second aspect is that contributions pinned to the wall become productive for starting conversations. Contributions become shared objects for shared attention and joint reference. Group B's contribution on Talkwall was projected on a large screen in front of the classroom, and the teacher used the contribution in Talkwall to trigger a justification from the group (line 1). Third, through the task and the public display of their contributions the groups become accountable to the learning community and have to provide reasons for their choice (line 2). Finally, the shared attention towards the contributions and the teacher's orchestration of the class provide opportunities for other students to participate with potentially different perspectives (line 3 and 4). Thus, what this exchange illustrates is how Talkwall to a certain extent affords joint construction of meaning through the public display of students' written contributions, through which the teacher can build a whole-class dialogue.

## References

- Alexander, R. (2008). *Towards dialogic teaching: Rethinking classroom talk (4th ed.)*. Thirsk: Dialogos.
- Linell, P. (2009). *Rethinking language, mind, and world dialogically: Interactional and contextual theories of human sense-making*. Charlotte, NC: Information Age Publishing.
- Littleton, K. & Mercer, N. (2013). *Interthinking: putting talk to work*. Abingdon: Routledge.
- Major, L., Warwick, P., Rasmussen, I., Ludvigsen, S., & Cook, V. (2018). Classroom dialogue and digital technologies: A scoping review. *Education and Information Technologies*, 23(5), 1995–2028.
- Rasmussen, I., & Hagen, Å. (2015). Facilitating students' individual and collective knowledge construction through microblogs. *International Journal of Educational Research*, 72, 149–161.



# Tools to Facilitate Teacher and Student Collaboration in Assessment

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**Abstract:** This paper reports on an ongoing design based research project in which researchers and teachers collaborate to design, teach and assess STEAM units of work. Drawing on research on project based learning and interdisciplinary collaboration, we investigate two computer-supported tools that mediated between: students in groups reaching consensus on disciplines included in their project, and students and teachers engaging in self- and teacher-assessment using a rubric. We make recommendations for future iterations of the research.

## Introduction and background

STEM education is a priority nationally and internationally, as countries identify areas of investment for future workforce planning. STEAM education includes the Arts (e.g. Herro & Quigley, 2017). STEM/STEAM education can include units of work that require students to make connections between discipline areas (e.g. Costin, Thompson & Chapman, 2018). STEM/STEAM learning environments provide challenges both for researchers to understand the interplay of teacher and learner activity, as well as for the design of assessment by teachers (Costin et al., 2018). Computer supported collaborative learning (CSCL) “refers to situations in which computer technology plays a significant role in shaping the collaboration” (Goodyear, Jones & Thompson, 2014, p. 440). Research that explores how individuals learn to work in interdisciplinary teams in graduate or professional settings (e.g. Pennington et al., 2015) focuses on the integration of disciplinary perspectives to create a shared model of a given system to then represent and mediate conversations about the phenomenon in study. Goodyear et al. (2014) argue that the computer component of CSCL can play different roles in the support of collaboration, including providing a visual representation of the task or scaffolding particular epistemic processes, such as knowledge building. In project based learning (PBL) students work in small groups where a question or problem organizes or drives activities, and these activities produce artefacts, products or solutions which address the driving question. (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). Jonassen (2000) provides a description of eleven problem types: logical, algorithmic, story, rule-using, decision making, trouble-shooting, diagnosis-solution, strategic performance, case analysis, design, and dilemmas. For students to become intentional, constructive learners they need to assume some authority and take responsibility for their learning. Black and Wiliam (2009) identify the core role of peers in formative assessment (through peer teaching and collaborative learning) and the learner themselves (providing opportunities to develop metacognition, motivation, interest, attribution, and self-assessment). Boud and Falchikov (1989) state that “Self-assessment refers to the involvement of learners in making judgements about their own learning, particularly about their achievements and the outcomes of their learning” (p. 529). There have been several studies indicating a discrepancy between teacher or tutor evaluation of student work, and self-evaluation, even using criteria co-developed with students (Orsmond, Merry & Reiling, 2000). We present a STEAM unit of work developed over several years, as part of ongoing design-based research project in which researchers and school teachers work closely to collaboratively design, teach and assess STEAM units. We examine two computer-supported tools that mediated the collaboration between: students in groups reaching consensus on disciplines included in their project, and students and teachers engaging in self- and teacher-assessment using a rubric, and provide recommendations for the next iteration of the research.

## Methods

Design-based research methods connect theory to the design of a particular activity, which is then implemented and evaluated (Sandoval and Bell, 2004). The combined design approach applied to the development of this project is explained in full elsewhere (Thompson et al., 2016). This study was conducted in an Australian high school, with eight girls and 14 boys in years 7 and 8. The curriculum for Government schools until Year 10 is mandated by a national body, the Australian Curriculum and Assessment Authority (ACARA). Given the different expectations of working for students in the STEAM areas, designing integrated assessment is challenging. Students participated in an 8-week program devised to scaffold independent STEAM inquiries in preparation for a local, regional science fair. The student STEAM projects were classified by the researchers according to Jonassen's (2000) typology of problem-solving. Data was collected using the students' portfolios. The assessment

rubrics were based upon standardised criteria sheets currently in use in the school. To encourage reflection and assessment literacy on the part of the student, a self-assessment rubric was included. In the results section we compare the overall score allocated by students and the teacher and investigate the elements of the rubric in which there was the greatest discrepancy in assessment.

## Results and discussion

Applying Jonassen's (2000) typology of problem-solving, of the nine projects, six were classified as decision-making, one as trouble-shooting and two were classified as design projects. Students tended to over-estimate the number of disciplines included in their project, although most groups did identify a focus discipline aligned with the researcher's. The strongest similarity was the importance placed on Science, which was generally a heavily weighted component in the projects. Arts received the least weighting by students. The STEAM projects provided clarity in learning, experience in developing stages of inquiry, the integration of skills from different disciplines, and an opportunity to synthesise past learning with emerging learning. The rubric was not used effectively as a tool to negotiate project scope or expectations with these students.

## Conclusions

The examination of the role of two tools to support collaboration and self-assessment has revealed the potential of enabling further student agency in STEAM units of work, and in subsequent iterations, the learning goals of the students will be more closely aligned with the rubric, negotiated with the teacher, and re-negotiated at key points during the Technology projects. By more closely scaffolding the different Science and Technology (design) processes, the rubric could be used to facilitate learning associated with metacognition, motivation and self-assessment. The effectiveness of project based learning, and in STEAM units of work is dependent on the willingness of educators to allow students to regulate and control their own learning, and the willingness of students to accept this responsibility.

## References

- Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, 21(1), 5-31.
- Blumenfeld, P., Soloway, E., Marx, R., & Krajcik, J., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, 26(3-4), 369-398, doi: 10.1080/00461520.1991.9653139
- Boud, D., & Falchikov, N. (1989). Quantitative studies of self-assessment in higher education: A critical analysis of findings. *Higher Education*, 18, 529-549.
- Costin, D., Thompson, K., Chapman, S. (2018). Productive collaborative design of a STEAM unit of work in a multi-age class. *Integrated education for the real world. 5<sup>th</sup> International STEM in Education Conference, 21<sup>st</sup>-23<sup>rd</sup> November 2018, Brisbane.*
- Goodyear, P, Jones, C., & Thompson, K. (2014). Computer-supported collaborative learning: Instructional approaches, group processes and educational designs. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 439-452). New York: Springer. Doi: 10/1007/978-1-4614-3185-5\_35
- Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development: implications for teacher educators. *Professional Development in Education*, 43(3), 416-438. <https://doi.org/10.1080/19415257.2016.1205507>
- Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development*, 48(4), 63-85. doi.org/10.1007/BF02300500
- Jonassen, D. H. (2003). *Learning to solve problems with technology (2nd ed.)*, Upper Saddle River, NJ: Merrill.
- Orsmond, P., Merry, S., & Reiling, K. (2000). The use of student derived marking criteria in peer and self-assessment. *Assessment and Evaluation in Higher Education*, 25(1), 23-38.
- Pennington, D., Bammer, G., Danielson, A., Gosselin, D. C., Gouvea, J., Habron, G., Hawthorne, D., Parnell, R. A., Thompson, K., Vincent, S., & Wei, C. (2015) The EMBeRS project: Employing model-based reasoning in socio-environmental synthesis. *Journal of Environmental Studies and Sciences*.
- Sandoval, W., & Bell, P. (2004). Design-based research methods for studying learning in context: Introduction. *Educational Psychologist*, 39(4), 199-201. doi: 10.1207/s15326985ep3904\_1
- Thompson, K., Gouvea, J., & Habron, G. (2016). A design approach to understanding the activity of learners in interdisciplinary settings: Environment and Diversity. *To be presented at the International Conference of the Learning Sciences, June 19-24, Singapore, 2016.*



# Negotiation of Epistemic Territories and Collaborative Learning in Workplace Interactions: The Case of Requests for Assistance

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**Abstract:** Vocational learning processes within interaction are poorly documented in the scientific literature. Difficulties lie in the need to identify “observables” that provide access to the interactional ingredients of learning processes as well as to the dynamic transformation of practices. In line with research work that focuses on epistemic asymmetries within interaction, we propose here to examine situations where novice professionals encounter difficulties and thus call upon their colleagues, more or less experienced, to ask for help. Building upon research work on the critical concept of “epistemic territories” as it has been developed within Conversational Analysis, we will highlight how request sequences for assistance project upcoming possible instructional activity. We are therefore interested in informal vocational learning situations that take place independently of a curriculum, and in the interactional processes that constitute them.

## A conversation-analytic approach of epistemics

We are interested in work situations where novice professionals encounter difficulties and thus call upon their colleagues to ask for help. We are therefore interested in informal vocational learning situations and in the interactional processes that constitute them. But how can a conversation-analytic approach usefully document learning processes in the workplace?

At a methodological level, the purpose of a conversation analytical approach (Mondada, 2013) is to provide insights into the organization of human interactional practices. These practices carry different pragmatic meaning that can be grasped through the analysis of verbal and non-verbal behaviour. Interactional analysis aims to group these practices, compare them and identify, for a given context, what brings them together and what opposes them. By identifying social functions of professional practices, conversation analysis reveals patterns of actions, namely, interactional strategies mobilized by participants in a work situation for all practical purposes. These patterns of actions then represent situated responses to practical problems that participants encounter moment after moment within the interaction. It is worth noting here that the interest in studying language practices leads to the need for audiovisual recordings and their fine-grained transcription.

Research work of the sociologist John Heritage on “epistemic territories” has particularly caught our attention (Heritage, 2012). The concept of “epistemic territories” refers to the set of theoretical and practical knowledge implemented within participants action: “*epistemic territories embrace what is known, how it is known, and persons' rights and responsibilities to know it*” (2012, p. 5-6).

Beyond the sequential and temporal organization of the interaction, Heritage’s work raises the knowledge issue as an interactional resource. He shows that any situated action is always based on the belief in a shared knowledge. Shared knowledge primarily concerns the different grammatically possible and socially acceptable ways of producing statements with unambiguous pragmatic value, depending on the speaker's knowledge about the status and knowledge of the other person. Thus, the same idea will not be expressed in the same way depending on whether you are addressing a colleague or a friend, someone who is an expert in the field or someone who knows nothing about what a particular idea or action implies and so on. Shared knowledge is not considered as an abstract cognitive process but it is analysed through the choices that are made and actions initiated by participants within an ongoing activity. Heritage's work has shown that shared knowledge is salient within interaction when tensions or discrepancies are observed between what is expected and what participants effectively achieve. Tensions are observed through the ways participants will either thematize a particular issue or treat it within interaction by reorganizing their activity by means of, among other things, reformulations, and sequences of explanations or evaluations.

Several key distinctions in Heritage’s recent work provide analytical tools that allow us to address the issue of interactional workplace learning processes. He distinguishes the “epistemic status” (linked to the socio-professional category of the participant) from the “epistemic stance more knowledgeable K+ versus less knowledgeable K-” (linked to the roles actually embodied by the professional within the interaction). The distinction between epistemic stance and epistemic status is important since, in action, one does not always coincide with the other. In other words, someone who has the status of expert does not always act or is not always identified as an expert (Mondada, 2013).

## Data

Data were collected in an insurance call centre in France over five days, for a total of thirty hours of video recordings. We filmed two teleprospectors with two cameras and a call recorder. The team is quite heterogeneous in terms of professional experience within this service. This is particularly interesting for our study, since it abounds with moments when teleoperators encounter "new" situations that are more or less problematic and for which they call upon the expertise of their team leader or colleagues.

## Analysis

The collection of excerpts on which we have worked documents requests for assistance when teleoperators face practical problems where they do not know how to answer a customer's question or encounter difficulties in applying a specific technical procedure. Systematically, these requests to co-workers are formulated "by turning off the microphone", which prevents the client from hearing the exchanges between professionals. Requests for assistance are the subject of several studies in the field of conversational analysis (Kendrick and Drew, 2016). In our study, we examine sequences of requests for assistance in the light of the participants' epistemic territories within interaction. We focus our attention on moments when a teleoperator presents an inadequacy in terms of professional knowledge with regard to the customer on the phone. We show that in the context of human service professions, this type of problem and its resolution can be problematic. In the following excerpt LOU is the teleoperator, YAN the manager and TEO the customer (shortened excerpt). TEO makes an appointment following LOU's call. He asks to send him confirmation through a text message but LOU does not know if this is possible. She turns off the microphone and questions her manager Yan (see Table 1).

Table 1: Transcript and analysis

Transcript	Analysis
9 LOU can we send an sms confirmation?	Question
10 YAN uh no	Answer
11 LOU do we send a letter\=	Relaunch, looking for another way to confirm
12 YAN =he is online?	Request for clarification
13 LOU yeah	Answer
14 YAN he just notes uh the appointment	Solution
15 LOU he just notes? we send nothing?	Confirmation request
16 YAN no we send nothing	Answer

What we find in our data is not simply about imitating or reproducing the different steps of a task. Indeed, a common conceptualization of the work and adherence to its organizing principles are necessary to transform LOU's K- stance to a K+. However, in a work situation, this conceptualization rarely involves traditional means of training such as anticipation, explanation, description, and so on. Our study shows how professionals make their actions visible and intelligible to their colleagues within disruptive moments.

## Conclusion

The analysis of participants relative epistemic positions (greater knowledge K+) versus (lesser knowledge K-) over the course of the interaction, as well as of the participation framework that they configure, aim to document interactional traces of implementing professional practices of others and deepen thus our understanding of the learning processes in work situations as they occur in interactions between more or less experienced professionals (Koschman, 2013).

## References

- Heritage, J. (2012). Epistemics in action: Action formation and territories of knowledge. *Research on Language & Social Interaction*, 45(1), 1-29.
- Kendrick, K.H. & Drew, P. (2016), "Recruitment: Offers, Requests, and the Organization of Assistance in Interaction", *Research on Language and Social Interaction*, 49(1),1-19.
- Koschmann, T. (2013), "Conversation analysis and learning in interaction", *In The Encyclopedia of Applied Linguistics (Carol A. Chapelle, ed.)*, Oxford, U.K., Wiley-Blackwell, pp. 1038-1043.
- Mondada, L. (2013), "Displaying, contesting and negotiating epistemic authority in social interaction: Descriptions and questions in guided visits", *Discourse Studies*, vol. 15, no. 5, pp. 597-626

# Understanding Teachers' Collaboration for Designing Technology-Enhanced Learning

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**Abstract:** This study examined the effectiveness of teacher collaboration in promoting teachers' attitudes and perceived competence toward design. Team design talk was analyzed. Additional data included teachers' attitude and perceived competence questionnaire. Results showed that teachers' perceived competence toward design improved after collaboration, yet their attitude toward design did not change significantly. Qualitative analysis showed that challenging ideas was found positively correlated to the formation of team shared mental model.

## Introduction

Encouraging collaboration among teachers is essential for effective professional development programs. As teacher design talk is the main resource for understanding teachers' collaborative design, this study attempts to analyze how teachers go through the collaboration. One promising line of research that may shed light on teachers' collaborative design process is shared mental model (SMM). SMMs are "knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members" (Cannon-Bowers, Salas, & Converse, 1993, p. 228). Johnson, Lee, Lee, O'Connor, Kahlil, and Huang (2007) identified five key dimensions of shared mental models: (1) team knowledge, (2) team skills, (3) team attitudes, (4) team dynamics, and (5) team environments. Research suggested that if members had very different response to questionnaire assessing the SMMs, team members were likely to have large gap towards completing tasks (Razzouk & Johnson, 2013). In this study, we focus on what kind of collaborative action helps the formation of SMM.

## Method

### Research questions

There are three main research questions in this study: (1) Whether the collaborative design helped to improve teachers' attitudes toward and perceived competence in designing technology-enhanced learning; (2) How teams went through the collaborative process; (3) How is the relationship between the collaborative process and SMM similarity within a team.

### Context and participants

This study was carried out in a summer graduate course about design technology-enhanced learning. Students who joined this graduate program were young teachers who were in first few years as a K-12 teacher. Each team were required to work in groups to create a technology-enhanced learning lesson. A total of 36 teachers with an average age of 25.5 participated in the study, with 28 females and 8 males. All of them held a bachelor's degree and had an average of 3.4 years of teaching experience.

### Instruments

Background information questionnaire. This questionnaire was composed to collect demographic information, including their gender, age, years in the profession, and subject taught.

Teacher attitudes and perceived competence questionnaire. There were 14 questions that measured teachers' attitudes toward designing, which was adapted from the Science Attitude Scale developed by Sumrall's (2008). The second part of the questionnaire contained 6 questions measuring teachers' perceived competence in designing, which was adapted from Voet and De Wever's (2017) questionnaire.

Shared mental model questionnaire. This questionnaire was adapted from team assessment and diagnostic instrument by Johnson et al. (2007). All the items were 5-point Likert-scale questions, ranging from "highly disagree" to "highly agree". It consisted of 15 items in five dimensions.

### Procedure

The design project module underwent three successive days. In the first day, all teachers took the attitudes and perceived competence questionnaire. Then they received lecture about design, practiced related cases, and discussed issues about designing. In the second day, teachers were randomly assigned to 12 teams. Teams were

engaged into an authentic collaborative design task for creating inquiry activities on WISE (Web-based Inquiry Science Environment) platform, with the purpose of enhancing their design competence by teamwork. The design task was divided into three phases: 1) topic identification, 2) needs analysis, and 3) project development. The three phases were made by consulting with other 2 teacher educators. The teachers' design talk was recorded as important evidence for understanding their collaboration. Finally, participants completed the teacher attitudes and competence questionnaire as posttest and SMM similarity questionnaire.

## Results

### Effects of collaborative design on teacher attitudes and perceived competence

The results showed that there was a significant increase in teacher perceived competence [ $t(35) = 2.49, p = .02$ ] from the pre-test to the post-test, but no significant difference was found in teacher attitudes [ $t(35) = .75, p = .46$ ].

### Teachers' use of collaborative actions during different phases

In phase 1, there was a significant difference in the percentages of the three types of collaborative actions [ $F(1.38, 48.30) = 8.73, p < .001$ ]. Post hoc test revealed that the percentage of developing ideas was significantly lower than those of the other two skills. In phase 2, there was also a significant difference in the percentages of the three types of collaborative actions [ $F(1.57, 54.85) = 44.08, p < .001$ ]. Post hoc test revealed that the percentage of developing ideas was significantly lower than those of the other two skills, and the percentage of presenting ideas was also lower than that of challenging ideas. In phase 3, there was no significant.

### The relationship between collaborative actions and SMM similarity

It was revealed that SMM similarity differed significantly across the five dimensions [ $F(2.11, 23.16) = 5.32, p = .012$ ]. The value of SMM similarity of dimension 2 was significantly higher than that of dimension 4, suggesting that teams reached greater consensus in the dimension of team dynamics than in the dimension of team skills. Correlation test suggested that the more frequently the team members with different expertise challenged each other's ideas, the more consistent understandings the team members formed. In contrast, the more frequently the team members developed ideas, the less likely the team members to form common perception in dimension 5.

## Discussion

The findings of this study have several implications. First, attitude change for teachers is not an easy process. They may need more opportunities to examine the effectiveness of their design for improving the attitude. Second, promoting teachers' collaborative actions of challenging ideas may lead to a greater team consensus. Therefore, researchers or teacher instructors could encourage teachers in design teams to question or challenge team members' ideas to facilitate the process of forming consensus. Finally, developing ideas was found to be negatively correlated with team consensus, which suggest that more guidance is needed to help improve the idea development and negotiation process among teachers with different expertise.

As this study is limited for its duration, it is suggested that future research conduct multiple assessments of SMM at different phases of collaborative process. It's also necessary to examine how the development of SMM are influenced by teachers' collaborative actions.

## References

- Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan (Ed.), *Individual and group decision making: Current issues* (pp. 221–246). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Johnson, T. E., Lee, Y., Lee, M., O'Connor, D. L., Khalil, M. K., & Huang, X. (2007). Measuring Sharedness of Team-Related Knowledge: Design and Validation of a Shared Mental Model Instrument. *Human Resource Development International, 10*(4), 437-454.
- Razzouk, R. , & Johnson, T. E. . (2013). Case studies' effect on undergraduates' achievement, attitudes, and team shared mental models in educational psychology. *Educational Technology Research & Development, 61*(5), 751-766.
- Sumrall, T. F. (2008). *South Mississippi Public Elementary School Teachers' Implementation of and Attitudes Toward Inquiry-Based Science* (Doctoral Dissertation). Retrieved from [https://aquila.usm.edu/theses\\_dissertations/852/](https://aquila.usm.edu/theses_dissertations/852/)
- Voet, M., & De Wever, B. (2017). Preparing pre-service history teachers for organizing inquiry-based learning: The effects of an introductory training program. *Teaching and Teacher Education, 63*, 206-217.

# **Special Sessions**



## **Eight Provocations for the CSCL Field: Current Significant Discussions and the Future of CSCL**

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The symposium is a follow up of the paper CSCL: History, status, and future direction or Eight provocations for the CSCL field by Wise and Schwarz's in December 2017 in IJCSCL. The paper was written in the form of an argumentative dialogue between a provocateur and a conciliator. Their initial approach was to examine review studies that created premises for the interviews with experts in the field. Another source of premises was their own work in the field for at least 15 years, by publishing papers in the CSCL proceedings and in this journal, as well as being active in the community's conferences and committees.

Based on their overview and synthesis of written interviews with CSCL experts, they distilled eight controversies in the field. These controversies are presented as conversations between a provocateur/provocatrice and a conciliator. The conversations could be viewed as narrative reviews of the field. The provocations are entitled as follows: 1) The blossoming of CSCL tools necessitates "one framework to rule them all." 2) Prioritize learner agency over collaborative scripting. 3) Collaboration and community should be scrutinized scrupulously rather than adhered to as a matter of ideology. 4) The co-habitation of analytical and interpretive approaches in CSCL is actually a situation of co-alienation that cannot be surmounted. 5) Vigorously pursue computational approaches to understanding collaborative learning. 6) Learning analytics and adaptive support should be priorities for CSCL. 7) Evolve or become irrelevant. 8) CSCL should give up on educational change.

In the argumentation between the provocateur and the conciliator, foundational problems in CSCL are at stake, such as how we conceptualize the relationship between computational artefacts and the collaboration they support. Other issues are raised by questions like: How can we understand or predict the nature of the mediation between humans and designed artefacts? What are the most appropriate units of analysis and levels of descriptions for CSCL studies? Should we use one unified theoretical stance, or are the multiple stances currently used more productive for our field?

The contents of these provocations and the pros and cons of the positions debated offer the field new and stimulating aspects to consider.

### **The responses: Squibs in IJCSCL**

The IJCSCL has received four squibs that has responded to the eight provocations. Two that's published in IJCSCL and two that's coming in June 2019 and Fall 2019.

Nikol Rommel argues that instead of attempting to agree on an overarching, unified conceptual framework for CSCL from the top down, and rather than synthesizing findings from CSCL research from the bottom up, the community could take a taxonomy of CSCL support dimensions as a starting point and engage in a concerted research effort with the aim of working towards a comprehensive framework of CSCL support. She proposes such a taxonomy, which currently comprises 12 dimensions.

Yotam Hod, Ornit Sagy and Yael Kali discuss especially the provocation about the impact of CSCL on educational change. They argue that the provocation is based on too limited a view of the kind of impacts that have already been achieved in the CSCL community and can be achieved in the future. They emphasize that some major CSCL initiatives have actually produced sustainable change at the three mentioned levels, and the design-centric research practice partnership model will continue to do so in the coming years.

Marcela Borge and Emma Mercier argue examination of collaborative processes at a single level of an ecological system is too limited. They argue that doing so prevents us from seeing the full complexity of the

types of decisions that teachers and learners make when implementing collaborative learning activities in technologically enhanced, real-world contexts. To address this problem, they propose a micro-ecological framework that recognizes collaborative learning as a complex, cognitively nested, ecological phenomenon and analyzes interactions in a way that aligns with this view.

Pierre Tchounikine argues that the future of direction that access to technology allowing collaboration is not a technical bottleneck anymore. Learners' agency and following, the design of computational artifacts supporting this agency, must be kept at the core of the CSCL research agenda. How this topic should be addressed, however, must be reconsidered. In this contribution, Tchounikine claims that adopting an emancipation perspective to learners' agency and its technological substratum is a desirable path for the future of CSCL, and discusses issues raised by this radical perspective.

## **Structure of the symposium**

Introduction:

- Sten Ludvigsen, University of Oslo

Responses to the eight provocation papers by:

- Nikol Rummel, Ruhr-Universität Bochum
- Yotam Hod, Haifa University
- Marcela Borge, Penn State
- Pierre Tchounikine, University of Grenoble

Summary and next steps:

- Alyssa Wise, New York University Steinhardt
- Baruch Schwarz, Hebrew University



## IAALDE Best Paper Session and Panel Discussion

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### **A study on learners? Behaviours in hands-on learning situations and their influence on academic performance**

Rémi Venant, Kshitij Sharma, Pierre Dillenbourg, Philippe Vidal, Julien Broisin

This study analyzes students' behaviors in a remote laboratory environment in order to identify new factors of prediction of academic success. It investigates relations between learners' activities during practical sessions, and their performance at the final assessment test. Based on learning analytics applied to data collected from an experimentation conducted with our remote lab dedicated to computer education, we discover recurrent sequential patterns of actions that lead us to the definition of learning strategies as indicators of higher level of abstraction. Results show that some of the strategies are correlated to learners' performance. For instance, the construction of a complex action step by step, or the reflection before submitting an action, are two strategies applied more often by learners of a higher level of performance than by other students. While our proposals are domain-independent and can thus apply to other learning contexts, the results of this study led us to instrument for both students and instructors new visualization and guiding tools in our remote lab environment.

### **Exploring causality within collaborative problem solving using eye-tracking**

Kshitij Sharma, Jennifer Olsen, Vincent Aleven, Nikol Rummel

When students are working collaboratively and communicating verbally in a technology enhanced environment, the system is not aware of what collaboration is happening outside of the technology, making it difficult to adapt the system to better support the collaboration of the students. In this paper, we analyze the causal relationships between collaborative and individual gaze measures and the influence that the students dialogue, prior knowledge, or success has on these relationships to find indicators that can be used within an adaptive system. We found that when students are discussing concrete aspects of the problem, the causal relationship between their eye gaze measures changes compared to other types of dialogue patterns. The results also show a clear difference in causal relations when the pairs with high prior knowledge or success are compared with the pairs with low prior knowledge or success. Collaborative gaze causes the individual gaze for pairs with high prior knowledge and the opposite for the pairs with low prior knowledge.

### **Panel discussion lead by Stephanie Teasley**

By Alyssa Wise representing SOLAR, Carolyn Penstein Rosé representing ISLS, Gaëlle Molinari representing EIAH, Danielle McNamara representing AIED, Wenli Chen representing APSE, Stephanie Teasley representing IAALDE.

# What Can 4E Cognition Tell Us About the Successes and Failures of CSCL Implementation

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## Embodied education: Technology-enhanced 4E learning in the classroom

Andri Ioannou

The concepts of embodiment and embodied learning are gaining traction in the field of Education, deeply rooted in theories of 4E (Embodied, Enactive, Extended, and Embedded) Cognition. New and affordable educational technologies (e.g., motion-based technologies, AR, VR) enable researchers and practitioners to include more gestures and body movements into their learning designs. In this short presentation, I will discuss previous and ongoing work in the era of 4E learning, mediated by technology. Phenomena of 4E learning were initially realized in our work with interactive tabletops, through observation of communicative gestures and dramatic play affecting cognition. Our subsequent studies aimed to address 4E learning, inspired by the possibilities offered by affordable, motion-based technologies such as Xbox Kinect. A first series of studies focused on students with special educational needs using a suite of Kinect-based learning games. The work provided insights into embodied education with respect to learners' motoric engagement (i.e., gains in motor performance skills and self-confidence) and sense of immersion/presence (i.e., emotional engagement). The work was later expanded in general education, demonstrating the feasibility of conducting embodied learning in the classroom and its positive impact on language learning and mathematics. Although our initial implementations involved class-wide student activities, our latest work adopted a CSCL setting and revealed several factors affecting students' learning experiences, positively or negatively. It became apparent that the implementation of embodied learning in CSCL settings requires special attention to issues of classroom orchestration, referring to how teachers design technology-enhanced 4E learning environments and manage the learning activities and constraints in real-time. Research in 4E CSCL is in demand; our ongoing work includes numerous implementations of 4E learning in CSCL settings.

## 4-E learning in languages

Didier Bottineau

If studied within the paradigm of 4-E cognition, human speech in natural languages can be envisaged as an ethological domain of interactivity fostering the emergence of "meaning" in all its senses (linguistic meaning as a separate mental event vs as coordination of interpretation and action within the material world). In language teaching, what is to be taught and learnt is not how mental representations are encoded by abstract forms and symbols (lexicon, grammar: morphology, syntax...), but how languaging as 4-E interactivity enables subjects to promote meaning as psychologically and physiologically experienced "micro-worlds" in the Varelian sense.

Under this definition, the transfer of 4-E cognition as a paradigm in cognitive science in languaging to 4-E learning and teaching of foreign languages has far-reaching consequences concerning the way in which embodied coordination is described and practiced and how participants are enrolled into an interactive 4-E learning process that will affect them far beyond the mere acquisition of computational knowhow.

In this short talk I would like to discuss ongoing experiments concerning (i) how the learning of oral interactivity in English, Spanish and French is improved by activities that include the entire bodies as coordinated levies and "simplex by-passes" to arrive at adequate practices in pronunciation, intonation and gesture, feeling and conceptualization, reflexive and mutual understanding, and (ii) how dramatic scenarios and role plays support the acquisition of "syntactic structures" as a collaborative sense-making routines. One crucial issue challenge is how digital teaching (the "4<sup>th</sup> E", "extended") should include innovations which promote the "first three Es" rather than take the learners away from them in virtual environments.

# **Interactive Events**



# RoomCast: Distributing Digital Resources in the Classroom of Things

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**Abstract:** RoomCast is a web-based learning resource distribution tool designed to support whole-class collective inquiry in multi-activity instructional units designs enacted on heterogeneous collections of personal and public devices in classrooms. As a design tool, RoomCast supports accommodation to local curricular adaptations and technology platform availability, enabling the configuration of curated learning and teaching resource collections over a broad range of classroom contexts. In the classroom, RoomCast offers rapid redistribution of resources during teacher-initiated activity transitions, automatically distributing tailored sets of resources needed for the activity to heterogeneous client portals. While informed by research in technology supports for orchestration, RoomCast is not intended as a scripting tool for complex activity sequences. Rather, it is designed to support coarse-grained activity structures involving diverse types of stakeholders, placing responsibility for detailed activity management in the hands of teachers or custom scripts, in pursuit of a descriptive framework accessible to practitioners.

## Introduction

In our research over the past several years we have developed and refined collections of digital resources that provide access to “room-sized” simulated objects of inquiry and tools for the collaborative construction of knowledge in whole-class investigations (Moher, 2006). The curriculum units that utilize these resources involve multiple activity segments enacted over weeks or months requiring distinctive resources for different activities and participant roles, delivered via coordinated suites of spatially distributed public and personal devices positioning the “classroom of things” as a composite community user interface.

Over time, we found ourselves reusing those resource collections in a variety of contexts—to support different learning goals and instructional designs, to accommodate differences in available device inventories in classrooms, and to construct contrastive research treatments. In order to reduce software redevelopment effort, we began development of software that would allow our research team to define and implement declarative *resource distribution plans* based on classroom activities and stakeholder types without the need for procedural programming. The outgrowth of that effort is a web-based system, *RoomCast*, that offers customized portals to multiple stakeholders—learners and teachers, but also designers, administrators, researchers, domain specialists, and researchers—working collectively on a curriculum unit using a curated collection of interoperable digital resources. We have used RoomCast to support the design and enactment of over a dozen curriculum units involving multiple resource suites, divergent instructional designs, and equipment inventories.

In designing RoomCast, we sought a descriptive framework that would be accessible to non-programmers—ultimately, to practitioners—while still providing enough power to accommodate the variations introduced and encountered in different classroom contexts. It combines orchestration support, allowing teachers to define and enact primo-scripts, with orchestrable features enabling enactment-time introduction and spontaneous use of resources in response to emerging classroom activity (Tchoukinine, 2013). As an orchestration resource, RoomCast is best seen as an “arranging” tool (Kollar and Fischer, 2013), affording adaptive configuration of reconfigurable learning and teaching resources. RoomCast draws from contemporary research in scripting systems in its adoption of components including roles, resources, and activities (Kobbe, et al., 2007) as basic structural elements, introducing a menu-based interface as an alternative to table-based view (Wang, et al., 2018) to specify a three-dimensional configuration (portals, activities, and resources). RoomCast is not designed to directly structure collaboration among learners at fine grains of activity found in systems such as Collage (Hernández-Leo, et al., 2006), Common Knowledge (Fong & Slotta, 2018) or FROG (Håklev, et al., 2017). While RoomCast affords the specification of resource distribution in a way that could support many collaborative flow learning patterns (CFLP, Hernández-Leo, 2005) as in Collage, it does not provide such patterns as primitive elements, nor does it provide teachers with assistance in selecting patterns based on their pedagogical benefits.

In the following, we draw on examples of the use of RoomCast in the design and enactment of distribution plans that utilize of a set of coordinated resources supporting investigations of population dynamics in simulated ecosystems. In WallCology (Moher, et al., 2008; Cober, et al., 2012), classroom communities

observe and manipulate distributed (simulated) ecosystems imaged to occupy the walls of their classrooms, collectively uncovering energy exchange relationships and constructing community models that allow them to predict the impact of biotic and abiotic perturbations of their ecosystems. The WallCology suite includes a rich set of interoperating resources: animations of simulated flora and fauna, controls for manipulating ecosystem properties, tools for capturing and representing population histories, forms for submitting evidence-based claims about energy relationships, graphic tools for drawing and annotating food webs, computational models for controlling the simulation, and many others. Below, we briefly describe how distributions plans are specified in RoomCast, offer examples of distribution variants that we have implemented using RoomCast, and discuss opportunities and limitations associated with our approach.

## RoomCast overview

The specification of a RoomCast *resource distribution plan* begins with the specification of the digital web *resources* to be used during the curriculum unit; these resources may include both components of a coordinated suite and stand-alone web pages. In pursuit of simplicity, RoomCast adopts a “one page, one resource” strategy rather than affording component-level design, and offers a uniform tab-based interface style to all stakeholders. The next task is to name the *activities* comprising the unit and the *portals* reflecting the types of stakeholders who involved in the design and enactment of the unit. Finally, the designer constructs a distribution *design* that specifies the resources to be distributed for each portal-activity pair. Figure 1 (left) shows a (partial) resource distribution plan for an eight-week enactment of a WallCology unit in fall 2018, specifying the resources that will be distributed to 'group' portals (shared tablet computers) during the 'biotic experimentalist' activity.

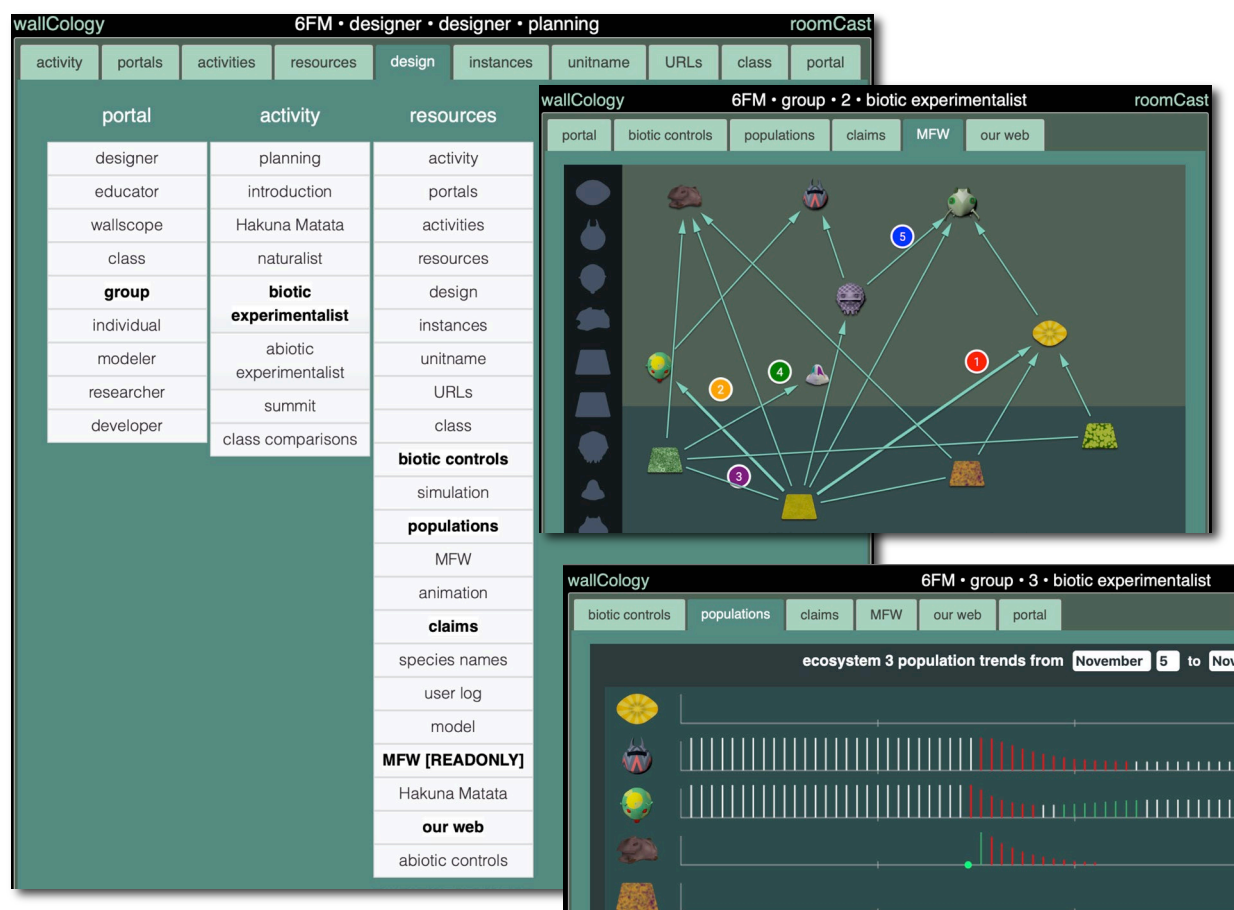


Figure 1. Partial distribution plan for a WallCology (population dynamics) unit.

Because RoomCast is designed to support synchronized, whole-class work rather than independent individual progression through an activity sequence, at any given time all clients are operating under the same activity rubric. RoomCast activities are not (necessarily) enacted in consecutive fashion; they represent

modalities of activity rather than steps in a pre-defined sequence. Figure 1, for example, includes a 'summit' activity used at multiple points during enactment of the curriculum unit. Control over activity selection is in the hands of the teacher rather than an underlying sequencing engine.

Participation in a RoomCast begins with the acquisition or selection of an available device and an intention to use that device to serve as a particular kind of portal into the enactment. This defers the binding of a specific device to the immediate moment of enactment, and readily accommodates device swapping necessitated by device failures or serial sharing between class sections. The recruitment of a device serving a public roomCast portal may be selectively initiated by any of the stakeholders, providing an opportunity for teachers to enlist students as collaborative managers of community technologies. This recruitment mechanism also invites concurrent portals of the same type. In roomCast, all portals of the same type share access to copies of the same set of resources, but interact as individual *instances* of that portal within the roomQuake enactment environment, and may contribute instance-attributable data to an enactment's shared data collection. There are no restrictions on the number of instances of each portal type; this is well suited to the use of participant (e.g., students) and public (e.g., seismographs) portals, although it requires social mediation to impose serial regimens with administrative tools whose use might create database "race" conditions, with concurrent administrative portals overwriting an enactment's "global" environment parameters.

## Supporting local adaptation

In the earliest enactments of WallCology, prior to the development of RoomCast, the determination of species population estimates played an important role in community work. Students were challenged to estimate populations by observing and actively counting individuals in dynamic animations of small window (wallscopes) into a classroom wall, and then estimating the populations within the whole wall by multiplying those counts by the ratio of the wall-to-window area ratio, and document those estimates through incremental additions to population graphs drawn on large poster sheets on the classroom wall. No individual or group devices were used. Groups developed different strategies for counting—dividing the screen into quadrants assigned to team members and merging results, or assigning different team members to different species—that became the subject of class discussions. Perturbations of the ecosystems were effected externally, in the form of global changes to abiotic (e.g., an increase in moisture due to leaking pipes) and biotic (e.g., the introduction of new, invasive species) conditions. The culminating activity involved the development of a whole-class consensus around an abiotic intervention—performed by researchers—to mitigate the impact of the invasive species, and an evaluation of the effectiveness of that manipulation. A RoomCast-based version of this instructional design could simply assign the *animation* resource to wallscopes, and provide the teacher's portal with the *abiotic* and *biotic* control resources for effecting the perturbations.

More recent WallCology enactments have focused on population dynamics and the determination of energy exchange relationships among species, with the goal of constructing a "master food web" depicting direct relationships among the community of species found in the collective ecosystems. In these units, students observe and directly manipulate local ecosystems, developing and submitting evidence-based claims about relationships to a shared database. Because of the change in learning goals, populations are no longer counted by students, but rather provided "automatically" through longitudinal graphs. A RoomCast configuration to support these enactments moves the ecosystem control and claims construction resources to workgroup portals hosted on tablet computers, and adds the 'population graphs' resource to the wallscopes to complement the ecosystem animation. For classrooms with fewer devices, the wallscope portals could be provided with all of these resources, eliminating the need for tablets altogether.

RoomCast has also proven useful as a tool for investigating contrastive research treatments. In a recent project, we restricted access to peer group claims in one classroom to periods when the full class was engaged in "summits" in which they evaluated peer group claims and updated the emergent community model. The goal in that treatment was to ensure that all peer group claims were considered within the context of the full community. In that classroom, we assigned the "master food web" to the teacher portal only. In the other classroom, a read-only version of the master food web was made available on work group tablets, affording groups with access to peer claims when students were working in groups around their local ecosystems.

## Opportunities and limitations

We believe that RoomCast strikes a promising middle ground between usability and expressive power. RoomCast imposes a demand to construct a three-dimensional specification. It would, of course, be possible to condition resource availability on criteria beyond portal type and the current class activity. Variables such as a user's location (e.g., physical proximity to a Bluetooth beacon), state (e.g., earned badges), or time of day (e.g.,

before or after lunch) could all be included as determinants, but at a combinatorial cost in the complexity of distribution plans, as each variable introduces a new dimension to the specification.

Who authors distribution plans? The adaptability we seek to offer requires that teachers become involved in developing and modifying distribution plans. While ambitious teachers might eventually create plans "from scratch" around resource collections, we envision the availability of indexed databases of reusable distribution plans, developed by curriculum designers (or other teachers), that teachers could use modify to adapt to local contexts. We have recently begun to design a RoomCast professional development program that would focus initially on frequently occurring enactment scenarios (e.g., adding new students, responding to device breakdowns), and the move through a progression of configuration resources (defining new activities, introducing new portal types) to build expertise. In addition to instructional designers and teachers, RoomCast is also intended for researchers; in our work, we have leveraged RoomCast to facilitate resource reuse across design revisions and to introduce and enact design variants for experimental research.

RoomCast is designed to reduce the costs in class time associated with activity and class transitions (Dillenbourg, 2013). The 'educator' portal includes the 'activity' resource that can be used to change the activity at any time, causing each client portal to be updated to reflect the resource set appropriate for the new activity. This obviates reconfiguration of public devices, and allows learners to transition among activities without the need to close and open applications.

RoomCast hints at a development strategy focusing on the growth of multiple instructional designs around curated disciplinary resource sets. In our work, we have partnered with scientific experts in developing resource suites embodying disciplinary practices and epistemic forms that we have been able to "mix and match" using RoomCast, allowing us to support multiple curricular designs without the need for extensive re-programming. This represents a more limited domain of reuse than that afforded by crosscutting tools such as the Concord Consortium's SageModeler and SmartGraph resources, but one that allows a tight focus on disciplinary forms and facilitates the construction of interoperable resource suites.

## References

- Cober, R., Fong, C., Gnoli, A., López Silva, B., Lui, M., Madeira, C., McCann C., Moher, T., Slotta, J., & Tissenbaum, T. (2012). Embedded Phenomena for Knowledge Communities: Supporting complex practices and interactions within a community of inquiry in the elementary science classroom. In *Proceedings of the 10<sup>th</sup> International Conference of the Learning Sciences*, Volume 2, pp. 64-71.
- Dillenbourg, P. (2013). Design for classroom orchestration. *Computers & Education*, 69, 485-92.
- Fong, C. and Slotta, J.D. (2018). Supporting communities of learners in the elementary classroom: the common knowledge learning environment. *Instructional Science*, 46 (4), 533-561.
- Håklev, S. & Faucon, L. & Hadzilacos, T. & Dillenbourg, P. (2017). FROG: rapid prototyping of collaborative learning FROG: rapid prototyping of collaborative learning scenarios.
- Hernández-Leo, D., Dimitriadis, Y., Asensio-Perez, J., Villasclaras-Fernández, E., Jorrín-Abellán, I., et al., Collage, a Collaborative Learning Design Editor Based on Patterns Special Issue on Learning Design. *Journal of Educational Technology and Society* 9(1), 58-71.
- Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, 2(2-3), 211-224.
- Kollar, I., & Fischer, F. (2013). Orchestration is nothing without conducting – but arranging ties the two together! A response to Dillenbourg (2011). *Computers & Education*. 69, 507–509.
- Moher, T. (2006). Embedded phenomena: Supporting science learning with classroom-sized distributed simulations. In *Proceedings of the ACM Conference on Human Factors in Computing System*, 691-700.
- Moher, T., Uphoff, B., Bhatt, D., Silva, B., & Malcolm, P. (2008). WallCology: designing interaction affordances for learner engagement in authentic science inquiry. In *Proceeding of the ACM conference on Human Factors in Computing Systems*, 163-172.
- Tchounikine, P. (2013). Clarifying design for orchestration: orchestration and orchestrable technology, scripting and conducting. *Computers & Education*, 69, 500-503.
- Wang, P., Tchounikine, P., & Quignard, M. (2018). Chao: a framework for the development of orchestration technologies for technology-enhanced learning activities using tablets in classrooms. *International Journal of Technology Enhanced Learning*, 10 (1/2), 1-21.

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# Computational Action in App Inventor: Developing Theoretical and Technological Frameworks for Collaboration and Empowerment

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**Abstract:** This special interactive session highlights the how the theory of computational action – which argues for an approach to computing education that is founded on the idea that, while learning about computing, young people should have the opportunity to do computing in ways that have direct impact on their lives and their communities – has informed the development of MIT’s App Inventor, a blocks-based programming language for building native mobile apps. Using examples from our work and from partner institutions, we will show how App Inventor has enabled learners from around the world to collaboratively engage in computational action. With an eye towards furthering App Inventor’s support of computational action, this session will also highlight: 1) The recently developed support for real-time collaboration between students working at different computers; and 2) How different App Inventor components allow students to engage in embodied, enactive, extended and embedded learning.

## Introduction

Seymour Papert famously claimed that the computer is a “protean machine” capable of representing nearly any idea (1980), allowing students to creatively express themselves, develop their own voices, concretize their ideas, and develop diverse and innovative ways to build and learn (Blickstein, 2016). However, despite the considerable promise of computing, and computing education, to support students in developing and implementing their “big ideas”, much of computing education’s focus is on students learning “fundamentals” of programming (e.g., variables, loops, conditional, parallelism, operators, and data handling) (Wing, 2011; Brennan & Resnick, 2011). This focus on students learning the concepts and formalisms of computing, largely decontextualizes the computing they are learning from how students might use computing in their everyday lives. Papert argued that this focus on “skills and facts” works as a bias against the development of personally transformative and meaningful ideas (Papert, 2000). The push for computing education that focuses on the acquisition of computing “knowledge” detached from its real-world applications threatens to instill in young learners that computing is not relevant to them and not something they will need in their future lives or careers – an issue persistently found in math and physics education (Williams et al., 2003; Flegg et al., 2012). If we are serious about computing as a core literacy for students to be productive members of the 21<sup>st</sup> century society and workforce (NRC, 2013), we need to seriously rethink our core assumptions about computing education.

Across the educational landscape, there have been initiatives to situate student learning in authentic contexts. For instance, Project-Based Learning (Blumenfeld et al., 1991), which has students working collaboratively on personally relevant projects, has been shown to increase students’ domain knowledge, intrinsic motivation, and a wide range of other critical 21<sup>st</sup> century skills. In contrast, many traditional approaches that situate computing in real-world contexts are often generic and impersonal (e.g., designing checkout systems for supermarkets) and fail to meaningfully to connect to the personal lives of students.

There are notable exceptions to this traditional approach. For instance, Scratch (scratch.mit.edu) has strived to make computing more personal, by allowing students to easily design and build games that can be shared with a worldwide community (Resnick et al., 2009). BlocklyTalky (Shapiro et al., 2016), is a platform that allows learners to easily combine sensors and physical computing to develop their own musical instruments and other physical computing as a means of self-expression and exploration. An interesting similarity between these platforms is that they largely eschew the traditional text-based approach to programming, preferring instead a block-based metaphor in which segments of code click together in a puzzle-like format. This approach allows users to focus on their designing and building, rather than the messy grammar and syntax that have long been a barrier for engaging youth in computational practices (Maloney et al., 2004).

Another critical barrier in engaging youth in personally relevant computing education is the contexts in which they learn computing – often taking place in traditional computing labs, far removed from students’ everyday lives (Klopfer, 2008). In order to truly make computing education meaningful for students and to connect to their lives outside the classroom, we need to develop educational solutions that transcend traditional classroom walls. Fortunately, the growing proliferation of mobile and ubiquitous computing can allow us to reconceptualize how and where students learn computing. By focusing on these devices, we can free students’

work from the desk-bound screen and connect it directly to their lives and communities. The use of mobile and ubiquitous technology as the platform students build on can open up new avenues for students to see their worlds as “possibility spaces” in which they can identify needs that are relevant to themselves and those in their communities and then build real solutions.

### **Computational action: Computing education for impact and empowerment**

In order to effectively develop educational interventions that engage students in computing education that prioritizes personal relevance and the potential for impact, we need to reexamine the goals of CS education, particularly within K-12 settings. Critically, the goal of computing education needs to move beyond computational thinking towards a perspective of *computational action*. A computational action perspective on computing is founded on the idea that, while learning about computing, young people should have the opportunity to do computing in ways that have direct impact on their lives and their communities (Tissenbaum, et al., 2019). Two key dimensions underly the theory of computational action for supporting learning and development: (1) computational identity, and (2) digital empowerment. *Computational identity* builds on prior research that showed the importance of young people's development of scientific identity for future STEM growth (Maltese & Tai, 2010). For us, computational identity is a person's recognition of themselves as capable of designing and implementing computational solutions to self-identified problems or opportunities. Further, the students should see themselves as part of a larger community of computational creators. *Digital empowerment*, builds from the work of Freire (1990) which situates empowerment as the ability to critically engage in issues of concern to them, and Thomas and Velthouse (1990), who see empowerment connecting to the concepts of meaningfulness, competence, self-determination, and impact. As such, digital empowerment involves instilling in young learners the belief that they can put their computational identity into action in authentic and meaningful ways on issues that matter to them.

In order to develop computational action educational initiatives, we have developed a set of criteria that outline the key elements required (Tissenbaum, et al., 2019). *Supporting the formation of computational identity requires:* 1) Students must feel that they are responsible for articulating and designing their solutions, rather than working toward predetermined “right” answers. 2) Students need to feel that their work is authentic to the practices and products of broader computing and engineering communities. *Supporting the formation of digital empowerment requires:* 1) A significant number of activities and development should be situated in contexts that are authentic and personally relevant. 2) Students need to feel that their work has the potential to make an impact in their own lives or their community. 3) Students should feel that they are capable of pursuing new computational opportunities as a result of their current work.

### **MIT App Inventor: A platform for supporting computational action**

#### **The App Inventor platform**

In order to realize the potential of computational action to move youth beyond Papert's vision of intellectually empowered students (1993) towards students who are empowered to change the world, we also needed to extend Papert's vision of bringing every learner into the computer lab (Papert, 1993; Klopfer, 2008) and instead move computing out into the world (Tissenbaum, Sheldon & Abelson, 2019). As a result, new platforms need to be developed that harness this potential and allowing students to focus on what they want to build and why (Lee et al., 2016), while simultaneously enabling them to quickly put their designs into action. In response, we have developed MIT App Inventor ([appinventor.mit.edu](http://appinventor.mit.edu)), a blocks-based programming that allows anyone to develop fully-functional mobile applications.

#### **App Inventor: Supporting collaboration both locally and globally**

The myth of the lone programmer turning out the next great piece of software or app has largely been debunked (Fitzpatrick & Collins-Sussman, 2012). The reality is that effective programming is a collaborative pursuit that draws in many different skills and competencies. In educational settings, to support novice programmers to collaboratively develop their apps, several pedagogical approaches have been used. Perhaps most prominent is the approach of pair programming, in which students work side-by-side at a *single computer* continuously collaborating on the same code (Williams & Kessler, 2000). Pair programming has been shown to be effective in supporting students in engaging in collaborative discourse and learning from each other (Plonka et al., 2015), in addition to increasing student retention, confidence, and program quality (McDowell et al., 2006).

However, pair programming does have some notable constraints that can hinder its broad adoption. Perhaps the most critical is that both students need to be in the same classroom at the same computer. This can

limit the settings supported by pair programming and is particularly problematic if users are globally distributed. To support students who are developing apps to address global challenges, may require students to work with peers outside their own classroom. For instance, the global Technovation Challenge ([technovationchallenge.org](http://technovationchallenge.org)) has young women (12-18 years old) from all over the world working in distributed teams to develop apps using MIT App Inventor which address challenges both in their local communities and globally.

In response to the desire to enable members of its global community to effectively collaborate, the MIT App Inventor team is testing new features that allow users to collaboratively develop apps together in real-time. Similar to other widely used collaboration tools, like Google Docs, multiple users can synchronously see and edit the same app, with App Inventor updating in real-time to reflect the changes of all collaborators.

An additional challenge of pair programming is that it is designed to only support collaboration between two students, limiting the types of group configurations possible. With App Inventor's real-time collaboration functionality, there are no hard limits to the size of the group. With larger group sizes, students can work on separate parts of the app or work together to collaboratively build and debug portions of an app. Another possible configuration to explore is to have students break up into smaller pair programming teams within a larger group, allowing them to leverage the unique advantages of both pedagogical configurations. In recent work by the research team during a 12-week study at a large urban high school, we observed how the real-time collaboration system allowed student groups to transition between individual and collaborative problem-solving while working on collaboratively developed apps (Tissenbaum & Kumar, 2019).

## Enabling 4E learning: Extending App Inventor into everyday objects and the world

By freeing computing education from the confines of the desktop and computer lab, App Inventor offers new opportunities for students to engage in 4E (embodied, enactive, extended, and embedded) learning. For instance, students used the newly integrated Bluetooth low energy (BLE) and Internet of Things (IoT) extensions to make apps that use light and moisture sensors to monitor and report on the health of plants (embedded); as well as, apps that use light and sound sensors along with embedded cameras to create security systems for their rooms (extended). Other students used motion and location sensors to help fishermen know when their traps get cut and track where they went, reducing waste and additional harm to the ecosystem (enactive). Another group combined interactive maps with geolocating and augmented interactive games to help users learn about and clean up the local river (embodied). Through these features, App Inventor allows students to develop new genres of apps that connect together and to the world in ways that resonate with the pedagogical goals of both computational action and 4E Learning.

## Computational action + App Inventor: A harmony of theory and technology

MIT App Inventor was not originally built with computational action in mind. Instead, the theory of computational action arose as we observed how students interacted with it and the opportunities it afforded for students from all around the world to develop apps that could have real impact in their lives. It helped us realize we needed to move beyond teaching kids to *code* and instead *empower them to be problem solvers*. By allowing students to solve problems as they arise, rather than through canned exercises, we mirror Papert's own visions of how students should learn computing (Papert, 1996) and, perhaps more critically, the authentic ways of professionals (e.g., though sites like [stackoverflow.com](http://stackoverflow.com)). Since its development (as shown in the examples above), computational action is now the underlying theoretical stance that drives the development and refinement of MIT App Inventor. Before a feature is released, we ask "How does this feature support learners to have an impact in their lives or those of their community? How does it reduce barriers for them to put their ideas into action? How does it support students to collaborate, share ideas, or contribute to the larger community of learners, creators, designers who use MIT App Inventor in classrooms, after school programs, makerspaces, and at home?" In this way, the MIT App Inventor team has been able to hold a lens up to its own development as well as to the apps users build, to refine our understandings of computational action, our methodical approaches for supporting it (e.g., materials and support tools), and approaches for measuring their efficacy.

## References

- Tissenbaum, M. & Kumar, V. (June, 2019). Seeing Collaboration Through the Code: Using Data Mining and CORDTRA Diagrams to Analyze Blocks-Based Programming. In *Proceedings of the 13<sup>th</sup> International Conference on Computer Supported Collaborative Learning*. Lyon, France.
- Tissenbaum, M., Sheldon, J., & Ableson, H. (2019) From Computational Thinking to Computational Action. *Communications of the ACM*, 62(3). 34-36
- Blikstein, P. (2016). Travels in Troy with Freire: Technology as an agent of emancipation. *Educação e Pesquisa*, 42(3), 837-856.

- Brennan, K., & Resnick, M. (2012, April). New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the American Educational Research Association, Vancouver, Canada* (pp. 1-25).
- Fitzpatrick, B., & Collins-Sussman, B. (2012). *Team geek: a software developer's guide to working well with others*. O'Reilly Media, Inc.
- Flegg, J., Mallet, D., & Lupton, M. (2012). Students' perceptions of the relevance of mathematics in engineering. *Intl. Journal of Mathematical Education in Science and Technology*, 43(6), 717-732.
- Klopfer, E. (2008). *Augmented learning: Research and design of mobile educational games*. MIT press.
- Lee, C. H., & Soep, E. (2016). None But Ourselves Can Free Our Minds: Critical Computational Literacy as a Pedagogy of Resistance. *Equity & Excellence in Education*, 49(4), 480-492.
- Maloney, J., Burd, L., Kafai, Y., Rusk, N., Silverman, B., & Resnick, M. (2004, January). Scratch: a sneak preview [education]. In *Creating, connecting and collaborating through computing, 2004. Proceedings. Second International Conference on* (pp. 104-109). IEEE
- Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education*, 32(5), 669-685.
- McDowell, C., Werner, L., Bullock, H. E., & Fernald, J. (2006). Pair programming improves student retention, confidence, and program quality. *Communications of the ACM*, 49(8), 90-95.
- National Research Council. (2013). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. National Academies Press.
- Papert, S. (1980). *Mindstorms: children, computers, and powerful ideas*. New York: Basic Books.
- Papert, S. (1993). The children's machine. *Technology Review*. Manchester NH, 96, 28-28.
- Papert, S. (1996). An exploration in the space of mathematics educations. *International Journal of Computers for Mathematical Learning*, 1(1), 95-123.
- Papert, S. (2000). What's the big idea? Toward a pedagogy of idea power. *IBM Systems Journal*, 39(3-4), 720-729.
- Plonka, L., Sharp, H., Van der Linden, J., & Dittrich, Y. (2015). Knowledge transfer in pair programming: An in-depth analysis. *International journal of human-computer studies*, 73, 66-78.
- Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., ... & Kafai, Y. (2009). Scratch: programming for all. *Communications of the ACM*, 52(11), 60-67.
- Shapiro, R. B., Kelly, A., Ahrens, M., & Fiebrink, R. (2016) BlockyTalky: A Physical and Distributed Computer Music Toolkit for Kids. *Proceedings of the 2016 conference on New Interfaces for Musical Expression*. Brisbane, Australia.
- Thomas, K. W., & Velthouse, B. A. (1990). Cognitive elements of empowerment: An "interpretive" model of intrinsic task motivation. *Academy of management review*, 15(4), 666-681.
- Williams, L. A., & Kessler, R. R. (2000). All I really need to know about pair programming I learned in kindergarten. *Communications of the ACM*, 43(5), 108-114.
- Williams, C., Stanisstreet, M., Spall, K., Boyes, E., & Dickson, D. (2003). Why aren't secondary students interested in physics? *Physics Education*, 38(4), 324.
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35.

# Toccata: A Multi-Device System for Activity Scripting and Classroom Orchestration

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**Abstract:** We present Toccata, a system supporting the management of rich multi-device pedagogical activities. Activities designed with Toccata are reusable, shareable and adaptable to the situation. Teachers face numerous challenges in designing and scripting pedagogical activities that incorporate rich media and applications, combine devices, group formations, and spaces. They also face challenges in orchestrating these activities in class, especially to guiding learners, following their progress, and maintaining a coherent learning experience. Our demonstration will showcase how Toccata answers these challenges by supporting individual or collaborative activities, in class or outdoors, under diverse technical conditions, e.g., offline on mobile devices, or fully connected with Desktop computers.

## Introduction

Toccata is an activity-centric system supporting orchestration of pedagogical activities for classrooms. Orchestration aims at helping teachers to create pedagogical scripts, adapt and execute them in a given context [2]. Based on interviews with teachers [3], we identified a set of recurring challenges for creating and conducting digital pedagogical activities in today's classrooms, such as resilience to networking problems, or support for a wide variety of devices. We developed Toccata to facilitate the management of rich multi-device pedagogical activities. In Toccata, activities are reusable, shareable and adaptable to the situation. Toccata supports tight or loose activity scripting. It lets teachers conduct digital activities in class and in more open environments. Toccata also lets teachers modify and adapt unfolding activities according to the situation in the classroom.

Teachers face numerous challenges in integrating digital tools into smooth and coherent teaching activities. Rich pedagogical activities are often fragmented in time, split into multiple sub-activities, built upon multiple media and applications, and may unfold in various locations. They can be initiated in a specific context (technical, physical or social) and continued in another, following a plan more or less strictly defined by teachers.

For example, in a vocational school, a horticulture lesson can start in class with a lecture leveraging an interactive whiteboard, continue in the school's greenhouse with individual work on tablets to inventory flowers and, finish back in the classroom with a synthesis in groups shared with others. Follow-up activities and homework can finally be conducted outside of the school on personal devices.

Combining various activities, devices, group formations, and spaces brings new pedagogical opportunities such as the scenario previously described. But organizing such scenarios is complex as teachers must be able to guide learners, and follow their progress, while maintaining a coherent learning environment. The lack of tools to support these practices makes it difficult for teachers to put rich pedagogical activities into place. And when such activities do happen, infrastructural problems (network, device set-up, content distribution) make it even more challenging.

We designed Toccata to work in schools with various technical set-ups and policies. Teachers can run activities in their classroom, on fixed computers with a reliable network, but also across several rooms or with multiple devices, even if there is no insurance of a reliable network. Toccata also supports disconnected contexts, such as in sports class or activities unfolding outside of school. We have tested Toccata in three different middle schools with highly varied situations: in classrooms over multiple sessions, in activities mixing digital and physical resources, in nomadic activities.

Our demonstration will showcase the versatility of Toccata. We will present activities created by teachers and run with Toccata such as: 1) a fact checking activity, in which students have to verify and correct wiki articles over multiple sessions; 2) a sales management activity which involves roaming, i.e. work on tablets and on a large display in the classroom, but also documentation in a greenhouse; and 3) a collaborative activity involving paper and tablets, in order to learn Agile project management. We will also discuss the underlying architecture allowing our system to work in schools with diverse technical and policy constraints, and its theoretical grounding

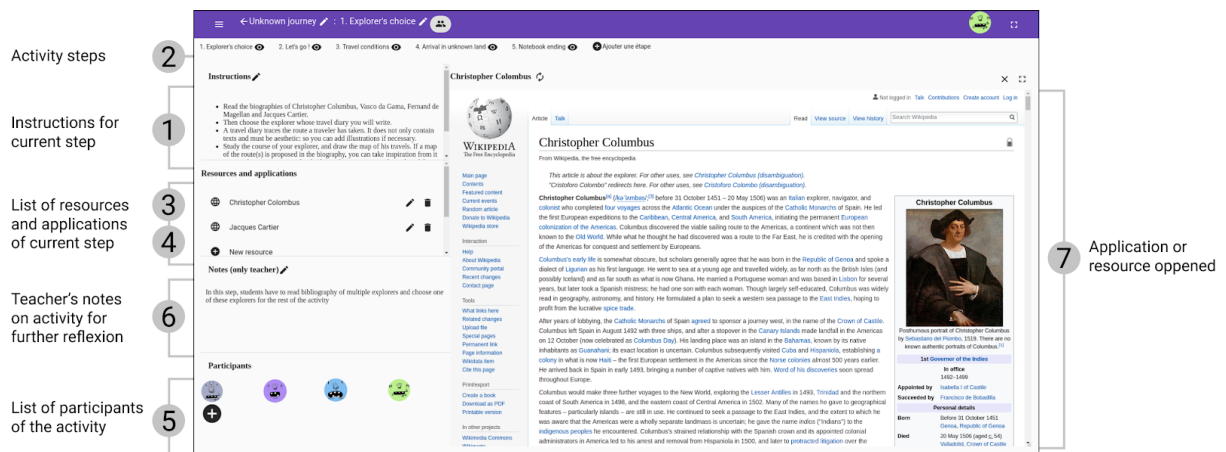


Figure 1. A preview of an activity in Toccata, and components of the activity.

## Toccata

Toccata is a Web-based application enabling teachers to create digital pedagogical activities and conduct them with a class. As a Web-based application, our system works with any kind of devices containing a web browser (computer, tablet, phone, video-projector linked to a computer). Toccata is developed to run in online or offline mode, with an optimal mode and two degraded modes according to network reliability.

## Activity scripting

Toccata builds upon an Activity Based [1] model to represent pedagogical activities. When teachers create an activity, they can define the following components, before enactment or live:

1. A set of **Instructions** for students to guide them in conducting the activity.
2. A list of **Sub-activities (steps)**, created by teachers to divide the activity according to pedagogical needs.
3. A set of **Resources** can be associated with activity or steps and are typically all kind of documents openable with a web browser (pdf, video, audio, website, etc.). These resources are read-only in our system.
4. A set of **Applications** are a set of tools allowing teachers and students to run operations on resources, such as text editors; and to control the activity flow, such as timers.
5. A list of **Participants** involved in the activity.
6. **Notes** that teachers can attach to an activity or step, to jot down things to remember or document of the class unfolded, to improve future iterations of the activity.

## Activity orchestration

During the enactment phase, the teacher and the students have a similar interface. However, the teacher can take notes on the activity, and has more options and actions available on the applications. S/he can edit during class each component of the activity. This run-time edition of the activity can help the teacher in the adaptation of the activity for students. For example, if a student is blocked on a particular exercise, the teacher can refine instructions and give new resources to help the student, or s/he can change the order of steps, add new exercises for specific group, change the visibility of steps for several groups.



Figure 2. (a) Tutor view of Toccata when looking at different group progression; (b) Student view of Toccata during an activity with a project management board and timer loaded.

## Scenario

We illustrate the use of Toccata with a scenario developed in collaboration with a teacher from a vocational middle school. The activity was run in the school over a period of 90 minutes, with two groups of learners to test Toccata in-situ.

Thomas is an economics teacher in a vocational middle school. At the end of the year, he decides to create an activity to review the topics covered during the year. He creates the activity with Toccata and divides it in three steps:

1. Students watch a video of a sale situation, analyze it, and answer questions about concepts from previous course chapters presented in the video in a text editor. They can use the pdf viewer to read the previous lessons related to the video.
2. Students calculate taxes and prices using a collaborative spreadsheet.
3. Students prepare the plant catalog of the school. They visit the greenhouses of the school, take pictures of plants with the tablet and store them in their space in order to build the catalog.

At the end of the first two steps, Thomas includes a correction: a student will do the exercise on the teacher environment in front of the class and project it with the classroom's video-projector. At the end of the third step, Thomas includes a class discussion: each group will present the pictures taken in the greenhouse by using the video-projector and discuss with the class how they could be used to create the sale catalog.

In the first phase, students analyzed a sales situation using external applications within Toccata. Due to an unreliable school network, external Web applications such as the collaborative text editor did not work perfectly, but resources hosted on Toccata could be properly accessed. Although the internet connection was fluctuating, students did not encounter major problems, and managed to move from one step to the next. During the second step, due to the use of an external application for the spreadsheet, changes made during the correction on the teachers' computer connected to the video-projector were not synchronized with students' activity, and students had to manually update the activity on their tablet. In the third step, students moved to a greenhouse, with no WiFi coverage. This step worked smoothly and students could grab their tablet and continue their activity as expected. In the greenhouse, they moved freely and took pictures of plants they later added to a sales catalog. When they came back to the classroom, the activity was updated on the global server and the teacher could access the pictures taken in the greenhouse.

## Implementation

Toccata architecture is built on three layers. The first layer consists of a main Web server and Web applications. The second layer is a local server running inside classrooms. The last layer is composed of client devices running Toccata. The second layer is not mandatory, and devices running Toccata can directly communicate with the remote Web server. When the third layer is not available, the devices synchronize with each other via a local server if they are connected to one. Otherwise they run independently.

Toccata is a Progressive Web Application built with Angular, with duplicated layers, and extra synchronization mechanisms. The server delivers a single page application running in the browser. It is hosted on

Firebase. Activities are stored on a CouchDB database. External applications are iframes opened inside Toccata and local applications are Angular components.

The local server acts as a WiFi hotspot, it can either connect to the Ethernet network of the school, or connect to a tethering smartphone, or run without any Internet connection. The server runs on Node.js and only delivers a simple Single Page Application with very little logic. The activities are stored in a CouchDB database that syncs with the remote one.

Each device runs Toccata and a PouchDB instance. PouchDB allows synchronization between multiple instances of CouchDB servers. As a Progressive Web Application, it offers some native-like features, like home icons on mobile OS, and strong caching mechanisms for the data, but also for the application shell: the webpage can load even when the device is totally offline, and it will synchronize back to the server when it becomes available.

Toccata is open-source and available on GitLab (<https://gitlab.com/lachand/Toccata>). Since Toccata is built on Angular with reusable web components, everyone can reuse components of Toccata in its own project and we think that this may lead to a better integration and assimilation of research projects in commercial and deployed in school systems. In addition, we create a demonstration page where people can use Toccata with a student or teacher account in order to enable teachers, researchers or system editors to test our system and concepts beneath Toccata. This demonstration is available at the following page: <https://en.demo.toccata.education>

## Future work

In future work, we will study the use of Toccata in different contexts, such as a collaborative activity with one device per student instead of one device per groups. We will also work on a classification of tasks and new interaction to support teachers when they had to manage an activity with several devices (attention management, support to students, etc.). Another interesting point for future work is to pass from a note-taking process (what is actually done by teachers) to a reflexive process to design and re-design pedagogical activities.

## Conclusion

We presented Toccata, a system allowing teachers to prepare multi-device activities before class. Toccata enables teachers to edit their activity at it occurs, in order to adapt it to students' progression or to unexpected events occurring in class. Toccata has been tested in different schools and pedagogical context, such as a course on several sessions, a course mixing paper and digital activities, and a course running in class and outside class, with no available network. The demo of Toccata offers participants the ability to edit and run existing activities created by real teachers, and to create their own scripts. Participants will be able to run their scripts on tablets during the demonstration.

## References

- Bardram, J. E. (2005, September). Activity-based computing-lessons learned and open issues. In *ECSCW 2005 workshop, Activity-From a theoretical to a computational construct*.
- Dillenbourg, P. (2013, 11). Design for classroom orchestration. *Computers & Education*, 69, 485-492. doi:10.1016/j.compedu.2013.04.013
- Jalal, G., Lachand, V., Tabard, A., & Michel, C. (2018). Design, Adjust and Reuse -- How Teachers Script Pedagogical Activities. *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. doi:10.1145/3170427.3188483



# Bridging Concepts as Intermediary Knowledge in Design: Productive Dialogues and the Talkwall Microblogging Tool

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**Abstract:** Talkwall is a freely available browser-based tool designed to support classroom dialogue and interaction. When aligned to an appropriate pedagogy, it is intended that Talkwall can encourage students to engage and share their developing ideas, and promote positive dialogic interactions. Research-practice partnerships and design-based research with teachers as co-designers is a key theme in this research programme. We argue the bridging concepts facilitate exchange both ways between theory and practice, and that the material outcome of the design incorporates and displays the ideas for future practice, and as such it contains the embryonic starting point of what ‘might be’.

## Introduction

Contemporary technologies such as microblogging can be integrated into, and are potentially transformative of, pedagogical practices that develop the ‘complex competencies’ today’s students need (for instance, critically thinking about one’s own ideas and how they relate to ideas of others through elaboration and reasoning).

Sociocultural perspectives on social and cognitive development (Vygotsky, 1962, 1978) consider language a central cultural tool for learning and a clear trajectory in academic discourse has been to consider dialogue as a particularly important tool for learning within classrooms (Barnes, 1976; Alexander, 2008; Howe & Abedin, 2013; Mercer & Dawes, 2014; Schwarz & Baker, 2016). Dialogue is ‘more than just talk’; rather, there is a specific focus on sharing and evaluating ideas, building ideas collectively, reasoning, providing justifications and elaborations, and using evidence to support arguments.

The notion of ‘bridging concepts’, initially proposed by research on Human Computer Interaction (Dalsgaard & Dindler, 2014), is used to address the problem of translating theoretical understanding to the design of technology intended to support a specific classroom practice. This form of concept-driven design research is explorative in nature, aiming at manifesting visionary theoretical ideas in concrete designs. The intention is to ‘bridge the gap’ between generalized theories and design instances with intermediary forms of knowledge in the form of conceptual constructs. Building intermediary forms of knowledge is also an essential part of our DBR approach. This is because insights into pedagogically appropriate uses of educational technology for representative teachers in school settings can be limited. Further, there is often a problematic gap between what could be effective technology-enhanced learning (TEL) in theory, and what can be effective TEL in practice (McKenney, 2013).

A long term research programme have been developed, highlighting the importance of material artefacts and material enactments based on tools such as Talkwall. Design in this view continue in the classrooms as teachers are rehearsing future practices (Binder et al., 2011) integrating microblogging in their dialogic teaching.

## A research programme for practice development

DBR is a practice-centered research method grounded in a collaborative partnership between teachers, researchers and technology developers (Roschelle & Penuel, 2006; Lund et al., 2012; Lund & Rasmussen, 2008; Rasmussen & Hagen, 2015). This systematic approach informs the developments of ‘products’, employing theory and research findings in combination with iterative use in real settings; data collection; analysis and evaluation; re-design and adaptation. Based on collaboration between researchers and practitioners, DBR leads to design principles, models and the adaptation of theory (Anderson & Shattuck, 2012).

During this research, all interventions (both dialogic and technology-based) are situated in real educational contexts with collaborating teachers taking part as co-researchers. This methodological approach bridges theoretical research and educational practice by (i) recognizing the lived experiences of teachers and students (ii) integrating their perspectives into the design of Talkwall.

Designing Talkwall has involved the alignment of three ‘modes’ of DBR (see Bell 2004): theories related to productive talk, a cultural-historical approach to understanding mediating technologies, and a situated understanding of limitations and opportunities in the classroom (articulated by teachers during the development process). Teachers have worked as co-researchers to tailor pedagogic approaches to subject discourses, trying,

exploring and developing new classroom practices, forming new tasks and activities, and adapting Talkwall and resources to their own needs. Theorizing thus strongly relates to real-life classroom contexts, and design principles and models ‘reflect the conditions in which they operate’ (Anderson & Shattuck, 2012, p. 17).

## Bridging concepts

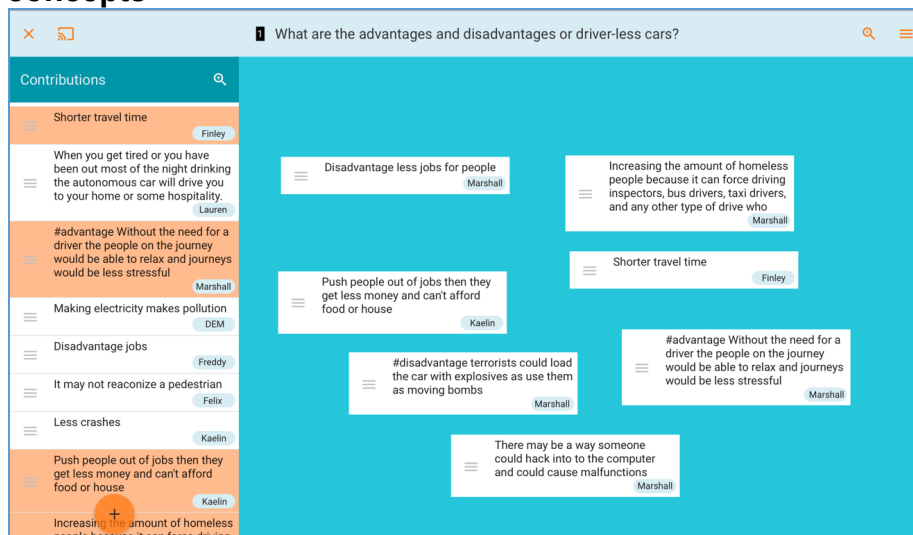


Figure 1. Talkwall with a feed (to the left), and a wall with contributions (centre).

The tool design is based on epistemological positions regarding learning and collaboration, and bridging concepts emerged during the research practice partnerships:

A **contribution** is a microblog, a digital representation of an idea. In Talkwall, a contribution is short, chosen to enhance oral interaction, and not substitute it. To allow the users more interactional control than what is often the case in other microblogging environments (e.g. Twitter) contributions are implemented by a card design. A contribution can be built on by someone else (e.g. extended, made more precise, etc.).

A **feed** provides mutual awareness of ideas. The blend of oral and digital contributions is central to Talkwall, and the feed provides awareness of participants' thinking, rather than a thread or sequence of ideas. The feed in Talkwall is shared on all participants' devices, as well as the teachers' screen, and offers means for students to effectively share their contributions with their peers. The feed is an awareness mechanism that may be used by students to acquire ideas from others and for the teacher to acquire both detailed information about how students are formulating their ideas, the sequence and emergence of ideas, and an overall idea of the dialogue in the classroom as a whole.

A **wall** allows for contributions to be promoted from the feed and be represented in a spatially organized surface. The feed and the wall are two different lenses to the contributions, the feed focuses on the temporal and emergent nature of ideas, while the wall is a means for selecting relevant contributions, and allowing spatial arrangement by means of direct manipulation of contributions in order to make connections, to aggregate and classify contributions, and to amplify means for synthesizing.

The bridging concepts can be regarded as a realization of a dialogic space (Wegerif 2015), as dialogue is mutually constructed by oral and digital contributions in the classroom. This hybridity, or combination of the oral and the written, poses new challenges both in how we understand the roles of technology in the digitalized classroom, but also in terms of how technology can be designed. By means of Talkwall, diverse voices are represented, made accessible over time, enabling the class to invoke and combine ideas, and to keep them alive in the dialogue.

Finally, a **space for the teacher** is a bridging concept that embody the empowerment of the teachers and has emerged from collaboration with teachers, and their own formulations of how they cope with new digital tools and materials in the classroom (Rasmussen & Lund, 2015). In Talkwall, the role of the teacher has been a key point in the design, and has promoted some privileges in the tool for teachers, such as access to all the participants' walls and ability to show any one of them on the shared screen in front of the class. Further, there are features that support the teacher as a leader of the dialogue, such as means to formulate tasks and to manage Talkwall sessions.

What the notion of bridging concepts enable is exactly the communicative work that is needed in the design work that aims to tailor a material product to a specific educational practice and drawing also on theoretical insights from this field of practice.

We argue the bridging concepts facilitate exchange both ways between theory and practice, and that the material outcome of the design incorporates and displays the ideas for future practice, and as such it contains the embryonic starting point of what ‘might be’ (Lund et al., 2012). Since ideas of what ‘might be’ are often volatile and hence hard to hold on to, teachers may find valuable a tool that inscribes significant aspects of dialogic theory and may be a ‘digital companion’ with potentially transformative impact for emergent dialogic practices.

Our translations of bridging concepts, into design articulations and a range of exemplars that demonstrate the scope and potential of their application (Dalsgaard & Dindler, 2014, p. 1635) have considered technology such as microblogging within a diverse set of educational context over many years. Thus, we draw from particulars to form more generalizable concepts for pedagogical practices that develop the ‘complex competencies’ today’s students need.

### **Findings based on a theory and design-based research program**

Talkwall is a result of longitudinal DBR involving collaboration with a total of nine schools over a period of five years. We have recorded 65+ sessions with Talkwall and analysed how teachers have aligned and enacted the tool with their intended dialogic teaching. The shared goals for this research program have their origin both in such situated experiences by teachers and in research, and can be summarized as follows:

- The technology should provide means for students to build on each other’s thinking, as this is crucial for a dialogue that is characterized by elaboration and reasoning.
- There should be means provided for broad participation in the classroom to make sure a diverse set of voices are participating in the dialogue.
- Diverse means should be offered beyond the oral for contributing to a dialogue, such as allowing for multimodal interactions.

A key empirical finding was the importance of moves between individual, group, and whole class interactions, and designs that address such shifts. This is a particular feature with Talkwall, based on dialogic theory and experiences teachers bring to the design process. Central in the design for shifts between individual, group and whole class interactions are the specific design articulation based on the bridging concepts of the feed and the wall. We will present findings suggesting that frequent shifts of participant structures are beneficial for broad participation in the classroom.

Our research program clearly demonstrates how an alignment of a tool’s development with a theoretical approach is valuable as intermediary knowledge emerge, in our case in the form of bridging concepts. These stimulates and guides the exchange between theory, design and classroom practices, and may be essential to bridge the gap between generalized theories, design instances and situated classroom practices.

As mentioned, the tool is enacted by competent teachers that will construct meaning of the artefact in a given and situated classroom context. The tool is designed for this meaning making to happen (Krippendorff 2005), and we associate some agency with the tool in this respect. In this perspective it is not productive to regard tools as theory free.

### **References**

- Alexander, R.J. (2008) *Essays on Pedagogy*, Routledge.
- Anderson, T., & Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational Researcher*, 41(1), 16–25.
- Barnes, D. (1976). *From Communication to Curriculum*. Harmondsworth: Penguin.
- Bell, P. (2004). On the theoretical breadth of design-based research in education. *Educational Psychologist*.
- Binder, T., De Michelis, G., Ehn, P., Giulio, J., Linde, P., & Wagner, I. (2011). *Design Things*. (K. Friedman & E. Stolterman, Eds.). MIT Press.
- Dalsgaard, P., & Dindler, C. (2014). Between theory and practice: Bridging concepts in HCI research (pp. 1635–1644). Presented at the Conference on Human Factors in Computing Systems - Proceedings, New York, New York, USA: ACM Press.
- Howe, C. & Abedin, M (2013) Classroom dialogue: a systematic review across four decades of research, *Cambridge Journal of Education*, 43:3, 325-356.
- Krippendorff, K. (2005) *The Semantic Turn: A New Foundation for Design*. CRC Press.

- Lund, A., & Rasmussen, I. (2008). The right tool for the wrong task? Match and mismatch between first and second stimulus in double stimulation. *International Journal of Computer-Supported Collaborative Learning*, 3(4), 387–412.
- Lund, A., & Smørdal, O. (2006). Is there a space for the teacher in a WIKI? *the 2006 international symposium* (pp. 37–46). New York, New York, USA: ACM.
- Lund, A., Rasmussen, I., & Smørdal, O. (2012). Visualisation of Trajectories of Participation in a Wiki: A Basis for Feedback and Assessment? *Nordic Journal of Digital Literacy*, 7(01), 20–35.
- McKenney, S. (2013). Designing and researching technology-enhanced learning for the zone of proximal implementation. *Research in Learning Technology*, 21(0), 67.
- Mercer, N. & Dawes, L. (2014) The study of talk between teachers and students, from the 1970s until the 2010s, *Oxford Review of Education*, 40:4, 430-445.
- Rasmussen, I., & Hagen, Å. (2015). Facilitating students' individual and collective knowledge construction through microblogs, 72, 149–161.
- Rasmussen, I., & Lund, A. (2015). Læringsressurser og lærerrollen – et partnerskap i endring? *Acta Didactica Norge*, 9(1), Art. 18, 20 sider.
- Roschelle, J., & Penuel, W. R. (2006). Co-design of innovations with teachers: definition and dynamics (pp. 606–612). International Society of the Learning Sciences.
- Schwarz, B. B. & Baker, M. J. (2016) *Dialogue, Argumentation and Education: History, Theory and Practice*. Cambridge University Press
- Vygotsky, L. S. (1962). *Thought and language*. Cambridge MA: MIT Press.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Wegerif, R. (2015). Technology and teaching thinking: Why a dialogic approach is needed for the twenty-first century. In *The Routledge International Handbook of Research on Teaching Thinking* (pp. 427–440). Routledge.

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# ElectroVR: An Electrostatic Playground for Collaborative, Simulation-Based Exploratory Learning in Immersive Virtual Reality

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**Abstract:** The ElectroVR interactive demonstration allows two participants to occupy a single physical and immersive virtual space with one another, in which they can learn through spatial interaction with an electrostatics simulation sandbox. Narrative sequences optionally offer exposition of key principles and suggestions of exploratory activities. The demo shows three key approaches operating in tandem: collocated, multi-user, positionally tracked Virtual Reality (VR); a spatial simulation-based exploratory learning environment; and a playback system that presents narrative sequences prepared by instructors in the virtual environment. As such, it offers a novel and powerful embodiment of the “4E learning” paradigm that is the theme of this conference.

## Introduction

We explore a promising design space for constructivist learning at the intersection of three well-established approaches: (1) embodied learning in immersive six-degree-of-freedom (6DoF) VR, (2) simulation-based exploratory learning, and (3) collaborative learning. These have not been combined previously to our knowledge. This demo brings together all three of these in a novel learning experience in the domain of electricity and magnetism. This domain was chosen because it is known to be both challenging and highly spatial, and hence likely to benefit from the use of stereoscopic 3D presentation, 6DoF head movement, and hand-based embodied interaction.

One further key idea put forth in the demo is that of recording and playback. The demo makes most prominent use of this in a series of narrative sequences that are recorded in the environment by instructors. Learners hear instructors’ explanations, accompanied by minimal avatars which move realistically, replicating the instructors’ real movements from the time of recording. This creates a strong sense of copresence – that is, the learner feels they are sharing a space with a human (Greenwald et al., 2017b). In addition, these avatars interact with the same interactive affordances (objects and tools) that are available to learner. Whatever is demonstrated by the instructor can be directly accessed by the learner as well. This sets the stage for engaging exploratory activities that follow the narrative sequences.

Not only is the playback of recorded narrative sequences powerful pedagogically, it is also a key strategy that can make the production of substantial quantities of content (from tens of minutes to hours) tractable for a small team. Using typical approaches, where experiences make significant use of animated sequences that are produced using digital art and graphic design tools, authoring 20 to 30 minutes of VR content is a highly resource- and time-intensive process. Our approach is analogous to bringing a video camera into a physics lab in order to create content – the lab equipment can be used in many different ways to illustrate a variety of ideas and principles. It is the instructor that creates a narrative and guided activity to address a given topic area, and the content is produced in real-time (of course, subject to repeat takes and manual preparation time in the virtual environment).

## Background and prior work

In the past five years, consumer VR devices have burst onto the market, and created new opportunities for the application of VR at scale. Although learning is thought to be one of the most promising areas, few attempts have been made at implementing it in formal learning settings. Among these, the most common approaches have been to expose learners to (1) the content that is available in online marketplaces in a very broad, nonpedagogical fashion, and (2) the process of making VR content using today’s tools. In contrast, this demo represents an attempt to convey a specific set of ideas in electricity and magnetism (Coulomb’s Law and Gauss’ Law), which are



Figure 1. Collocated use of positionally tracked VR.

challenging, and can benefit from an intuition-building approach that is complementary to algebraic approaches that are the usual focus of the corresponding coursework.

We briefly review prior work in the areas of (i) collocated 6DoF VR, (ii) science learning in VR, and (iii) non-VR collaborative science learning.

Several projects have implemented systems to explore collocated, 6DoF VR. One system for group-togroup telepresence created a shared immersive virtual reality for local and remote groups of participants, using projection-based multi-user 3D displays (Beck et al., 2013). The “Holojam” system used head-mounted displays to allow many users to share a physical and virtual space. Use cases in data visualization and creative expression were demonstrated (Royston et al., 2016; Masson et al., 2017). “CocoVerse” is a shared collocated immersive virtual environment utilizing multiple head-mounted displays (HMD’s), and including several different multiuser co-creation interactions through hand-bound tools, including 2D and 3D painting, import and placement of arbitrary 2D images and 3D models, and a virtual camera tool (Greenwald et al., 2017a). A later version of this environment also included a software framework for recording and replaying users’ actions and their effects on the virtual environment. Users are represented using minimal avatars. In subsequent work building on this system, the authors explore the quality of non-verbal communication afforded by this form of avatar representation. Using subjective and objective measures, they find that the movement realism of embodied minimal avatars yields a strong sense social presence and an effective medium for gestural communication (Greenwald et al., 2017b). In our demo, we build on the same technology and avatar representation as CocoVerse, with the goal of leveraging the demonstrated communicative benefits into an environment containing rich science-oriented content.

In the area of spatial learning, *ScienceSpace* (Dede et al., 1996) was a pioneering work, implementing science-oriented educational content in 6DoF VR, including *MaxwellWorld* focused on electrostatics using interactive visualizations of charge, electric field, and electric flux. A refined model was developed for understanding the impact of the various affordances of immersive virtual reality on conceptual learning (Salzman et al., 1999). The much newer, more performant VR technology we use improves significantly on the user experience of *ScienceSpace*. A recent paper makes a direct comparison between learning on a 2D screen and learning in VR using electrostatics activities. Learners reported deeper spatial insights when using the VR version (Greenwald et al., 2018). Both of these prior works indicate that science-oriented spatial learning in VR is highly promising. Our demo goes further than both by incorporating collaboration, recorded in-world instruction, and an extensive set of affordances for exploration.

Finally, some notable prior works explored the area of non-immersive, simulation-based computer supported collaborative learning (CSCL). One of these used a system for co-located collaborative learning, particularly of topics in physics, through a 2D (traditional screen) web interface, leveraging spatial arrangement of information, interactions such as drawing, graphing, and text input (Coopey et al., 2013). This system enabled classroom-scale collaboration leveraging 2D representations. Our demo does not support a large number of users in this fashion, and it is oriented towards deep spatial insight, rather than algebraic and quantitative analytical skills. Other authors explore the use of 3D virtual environments using non-immersive technology in collaborative learning, through the design of a problem-based physics learning activity in *Second Life*, finding that such a virtual collaborative learning activity can be engaging and effective (Vrellis et al., 2010). In contrast, the direct spatial manipulation affordance of 6DoF immersive VR offers a more learnable, natural interface than the keyboard and mouse, in addition to the forms of non-verbal communication mentioned above.

This brief survey of prior work has shown how each of the approaches we leverage in our demo has been explored to some extent, but they have not been brought together in one system before.

## User experience

The interactive content in the demo targets learning goals related to Coulomb’s Law and Gauss’s Law at the undergraduate level. Participants enter VR together, and are given the option to either explore the affordances of the toolbox, or view immersive narrative sequences, in which recorded avatars operate the various tools and explain principles of physics (Figure 2). In the case that they view narrative sequences, they are at first somewhat passive, gradually learning to interact with the simulation system as they see demonstrations from the recorded instructors. In the case that they opt to explore using the toolbox, they use the graphical and text elements to infer what is possible, and proceed to experiment. They can opt at any time to switch between the exploratory toolbox-oriented mode and the explanatory narrative-sequence-oriented mode of interaction.

The toolbox contains three kinds of items: charge distributions, visualization objects, and hand-based tools. Charge distributions create the electric field that permeates the 3D space (Figure 3). Visualization objects allow participants to visualize the field in different ways that are spatially local, and they can choose to place or move these objects (Figure 4). Hand-based tools determine the functions of the handheld controllers (Figure 5). Considering each of these from the perspective of collaboration: when one participant spawns a new charge



distribution, it affects the field everywhere in space. This means that each participant can drastically affect the visual and interactive experience of the other participant, regardless where they are standing or whether they are attending to one another. Visualization objects, on the other hand, are local and will only be observed by the other participant if they look in the relevant direction – choosing to explore visually and perhaps interact with the other participant. Finally, the hand-based tools are controlled exclusively by one user, as they are bound to the controllers. Each can be independently assigned– there is no mutual exclusion when instantiating handheld tools.

## System

ElectroVR creates a shared physical and virtual space among multiple users with HMD's and handheld controllers. This section describes three aspects of the system: the physical and network architecture; the simulation engine; and the recording and playback system.

Each user requires a dedicated computer to run their HMD (our system uses the HTC Vive). Each computer runs an instance of the interactive environment, and the instances are synchronized across the network. This is accomplished through a client-server architecture, in which one of the connected machines acts as both a client and as the authoritative server. Each client represents its user with an avatar, which shows the user's headset and controllers on all connected machines. Each client instances also runs its own copy of the simulation. Because some aspects of the input to the simulation are non-deterministic, some simulated elements such as the positions of point charges are periodically synchronized with the server.

The simulation engine computes the electric field analytically using superposition of the charge distribution primitives. The field due to each of these primitives is given by a simple expression – for example for point charges, the contribution to the field is inversely proportional to the inverse square of the distance from a given point to the location of the point charge. The dynamics of the system of point charges is computed with a fourth-order Runge-Kutta algorithm.

The recording and playback system allows for the capture and reproduction of the actions of users in the environment. During recording, ElectroVR captures users' microphone audio, the movement of their avatars, and the evolving state of the virtual environment. In particular, the system logs each state change and high-level command that is executed on the server, along with an associated time stamp.

## Project history and outlook

Begun in the summer of 2016, this project has proceeded through an iterative design process involving exploratory prototyping, a focus group of physics instructors, co-design with physics instructors, and piloting with students and instructors. In the spring of 2018, it was piloted with roughly 50 students, who each spent between 45 minutes and two hours, either solo or together with one or more partners, immersed and interacting with the system. The system successfully achieved its design goals, with very positive feedback from students. An analysis of collaborative behavior during the said pilots is ongoing work, and future applications of this system will enable the effectiveness of collaborative learning in VR to be rigorously tested and characterized.

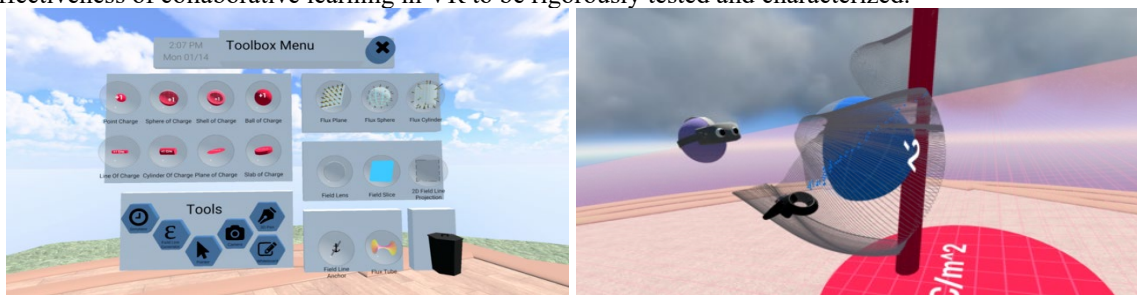


Figure 2. Toolbox (left) and narrative sequence with instructor avator (right).

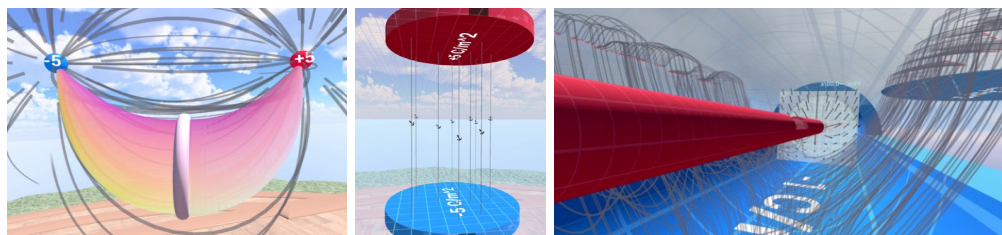


Figure 3. Example charge distributions (left to right): point charges, infinite slabs, and infinite cylinders.

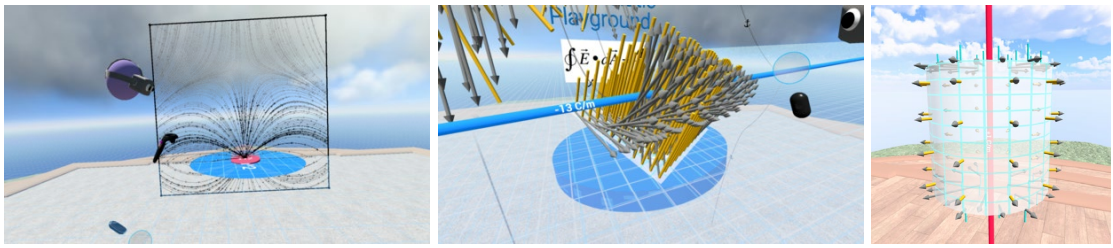


Figure 4. Visualization objects (left to right): 2D field line plane, flux plane, flux cylinder.

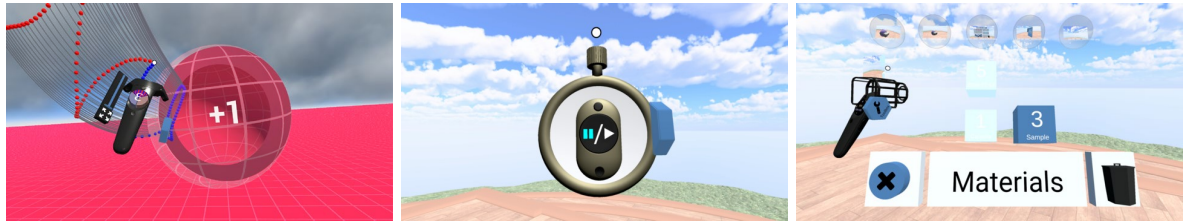


Figure 5. Hand-based tools (left to right): field line generator, simulator, camera.

## References

- Beck, S., Kunert, A., Kulik, A., and Froehlich, B. (2013). Immersive group-to-group telepresence. *IEEE Transactions on Visualization and Computer Graphics*, 19(4):616–625.
- Coopey, E., Danahy, E., and Schneider, L. (2013). Interlace: Interactive learning and collaboration environment. In *Proceedings of the 2013 Conference on Computer Supported Cooperative Work Companion, CSCW '13*, pages 11–14, New York, NY, USA. ACM.
- Dede, C., Salzman, M. C., and Bowen Loftin, R. (1996). Sciencespace: virtual realities for learning complex and abstract scientific concepts. In *Proceedings of the IEEE 1996 Virtual Reality Annual International Symposium*, pages 246–252.
- Greenwald, S. W., Corning, W., Funk, M., and Maes, P. (2018). Comparing learning in virtual reality with learning on a 2d screen using electrostatics activities. *Journal of Universal Computer Science*, 24(2):220–245.
- Greenwald, S. W., Corning, W., and Maes, P. (2017a). Multi-user framework for collaboration and co-creation in virtual reality. In *Making a Difference: Prioritizing Equity and Access in CSCL/Proceedings of the 12th International Conference on Computer Supported Collaborative Learning*, volume 2 of CSCL '17, pages 879–880. International Society of the Learning Sciences.
- Greenwald, S. W., Wang, Z., Funk, M., and Maes, P. (2017b). Investigating social presence and communication with embodied avatars in room-scale virtual reality. In Beck, D., Allison, C., Morgado, L., Pirker, J., Khosmood, F., Richter, J., and Gütl, C., editors, *Immersive Learning Research Network*, pages 75–90, Cham. Springer International Publishing.
- Masson, T., Daffy, and Perlin, K. (2017). Holo-doodle: An adaptation and expansion of collaborative holojam virtual reality. In *ACM SIGGRAPH 2017 VR Village, SIGGRAPH '17*, pages 9:1–9:2, NY, NY, ACM.
- Royston, S., DeFanti, C., and Perlin, K. (2016). A collaborative untethered virtual reality environment for interactive social network visualization. *CoRR*, abs/1604.08239.
- Salzman, M. C., Dede, C., Loftin, R. B., and Chen, J. (1999). A model for understanding how virtual reality aids complex conceptual learning. *Presence: Teleoperators and Virtual Environments*, 8(3):293–316.
- Vrellis, I., Papachristos, N. M., Bellou, J., Avouris, N., and Mikropoulos, T. A. (2010). Designing a collaborative learning activity in second life - an exploratory study in physics. In *2010 10th IEEE International Conference on Advanced Learning Technologies*, pages 210–214.



# The CUBE: A Tangible for Embodied Learning, Balanced Engagement, and Classroom Orchestration

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**Abstract:** This classic interactive demo paper presents the CUBE, a recently developed Arduino-based tangible that can be used in collocated collaboration for a multitude of research and teaching purposes. The CUBE was designed with three instructional needs in mind: (a) offer opportunities for embodied learning to the students, (b) monitor and enhance balanced engagement in a group, and (c) allow the teacher to monitor and orchestrate a classroom.

## Improving collaboration in collocated settings

The CUBE presented in this paper focuses on monitoring, analyzing, and supporting collocated collaboration by offering opportunities for embodied learning and providing immediate and summative individual/group feedback on the collaboration activity and on each person's contribution, to motivate students towards balanced engagement. Via Wi-Fi connectivity and a dashboard, the CUBE can inform the teacher on the state and progress of collaborating groups, allowing real-time classroom orchestration.

Embodied learning has recently been established as an important field (Lindgren & Johnson-Glenbegr, 2013). Incorporating movement of the entire body or embodied phenomena as gestures and hand movements, the embodied learning paradigm suggests that body and environment are linked to cognitive processes (Shapiro, 2010). Tangible interfaces, often with cubic shapes, have been used in embodied learning in several ways (e.g., Sapounidis, Demetriadis, Papadopoulos, & Stamovlasis, 2018; Terrenghi, Kranz, Holleis, & Schmidt, 2006), for example for making interface elements directly available to all participants or to enhance group self-organization around the manipulation of a single tangible.

Balanced engagement in collocated collaboration settings is crucial as lower participation is often linked to poor academic performance (Bachour, Kaplan & Dillenbourg, 2010). By combining microphones and visual representations of participants' speaking time, the Reflect table (ibid.) provided immediate feedback to discussants. Similarly, the Conversation Clock (Bergstrom & Karahalios, 2007) provided visualizations of audio patterns in a spiral timeline, offering a representation of how much and when each discussant talked during collaboration.

Finally, tangibles such as the Lantern (Alavi & Dillenbourg, 2012) and FireFlies2 (Verweij, Bakker, & Eggen, 2017) have been used for classroom orchestration, focusing on enhancing communication between students, teachers, and groups.

These characteristics along with additional ones can be found in the CUBE tangible presented next.

## CUBE description

This section presents the basic technical characteristics of the CUBE, along with its main functionalities. Since the artifact was developed recently, there is no empirical evidence at this point to validate which combination of the offered affordances would be more effective/efficient in a learning scenario. A series of research activities involving the CUBE will commence in Spring 2019.

## Technical characteristics

Figure 1 presents the first, fully functional, version of the CUBE. The CUBE is an Arduino-based system that includes screens, monitors, microphones, and a set of sensors and modules. It has a cubic shape, with 11 cm long edges and weights a bit less than 1 kg (including the batteries). Each side has a square 2.8" in. TFT screen (the actual screen is bigger, but covered for symmetry). In addition, the screens offer touch capabilities, but this characteristic has not been used in this prototype. The model (i.e., skeleton and sides) was produced in a standard FDM 3D printer, using PLA material. Improved models printed in a high-end SLS printer have also been produced, but not used yet.

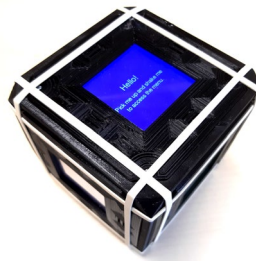


Figure 1. The CUBE prototype.

## Functionalities

The list below describes the functionalities of the current prototype, while additional functionalities could be added in near future, either by extending or by combining the current ones. Arguably, it is not expected that all the affordances of the CUBE will be necessary for the envisioned learning scenarios. For example, rotation detection might not be important in situations where the CUBE is used as ambient technology.

### Display information

The cubic shape of the artifact and the sitting arrangement of a group of students around a table create two distinctive spaces (Figure 2). Each side screen is visible by only one student (private space), while the top screen is visible by all, including the teacher (public space). This split between private and public could be useful in a learning design. For example, feedback can be directed to a specific student or to the whole group. In addition, the side screens can be used for detailed information, while the top one could be used to denote the state of the group. It should be mentioned that information targeted to all students should be presented in the side screens, since the top screen is flat and (text) orientation will be an issue for three of the students. The analysis of the (visible) screen is 320x320 pixels, which means that it is suitable for short messages and graphs. Longer blocks of information could be divided into several screen pages (e.g., 1/2, 2/2, etc.). Finally, due to the processing power of the Arduino, the screens are updated sequentially, while the frame rate is very low. This means that the screens are not suitable for playing videos, while there is a small lag between screens (30-300 ms, depending on the size of information presented). However, this lag does not pose an issue, since students can only see the screen in front of them (and the top) and such lag is not critical in learning scenarios.

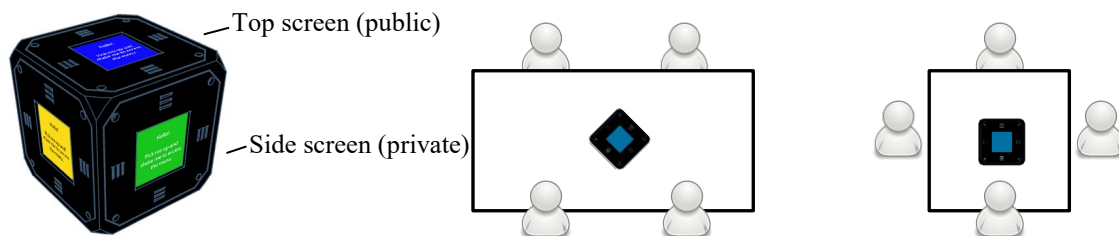


Figure 2. Sitting arrangement and private/public spaces.

### Rotation detection

The CUBE can detect rotation on the x- and y-axis. Rotation on the z-axis is considered turning and cannot be detected accurately by the sensors used. At any given moment, the CUBE can identify the side that is on top and as such, rotation can be used as a selection action. For example, the screens may show different options, asking students to make a choice. The students could rotate the CUBE to have their selection on the top. As it is expected that the students may move around the artifact or hold them in their hands during a selection task, the final option is confirmed when the CUBE detects that it has stopped moving for three seconds. Then, the side that is on top is considered the students' choice.

### Shaking detection

Because of the physical characteristics of the CUBE, shaking requires both hands. As such, shaking is a more powerful move than rotation and can be used during significant moments of the activity. For example, shaking can be used to tell the CUBE to wake up (and start an activity) or to interrupt the ongoing activity. Similarly, it can be used as a celebratory gesture denoting the successful completion of a task, a strong disagreement between group members, or the need for teacher's intervention.

### Vibration

The CUBE can vibrate to provide haptic feedback to the students. This functionality can be used to confirm a selection, draw the attention of the person holding it, or accompany audio/visual feedback. The intensity and duration of vibration can be modified according to the learning scenario needs to denote different types of haptic feedback. Vibration, along with rotation and shaking can be used in embodied learning settings.

### Audio play

A small speaker inside the CUBE is capable of playing tone sounds and midi files loud enough for a surrounding group of people to hear clearly. Playing voice files or sounds of higher quality would require a larger and heavier speaker, along with the need for audio controls (i.e., pause, stop, rewind, etc.). As such, audio is used primarily as auditory feedback to confirm an action, or draw attention.

### Audio recording

The system can record the discussion that occurs around it and saves it in an SD card. The recording could cover the whole activity or start/stop according to an event triggered by the students (e.g., rotation), the teacher (e.g., remote control through a dashboard), the system itself (e.g., pre-defined script conditions). The recording can be a single file, or several, and can be used after the activity for post hoc analysis of the interaction or become available to the students as feedback. Functionalities such as rotation and shaking can be used in parallel to the audio recording to allow the students to self-annotate. For example, during an argumentation task, students can rotate the CUBE in different directions to mark when a fact or a warrant has been mentioned. Self-annotation information could later be used along with the audio file of the discussion.

### Audio source monitoring

Each side of the CUBE is equipped with a microphone. By comparing the sound received by each microphone, the system can infer in which side a speaker is sitting. The system cannot understand what a student is saying, since the analysis and monitoring of the audio source are based only the volume of the sound. This function is similar to the two tables cited earlier (Bachour, Kaplan, & Dillenbourg, 2010; Bergstrom & Karahalios, 2007), with an added benefit that the CUBE is portable and can be used in more settings. The ability to monitor the audio source can be used to support balance engagement during a discussion.

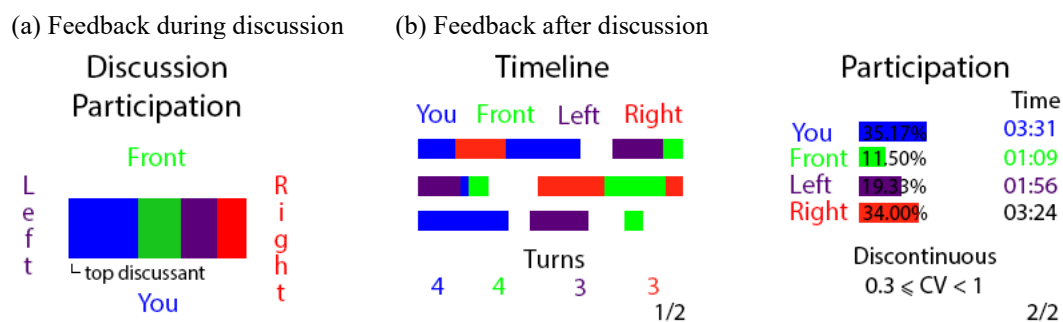


Figure 3. Feedback that appears in the side screens during and after peer discussion.

The system can provide both immediate and summative feedback, focusing on the length of a person's talk and not on its content. Figure 3 shows some of the feedback metrics the prototype can offer during and after the discussion. So, during the discussion (Figure 3, a), the students can see how much each student talked (%). Each color represents a different student, with the top screen colored in the color of the person that spoke the most. This graph is updated every five seconds. After the discussion (Figure 3, b), additional metadata on students' engagement are presented. First, the timeline shows the order and length of each person's speaking time, while gaps in the timeline denote periods of silence. In the same screen, the students can also see how many times each person talked. In the second post-discussion feedback screen, the students can see aggregated feedback on their participation in terms of actual time and percentage. The Balanced/Discontinuous/Unbalanced indication is based on the coefficient of variation (Lovie, 2005) for the group and it is an example of additional metrics that could be used as feedback.

After a CUBE rotation, the audio source monitoring will start a new session, unless provisions are taken in the learning scenario so that the rotated CUBE can link previous and current sitting arrangements.

### Connectivity

As mentioned earlier, the CUBE is equipped with a Wi-Fi module allowing it to communicate with the server, and through that with other CUBEs and with the teacher's dashboard, thus supporting classroom orchestration. Because of the technical limitations of the Arduino, the wireless connection is established periodically every few seconds and data from and to the CUBE are transmitted in short bursts. This is the reason why the CUBE cannot transmit the audio of the discussion in real-time to the server, acting also as a fly-on-the-wall for the teacher. However, this limitation is not crucial for the envisioned learning scenarios and the few seconds (<2") delay in updating the teacher's dashboard is not expected to raise significant issues for the participants.

### Script editor

During the testing period of the CUBE, collaboration scripts are coded directly in the Arduino IDE. However, an online script editor is also under development to allow non-technical teacher/researchers to design their own learning scenarios with the CUBE.

### Activity monitor

Currently, monitoring a test activity with the CUBE occurs by observing the server's database. The activity monitor, which is also under development, refers to the dashboard the teacher/researcher will be able to use in the classroom during the runtime of a CUBE activity. Apart from monitoring, the dashboard will allow the teacher to intervene. For example, the teacher may choose to pause an activity in one CUBE or send a message to the screen of the least engaged student in another CUBE.

## **Conclusions**

The functionalities and robustness of the CUBE have to be evaluated in research activities. Its design is based on three main pillars: embodied learning, balanced engagement, and classroom orchestration. However, additional uses and theoretical underpinnings may be identified by the reader. This paper serves as a first introduction of the CUBE to the CSCL audience, in search of constructive feedback and future collaborations.

## **References**

- Alavi, H. S., & Dillenbourg, P. (2012). An ambient awareness tool for supporting supervised collaborative problem solving. *IEEE Transactions on Learning Technologies*, 5(3), 264-274.
- Bachour, K., Kaplan, F., & Dillenbourg, P. (2010). An Interactive Table for Supporting Participation Balance in Face-to-Face Collaborative Learning. *IEEE Transactions on Learning Technologies*, 3(3), 203-213.
- Bergstrom, T., & Karahalios, K. (2007). Conversation Clock: Visualizing audio patterns in co-located groups. In Proceedings of the 40th Annual Hawaii International Conference on System Sciences (HICSS '07). IEEE Computer Society, Washington, DC, USA, 78-78.
- Dillenbourg, P., & Jermann, P. (2007). Designing integrative scripts. In F. Fischer, H. Mandl, J. Haake & I. Kollar (Eds.), *Scripting computer-supported communication of knowledge - cognitive, computational and educational perspectives* (pp. 275-301). New York: Springer.
- Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher*, 42, 445-452.
- Lovie, P. (2005). Coefficient of variation. *Encyclopedia of statistics in behavioral science*.
- Sapounidis, T., Demetriadis, S., Papadopoulos, P. M., & Stamovlasis, D. (2018). Tangible and graphical programming with experienced children: A mixed methods analysis. *International Journal of Child-Computer Interaction*. <https://doi.org/10.1016/j.ijcci.2018.12.001>.
- Shapiro, L. (2010). *Embodied cognition*. New York, NY: Routledge.
- Terrenghi, L., Kranz, M., Holleis, P., & Schmidt, A. (2006). A cube to learn: a tangible user interface for the design of a learning appliance. *Personal and Ubiquitous Computing*, 10(2-3), 153-158.
- Verweij, D., Bakker, S., & Eggen, B. (2017). FireFlies2: Interactive Tangible Pixels to enable Distributed Cognition in Classroom Technologies. In Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces (ISS '17). ACM, New York, NY, USA, 260-269.

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# Synergy: An Online Platform for Dialogic Peer Feedback at Scale

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**Abstract:** In this paper, we introduce an online platform called Synergy that is developed to support dialogic peer feedback at scale. The design of Synergy is founded on a theoretical model of dialogic feedback. In this model, dialogic feedback is conceptualized as a collaborative learning activity with three interconnected phases, involving different levels of regulated learning. Grounded in this model, Synergy comprises tools to support learning activities during dialogic feedback. These tools incorporate scripting and learning analytics support to guide learners. By using Synergy as an example, we discuss the importance of informing the design of CSCL tools with theories.

## Introduction

The goal of this paper is to introduce a CSCL platform called *Synergy* that utilizes scripting and learning analytics to support dialogic peer feedback at scale and to describe its constituent model. The model outlines regulatory learning processes necessary to coordinate, maintain, and make use of dialogic feedback. Synergy assists learners in regulating their learning and collaborative activities as defined in the model. Scripting support is integrated to facilitate learners' individual and collective actions while learning analytics support is integrated to allow learners to monitor their activities and to make changes to improve their engagement. Synergy aims to overcome existing practices which mainly focus on dialogue with instructors and lack capacity to scale dialogic feedback.

In this paper, we favour theory-driven approaches to the design of CSCL tools. We support our stance by providing a detailed description of the alignment between the design of Synergy and the underlying theoretical model. We intend to envision how the design of the Synergy tool would be without a theoretical support, and we refer to several existing feedback tools that are *theory-free* to highlight the importance of having solid theoretical foundations to inform the design. Thus, rather than providing a detailed description of the tool, in this paper we focus more on answering the following question: why should the design of CSCL tools be informed by theories?

## Conceptualizing dialogic peer feedback

Dialogic approaches have been proposed to boost the power of feedback for learning (Zhu & Carless, 2018). As a dialogic activity, feedback is translated into a collaborative learning activity that involves social interactions between the students to help them construct meaning from feedback and regulate their learning (Ajjawi & Boud, 2017). When learning occurs at scale, instructor dialogue with each student is unaffordable. However, in such contexts, large learning cohorts can be exploited to conduct dialogic feedback with peer support. Yet, there is a lack of theoretical models to capitalize on this potential to design solid feedback practices. The literature is limited to the definition of dialogic feedback as a process where students engage in a dialogue to understand the feedback.

We present a model of dialogic peer feedback in Figure 1. To the best of our knowledge, this model is the first to provide a comprehensive conceptualization of dialogic peer feedback targeting large scale online or blended learning environments. This model postulates that dialogic feedback is composed of three interconnected phases: (1) negotiation and coordination of the feedback activities, (2) dialogic interactions for the uptake of the feedback, and (3) translation of the feedback into task progress. Within each phase, several iterations might be necessary to complete the targeted activities (e.g., several iterations of discussion between peers to build a consensus on the focus of the feedback). Additionally, these phases are not linear in nature, and they may run parallel to each other (e.g., continuing to coordinate the feedback provision activities while engaging in dialogue). That is, the model embraces flexibility to design dialogic feedback practices for different tasks and contexts.

In the first phase, peers providing feedback work together to coordinate feedback provision. The goal of this phase is to ensure that later during the dialogue with the target student, peers generate coherent feedback based on a shared task understanding and participate according to a common plan and goal. Inconsistent peer feedback may disorient students and damage their learning (Hounsell, Mccune, Hounsell, & Litjens, 2008). The product of this phase is the plan for the feedback (e.g., the focus of the feedback, changes to be suggested, daily contributions to the dialogue). Peers can update their plan collectively based on ongoing dialogue with the student. In the second phase, peers provide the planned feedback and engage in dialogue with the student to support the uptake of the feedback. This phase is literally the dialogue component, which has been the main focus of the literature (Zhu & Carless, 2018). The outcome of this phase is the planning of the actions that students agree to perform to enhance their learning and to progress on the task. In the last phase, students enact the planned

activities, aiming to translate the feedback into strategic task engagement and progress toward the learning goals. During this phase, when facing a difficulty, students can refer to the dialogue and ask for further peer support.

In this model, we hypothesize that each phase is driven by different levels of regulated learning. The first phase involves the peers' socially shared regulation of learning (SSRL) (Hadwin, Järvelä, & Miller, 2011) to negotiate and coordinate the feedback activities. In the second phase, during the dialogue learners engage in co-regulation of learning (CoRL) as peers guide students' regulation of learning (Hadwin, Oshige, Gress, & Winne, 2010). Through CoRL during, students' transition toward self-regulation (i.e., the last phase of dialogic feedback) is enhanced (Hadwin et al., 2011). The last phase is students' self-regulation of their learning (SRL) framed by the dialogic they were (or are being) engaged in (Winne & Hadwin, 1998). Table 1 outlines the regulatory events occurring in each phase. These events are derived based on Winne and Hadwin's (1998) model, which is chosen because it can be applied to identify the regulatory processes at both individual and social learning.

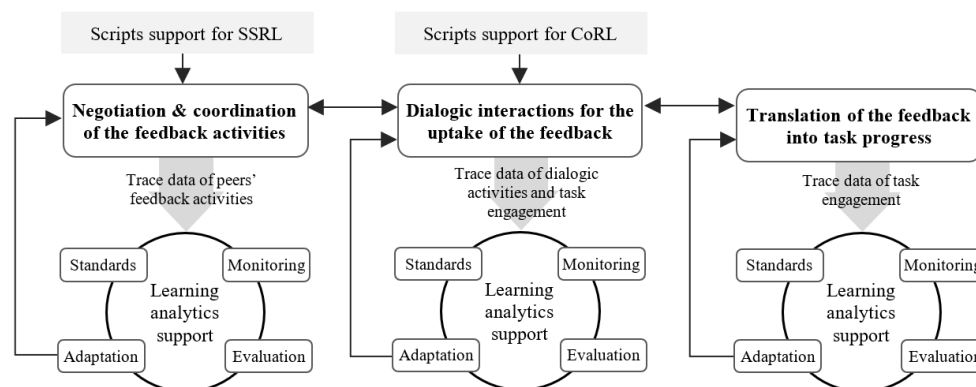


Figure 1. A model of dialogic peer feedback.

Table 1: Macro- and micro-regulatory events in each phase of dialogic peer feedback

Negotiation & coordination of feedback activities (SSRL between the peers providing feedback)	Dialogic interactions for the uptake of the feedback (CoRL between the peers and the student receiving feedback)	Translation of the feedback into task progress (SRL by the student)
<p><b>1. UNDERSTAND THE FEEDBACK TASK</b></p> <p>1.1. Get to know each other</p> <p>1.2. Reach agreement regarding the goals of the feedback task [SCRIPT]</p> <p><b>2. AGREE ON THE FEEDBACK</b></p> <p>2.1. Assess the student work with a rubric</p> <p>2.2. Align the perspectives toward the student work [SCRIPT]</p> <p>2.3. Identify the focus of the feedback [SCRIPT]</p> <p><b>3. PLAN THE PARTICIPATION</b></p> <p>3.1. Identify the responsibilities and decide on the activities [SCRIPT]</p> <p>3.2. Set standards for engagement in feedback provision [SCRIPT]</p> <p><b>MONITOR AND UPDATE</b></p> <p>3.3. Monitor and evaluate the collective activities [LA]</p> <p>3.4. Decide on the changes to improve the feedback activities [SCRIPT]</p>	<p><b>1. PROVIDE THE FEEDBACK</b></p> <p><b>2. ENGAGE IN THE FEEDBACK DIALOGUE</b></p> <p>2.1. Support the task understanding [SCRIPT]</p> <p>2.2. Discuss the feedback with the student to enhance the understanding of the feedback</p> <p>2.3. Guide the student when building the plan for the changes [SCRIPT]</p> <p><b>MONITOR AND UPDATE</b></p> <p>2.4. Monitor and support the student's task engagement [LA]</p> <p>2.5. Support the student to monitor and evaluate the task engagement [LA &amp; SCRIPT]</p> <p>2.6. Help the student decide on the changes to improve the task engagement [SCRIPT]</p>	<p><b>1. APPLY THE PLANNED CHANGES</b></p> <p><b>2. MONITOR AND UPDATE</b></p> <p>2.1. Self-monitor and self-evaluate one's own engagement [LA]</p> <p>2.2. Refer to the feedback dialogue to inquire further support [LA]</p> <p>2.3. Decide on changes to improve the task engagement</p>

As indicated in Table 1, scripting and learning analytics support are incorporated to support learners' various regulatory activities in different phases of dialogic feedback. In particular, scripts guide learners' activities during SSRL in the first phase and during CoRL in the second phase. Given the complexity of activities, scripting support aims to shape the interactions between learners. Learning analytics support aims to enable learners to monitor and evaluate their (collective or individual) engagement and progress based on certain standards, and accordingly to make adaptations in their task perceptions, goals, and strategies. These supports are critical given the limited facilitation of instructors in crowded classrooms.

## Synergy: An online platform for dialogic peer feedback

Synergy is an online platform developed to design and facilitate dialogic peer feedback in online or blended learning contexts. Synergy is designed based on the theoretical model described above. Corresponding to the phases of dialogic feedback, the Synergy platform is composed of three tools: The Coordinator (to support peers' negotiation and coordination of feedback activities), The Dialoguer (to support peers' feedback activities and to maintain their dialogue with the student to enhance the uptake of the feedback), and The Task Booster (to support students' engagement on the task and help them progress). Scripting and learning analytics support are incorporated into these tools as guided by the model (see Table 1).

Figure 2 below outlines the sub-components included in these three tools and illustrate their alignment with the theoretical model. As seen in the figure, every component of Synergy is designed with the purpose of supporting a certain action conceptualized in the model. Being informed by the theoretical model, the platform inherently holds an internal organization of its components that sequences and connects various activities of learners to support dialogic feedback. It is noteworthy that the complexity of the model is reflected in the design of the tool, which comprises several components for learners' use to complete different tasks with different roles. Scripting and learning analytics support is incorporated to guide learners when they are working on these tasks during dialogic feedback. As an example, Figure 3 illustrates the design of scripting support in the Let's Start component (to guide peers' negotiation of the task goals) and learning analytics support in the Let's Monitor component (to help peers monitor and evaluate their collective activities) of the Coordinator Tool.

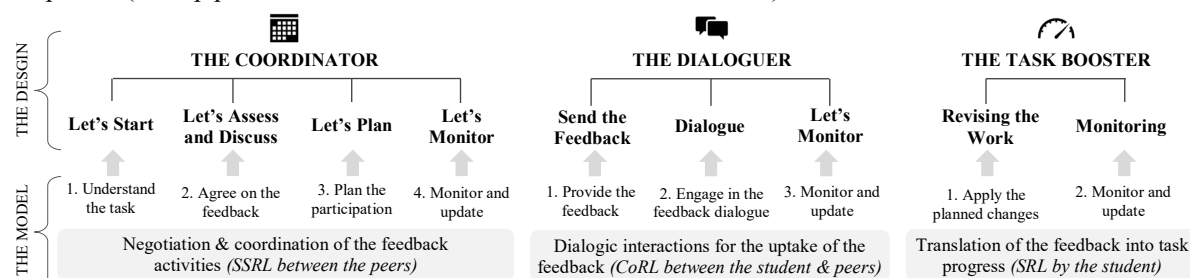


Figure 2. Design of Synergy (tools and their sub-components) and the alignment with the theoretical model.

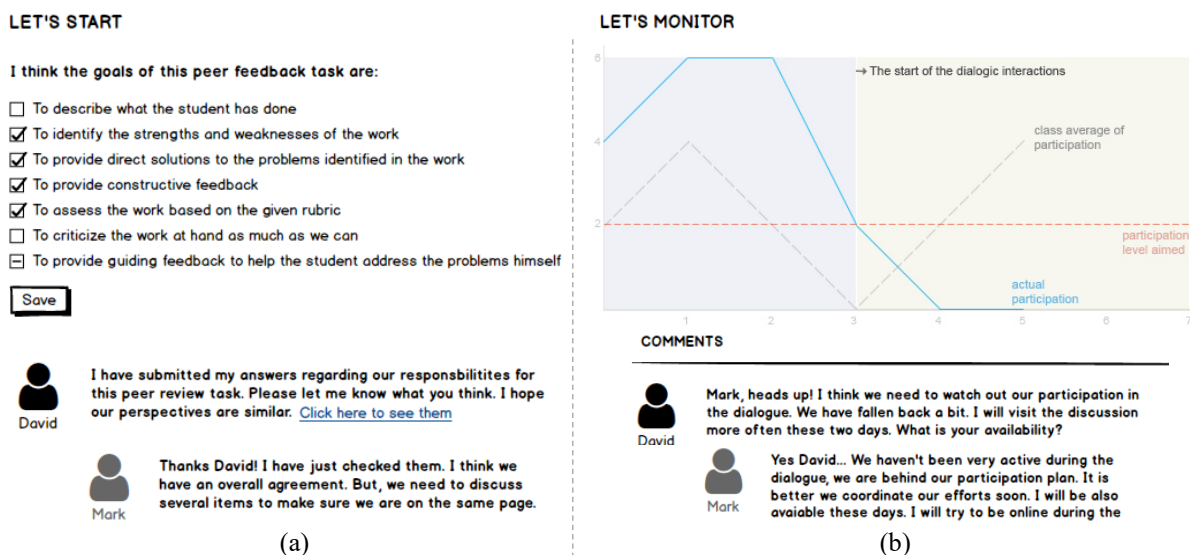


Figure 3. (a) Scripting support in Let's Start and (b) learning analytics support in Let's Monitor components.

## Why theory matters?

We favour the position that the design of CSCL tools should be grounded in theories. To support this stance, we follow two approaches. First, we discuss the design of Synergy platform if it were a *theory-free* tool developed based on practical needs to facilitate dialogic peer feedback. Second, we compare Synergy with other pragmatic feedback tools from the literature to highlight the advantages of being theory driven.

An alternative scenario of the design process could be rather simple if it were informed by the current practice of dialogic feedback noted in the literature. It would be driven by the technological affordances that can

facilitate the classical processes involved in peer review. In particular, the platform would include basic tools to allow students to upload their work to be reviewed by peers and to enable the peers to send their feedback, as well as a discussion or a chat tool to facilitate the feedback dialogue (synchronously or asynchronously). Although facilitating these tasks is useful, the Synergy platform would not be able to support learners' critical regulatory actions during the preparation for providing feedback, during the dialogue to discuss the feedback received, and during task engagement informed by the feedback. In that case, the impact of feedback on learning would optimistically rely on presumed coherent peer feedback that satisfies the task requirements (without peers being aware of each other's understanding of the feedback task and perspectives toward the student work) and presumed active peer participation in dialogue (without a collective goal and plan). That is, when designed with a pragmatic approach with no theoretical groundings, the Synergy platform would still help implement the peer feedback activity in practice; however, unsurprisingly it would not support critical regulatory processes of dialogic feedback and guarantee productive feedback interactions since by design these processes would not be taken into account.

There exist many online feedback tools in the literature that were designed without a solid theoretical foundation. These tools were generally built on the same premise that feedback provided online offers several advantages that favour learning such as studying the feedback without time limitations and the ability to refer to it whenever needed (Hepplestone, Holden, Irwin, Parkin, & Thorpe, 2011). As a result, these tools developed independently carry very similar features to facilitate a very similar feedback task flow (e.g., uploading the work and sending the feedback). One exception is the peer review system proposed by Yang (2011), designed based on the six processes suggested by cognitive apprenticeship theory. The system included distinct features to support students during these processes. According to the results of the study, the tool supported these processes and resulted in greater learning gains (Yang, 2011). Similarly, Synergy is built based on a theoretical model and it contains particular tools to support learners' various regulation activities during different phases of dialogic feedback. Although grounded in a certain theoretical stance, Synergy allows instructors' (or instructional designers') customization (e.g., changing the script content) for creating different feedback designs depending on the characteristics of the learning environment and the task. That is, we argue that having a theoretical stance should not necessarily limit the capacity of a CSCL tool for adapting to various learning settings.

## References

- Ajjawi, R., & Boud, D. (2017). Researching feedback dialogue: An interactional analysis approach. *Assessment and Evaluation in Higher Education*, 42(2), 252–265. <https://doi.org/10.1080/02602938.2015.1102863>
- Hadwin, A. F., Järvelä, S., & Miller, M. (2011). Self-Regulated, Co-Regulated, and Socially Shared Regulation of Learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of Self-Regulation of Learning and Performance* (pp. 65–84). <https://doi.org/10.4324/9780203839010.ch5>
- Hadwin, A. F., Oshige, M., Gress, C. L. Z., & Winne, P. H. (2010). Innovative ways for using gStudy to orchestrate and research social aspects of self-regulated learning. *Computers in Human Behavior*, 26(5), 794–805. <https://doi.org/10.1016/j.chb.2007.06.007>
- Hepplestone, S., Holden, G., Irwin, B., Parkin, H. J., & Thorpe, L. (2011). Using technology to encourage student engagement with feedback: a literature review. *Research in Learning Technology*, 19(2), 117–127.
- Hounsell, D., Mccune, V., Hounsell, J., & Litjens, J. (2008). The quality of guidance and feedback to students. *Higher Education Research & Development*, 27(1), 55–67. <https://doi.org/10.1080/07294360701658765>
- Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesse (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Hillsdale, NJ: Erlbaum.
- Yang, Y.-F. (2011). A reciprocal peer review system to support college students' writing. *British Journal of Educational Technology*, 42(4), 687–700. <https://doi.org/10.1111/j.1467-8535.2010.01059.x>
- Zhu, Q., & Carless, D. (2018). Dialogue within peer feedback processes: Clarification and negotiation of meaning. *Higher Education Research & Development*, 37(4), 883–897.

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# Lines We Trace: Comparing Data Displays to Support Youth Sailing

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**Abstract:** This submission to the special interactive session aims to develop testable design conjectures for a design-based research project involving a youth sailing camp. Youth sailing involves intensely immersive embodied experiences in boats, but also reflection on broader principles and processes. Coordinating between these two levels is often difficult for youth, particularly over a short time frame in an interest-driven environment. We present two existing tools that we believe have the potential to bridge this difficult conceptual and motivational gap, but involve very different epistemological hurdles. Using both existing footage of the tools in action and interactive reworking, we hope to collaborate with other participants to further specify the affordances and constraints of these tools, and potentially more effectively hybridize them toward our curricular goals.

## Overview and background

This interactive session will contrast the affordances of two existing tools—GoPro’s latest “gauge” displays, and Re-Shape (developed by the second author)—in the context of youth learning to sail small boats. Our purpose is to consider the potential for each tool to contribute to youth’s development along two related lines: 1) coordinating between their experiences in boats and the birdseye view typical of sailing instruction, and 2) considering broader principles of sailing and design.

The first author is in the initial phases of a design study (Cobb et al., 2003) during which she identified a general conception of the “no go zone” as a persistent problem of practice in youth sailing camps. Essentially, the “no go zone” is the range of orientations toward the wind at which it is impossible to sail. During a pilot session, students struggling with this concept were shown video of themselves sailing and asked to think about what they could tell from the video and in particular from the GPS-enabled gauges that show speed and cardinal direction. Preliminary analysis suggests that this task helped students coordinate between their experiences in the boats and the birdseye representations that sailors frequently use to illustrate the points of sail. This coordination appeared to be more salient for the focal student and suggests both that highly interactive technology is useful in this domain, and that more work is needed to facilitate coordination between first-person embodied experiences of sailing and group-level processes.

The second author, by contrast, has done significant work in recent years developing and piloting Re-Shape, which allows students to use GPS data to visualize their movements in space-time and compare these to their peers’ movements, as well as to aggregate data from other sources (Shapiro, 2017). This tool grew out of work with museum professionals (Shapiro, Hall, & Owens, 2017), and has been used in classes with pre-service Social Studies teachers to help students think about their patterns of movement in relation to demographic information as arranged on a city grid.

## Theoretical framing

This presentation draws from and contributes to a growing body of work looking at what researchers are calling “learning on the move” (Marin & Bang, 2015; Marin, 2013; Radinsky et al., 2008; Silvis et al., 2018; Taylor, 2017; Taylor & Hall, 2013). This term helps to organize a diverse body of work that seeks to both describe how people learn by moving through the physical environment, and use these descriptions to help design learning activities that require such movement. Notably, much of this research has been made possible by the steady development of mobile and location-aware technologies, which provide the capacity to geo-locate media collected by learners as well as to generate location data for and about learners’ activities. For example, this body of work encompasses theoretical and empirical work that frames learning as place-based and mobile (Danish et al., 2015; Enyedy et al., 2015; Lindgren, 2015; Taylor, 2017; Zimmerman et al., 2016) or characterizes learning as the process by which people “make places” to pursue their own interest-driven learning as they move through physical environments rich with meaning potential (Leander et al., 2010). Furthermore, it also encompasses efforts to design experiences in urban environments where relations between people and the designed environment are in question (Dennis, 2006; Elwood & Mitchell, 2013), study everyday practices in forested areas or nature parks where relations between people and animals, ground, water or air are the focus of learning (Marin & Bang, 2015; Marin, 2013), and look at technologically mediated activities such as mobile story telling (Farmen, 2014; Sakr et al., 2016) and simulations organized as games (Squire & Klopfer, 2007).

## Implicit and explicit epistemological orientations

Traditional youth sailing instruction is an intensely collaborative, hands-on activity. Unlike many classroom structures where youth are expected to listen to detailed instructions ahead of time and then execute once before moving on to the next topic, sailing is understood to be a personal, embodied learning experience—there’s only so much that can be achieved through talking, sailing has to be performed and practiced. Even so, a certain amount of instruction happens outside of the boats, sometimes to ensure safety and collaboration, and sometimes in an effort to make connections to broader principles of sailing. The technological tools presented in this interactive demonstration have the potential to help bridge the gulf between broader principles or group-level coordination and individual performance in small boats, but each has its own affordances that influence its implicit epistemological position.

Much like sailing instruction, action cameras such as the GoPro are frequently used to capture an individual’s experiences, which can later be shared with an audience on reviewing. While working with friends (or using technological innovations like drones) can allow for more traditional cinematography, most action camera footage is shot either from a first-person perspective (e.g. mounted on a helmet) or first-person-adjacent (e.g. a selfie stick that captures the subject’s face or shoulder along with the close-tied footage). The new system of gauges provides a birdseye record by including a location trace and average speed over time. Still, the dominant cultural assumption is that videos are meant to be watched as they are displayed (in real time, or sped up if edited for timelapse). The GoPro footage with coordinated gauges thus shares significant epistemological orientations with traditional sailing instruction—the main action is an individual experience that can be explained to others later, but never quite experienced or shared by those not present during the original event.

The Re-Shape tool, by contrast, emphasizes the group-level processes; while individual GPS traces constitute the most salient data, the focus of the tool is on the aggregate, and on comparisons between group-level aggregate data and imported data displays (such as city-level demographic information). Furthermore, the tool is built to be manipulated, rather than simply watched. Thus, use of the tool is a creative experience implying an active epistemological stance to a productive investigative activity, rather than the passive reception of an imperfect copy of an earlier experience. This tool thus offers the potential for an experience with the broader principles of sailing that is on its face far removed from traditional sailing instruction, but ultimately shares epistemological assumptions behind the curricular decision to just put kids in boats.

## Specific commonalities and differences

Both tools involved in this demonstration are aimed at helping students to coordinate between their first-person experiences and a representation of those experiences over time. In the case of the GoPro gauges, the individual camera is coordinated with a birdseye representation of the location and speed over time (see figure 1); in the case of the coordinated multi-angle video, the placement of two of the cameras also adds to the coordination between ego view and birdseye view (see figure 2); in the case of the Re-Shape tool, the first person account is less explicit (i.e. there is no ego-view footage, only the GPS trace; see figure 3).

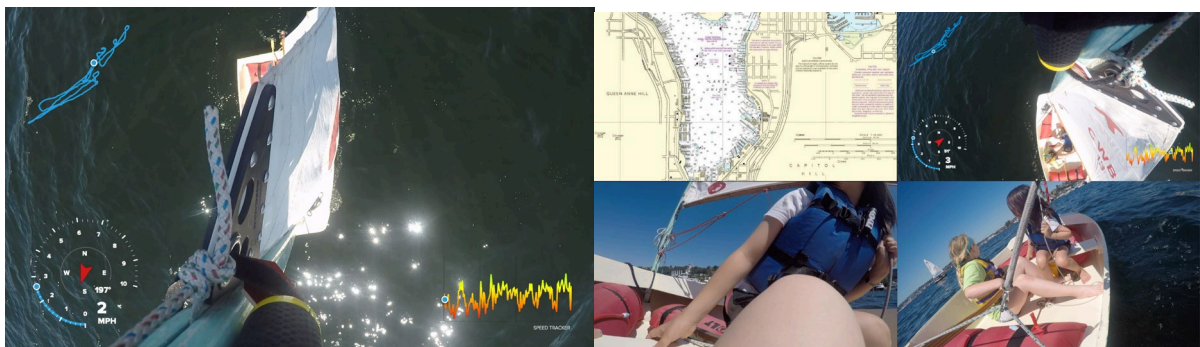
Both tools also make some effort toward coordinating individual traces with broader phenomena. In the case of the Re-Shape tool, individual GPS traces are visible on a map over which other individual traces can be overlaid. The map itself can also include relevant large-scale data displays—in the case of the social studies class, demographic data from the city was included to illustrate a curricular point. With the gauges, more of the work of coordinating with broader phenomena is left to the user—the gauges include a trace of the average speed, and a GPS trace over time, but there is little scaffolding to coordinate these even with each other, let alone with geography or wind, which are the curricular goals.

Finally, while in both cases the user is able to move through space-time as represented in the tool—either by scrolling the video or by manipulating what data are displayed—the Re-Shape tool is specifically designed to invite this kind of reworking of the data display, whereas the GoPro gauges are simply an add-on to video, which is often read by users as a passive display.

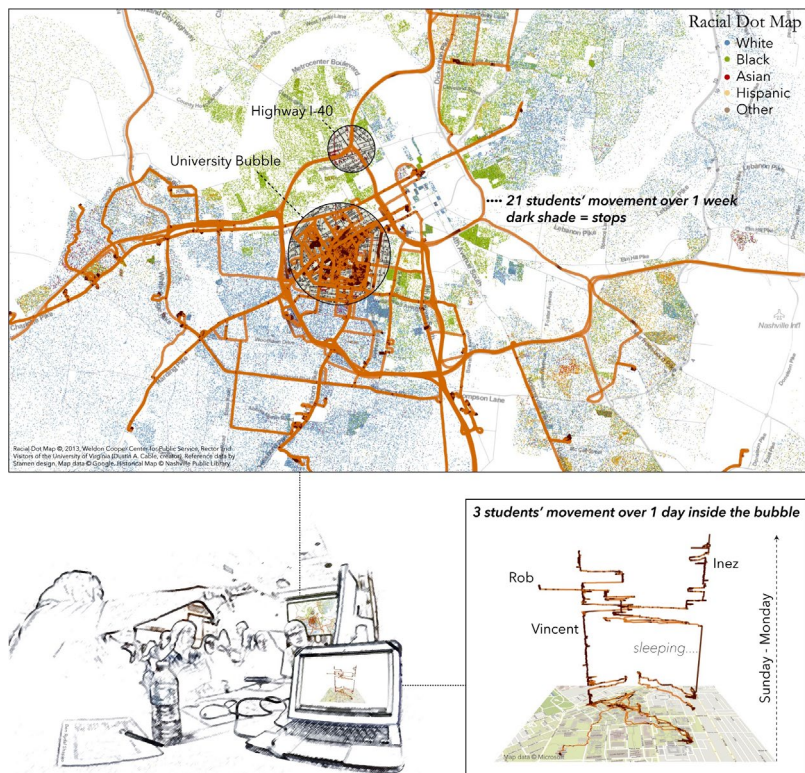
Table 1: Major design features of each tool (see figures 1–3 for illustrations).

Design feature	Conjectured contribution to learning	GoPro Gauges alone (figure 1)	GoPro Gauges w/ coordinated display (figure 2)	Re-Shape tool (figure 3)
GPS trace	help establish third-person perspective & continuity over time	upper left corner	upper right corner	main display

<b>First-person view</b>	make explicit connections to first-hand embodied experiences	none	secondary displays	none
<b>Coordination with other data sources</b>	help coordinate between first-hand experience and group-level processes	none	tertiary display of static map	secondary display (e.g. demographic data) integrated into main display
<b>Invites manipulation</b>	provoke exploratory epistemological stance (vs. typical "received" knowledge)	less apparent	less apparent	major goal of tool



**Figure 1 (left).** Screenshot of top-down boat-level video showing GPS displays, as shown to students.  
**Figure 2 (right).** Screenshot of coordinated video from three cameras (and a static chart) showing GPS displays.



**Figure 3.** Screenshot from Re-Shape tool (top and right) with still of pre-service Social Studies teachers (left). Full demonstration available at [https://youtu.be/H8vd\\_HX9RVs](https://youtu.be/H8vd_HX9RVs).

## Next steps

The aim of this interactive demonstration is to generate testable design conjectures, whether from existing tools or novel hybridizations (or novel tools). Given that we intend to approach this problem with youth, we are hoping to think through some of the assumptions and potential stumbling blocks with colleagues and potential collaborators before we iterate in practice with young sailors.

## References

- Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of Learning Sciences*, 2(2), 141-178.
- Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational researcher*, 32(1), 9-13.
- Danish, J.A. et al. (2015). Science Through Technology Enhanced Play: Designing to Support Reflection Through Play and Embodiment. In S. Ludvigsen & O. Lindwall (Eds.), Proceedings of the 11th International Conference on Computer Supported Collaborative Learning. Gothenburg, Sweden: International Society of the Learning Science.
- Dawson, E., & Jensen, E. (2011). Towards a contextual turn in visitor studies: Evaluating visitor segmentation and identity-related motivations. *Visitor Studies*, 14(2), 127-140.
- Elwood, S., & Mitchell, K. (2013). Another politics is possible: Neogeographies, visual spatial tactics, and political formation. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 48(4), 275-292.
- Enyed, N., Danish, J.A., and DeLiema, D. (2015). Constructing liminal blends in a collaborative augmented-reality learning environment. *International Journal of Computer-Supported Collaborative Learning*, 10(1), 7-34.
- Farman, J. (Ed.). (2013). *The mobile story: Narrative practices with locative technologies*. Routledge.
- Hawkins, J., & Pea, R. D. (1987). Tools for bridging the cultures of everyday and scientific thinking. *Journal for Research in Science Teaching*, 24, 291-307.
- Howe, A. C. (1996). Development of science concepts within a Vygotskian framework. *Science Education*, 80(1), 35-51.
- Leander, K.M., Phillips, N.C. and Taylor, K.H. (2010). The changing social spaces of learning: Mapping new mobilities. *Review of Research in Education*, 34, 329-394.
- Lindgren, R. (2015). Getting into the cue: Embracing technology-facilitated body movements as a starting point for learning. In V. R. Lee (Ed.), *Learning technologies and the body: Integration and implementation in formal and informal learning environments* (pp. 39e54). New York, NY: Rutledge.
- Marin, A. M. (2013). *Learning to attend and observe: Parent-child meaning making in the natural world* (Doctoral dissertation, Northwestern University).
- Marin, A., & Bang, M. (2015). Designing pedagogies for Indigenous science education: Finding our way to storywork. *Journal of American Indian Education*, 54(2), 29-51.
- Radinsky, J., Loh, B. & Lukasik, J. (2008) "GIS tools for historical inquiry: Issues for classroom-centered design," *Journal of the Association of History and Computing*, v.XII(2).
- Sakr, M., Jewitt, C., & Price, S. (2016). Mobile experiences of historical place: A multimodal analysis of emotional engagement. *Journal of the Learning Sciences*, 25, 51-92.
- Shapiro, B. R. (2017, May). Using Space Time Visualization in Learning Environment Design. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 178-183). ACM.
- Shapiro, B. R., Hall, R. P., & Owens, D. A. (2017). Developing & using interaction geography in a museum. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 377-399.
- Silvis, D., Taylor, K.H. & Stevens, R. (2018). Community technology mapping: inscribing places when "everything is on the move". *International Journal of Computer-Supported Collaborative Learning*.
- Squire, K., & Klopfer, E. (2007). Augmented reality simulations on handheld computers. *The journal of the learning sciences*, 16(3), 371-413.
- Taylor, K. H. (2017). Learning along lines: Locative literacies for reading and writing the city. *Journal of the Learning Sciences*, 26(4), 533-574.
- Taylor, K. H., & Hall, R. (2013). Counter-mapping the neighborhood on bicycles: Mobilizing youth to reimagine the city. *Technology, Knowledge and Learning*, 18(1-2), 65-93.
- Vygotsky, L. (1986). *Thought and language* (A. Kozulin, Trans.). Cambridge, MA: Harvard University Press.
- Zimmerman, H. T., Land, S. M., Maggiore, C., Ashely, R. W. & Millet, C. (2016). Designing outdoor learning spaces with iBeacons: Proceedings of the Twelfth International Conference for the Learning Sciences.

# FROG, A Tool to Author and Run Orchestration Graphs: Affordances and Tensions

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**Abstract:** Orchestration Graphs (OG) consist of sequences of activities placed in a two-dimensional coordinate system, with the x-axis denoting time (absolute or relative), and the y-axis the social planes. This contribution to the Special Interactive Session will discuss FROG, a tool based on the OG notation, and the affordances and tensions between the theoretical framework and the theory instantiated as a tool.

## Orchestration graphs

Pierre Dillenbourg introduced Orchestration Graphs (OGs) in 2015 as a new notation for modeling the design and orchestration of sequences of learning activities. OGs consist of sequences of activities placed in a two-dimensional coordinate system, with the x-axis denoting time (absolute or relative), and the y-axis the social planes, usually individual, team and whole class, but expandable to also include periphery, community and world.

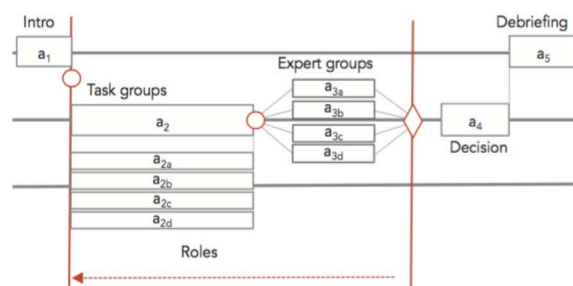


Figure 1. Example of an Orchestration Graph.

Graph activities (nodes) are connected by edges, which represent both pedagogical and data dependencies. The pedagogical relationship between two activities might be described as motivation, advanced organized, induction, etc. However, in order to enable rich collaborative sequences, edges can also express data flow through the use of operators, which transform the data structures produced during a learning activity into the data structures needed to run the next activity. For example, student opinions about an ethical dilemma could be aggregated and converted to a visual representation that the teacher can show the class, but can also be used to automatically group students with different opinions. Edges can also contain control structures, such as conditional operators or loops.

Several researchers have used OGs to analyze and communicate their experimental designs, such as Acosta (2018), who added a learning analytics layer, White (2018) used OGs as an analytical tool to analyze shifts between social planes in a math classroom, and Prieto, et al. (2018) attempted to automatically reconstruct an orchestration graph from multi-modal teacher data. In Singapore, some teacher education courses use OGs to train teachers in learning design (Samuel Tan, personal communication, December 5, 2018). In this paper, we will introduce a platform called FROG, which lets users design and run learning designs based on OGs.

## Learning design notations

There have been a series of proposals for educational modeling languages (Botturi, 2007). While a data format for encoding instructional designs, such as IMS-LD, would aim to capture all information relevant to the design, graphic notations must choose judiciously which aspects of the design to make explicit. Many proposals visualize sequences of activities, and some introduce swim lanes (such as CADMOS, Katsamani, Retalis & Boloudakis, 2012) to distinguish between different entities, such as students, teachers, and resources. Others, like the Learning Designer (Laurillard, 2013) emphasize the kind of learning process an activity is designed to foster through colors. The elements that are visually emphasized in OGs, on the other hand, are the activity



sequence relative to time, the social planes, and the data flow between activities. Pedagogical information is focused on the relationship between activities (edges) rather than the purpose of individual activities, and resources or tools are not explicitly modeled.

## FROG

FROG is our group’s attempt at building a platform that lets users author executable Orchestration Graphs. It is an open source (<https://github.com/chili-epfl/FROG>) browser-based application where teachers use the graph editor to author graphs, and the orchestration view to run and monitor sessions. It is currently focusing on synchronous sessions, both in one-to-one classrooms, and in fully online settings, and has so far been tested in a Swiss middle school, and several university lectures in Switzerland, the US, Norway and Greece, ranging from 150-300 student undergraduate lectures, 30 student graduate seminars to small online courses.

## Open-ended learning design versus authoring a concrete FROG lesson

One interesting tension is between on one hand enabling teachers to rapidly and correctly input all the information necessary to let an “orchestration engine” actually instantiate a learning design, and on the other hand to support an open-ended and creative design process for a lesson that might even happen elsewhere, or fully offline. FROG has so far focused on the former, which means that you can only add activity types that already exist in the system, and there is not much space to capture unstructured ideas, or pedagogical information that is not strictly necessary for the orchestration engine to run (see the graph editor in Figure 2). Although we often engage in learning design work around FROG, whether when working with teachers to co-design collaborative learning lessons, or when students in a graduate course on Digital Education use FROG to design lessons that reflect the learning theories that they have been examining, we tend to do the actual design process on paper or in a Google Doc, while referencing the OG notation (“this activity is on plane 3, and we will use this operator to connect with this other activity”).

In order to capture enough specific information for the information flow within a graph to be instantiated, we have also had to deviate somewhat from the original design. For example, we represent operators not as parts of edges, but as entities that can have multiple inputs and outputs, to make the information flow much more explicit. We also added an additional plane for teacher tasks, to explicitly model things that teachers might need to do as part of the graph workflow (grading, classifying examples, etc.). According to OG theory, these would be “interactive operators”, but they importantly have a time dimension, which justifies modeling them as activities.

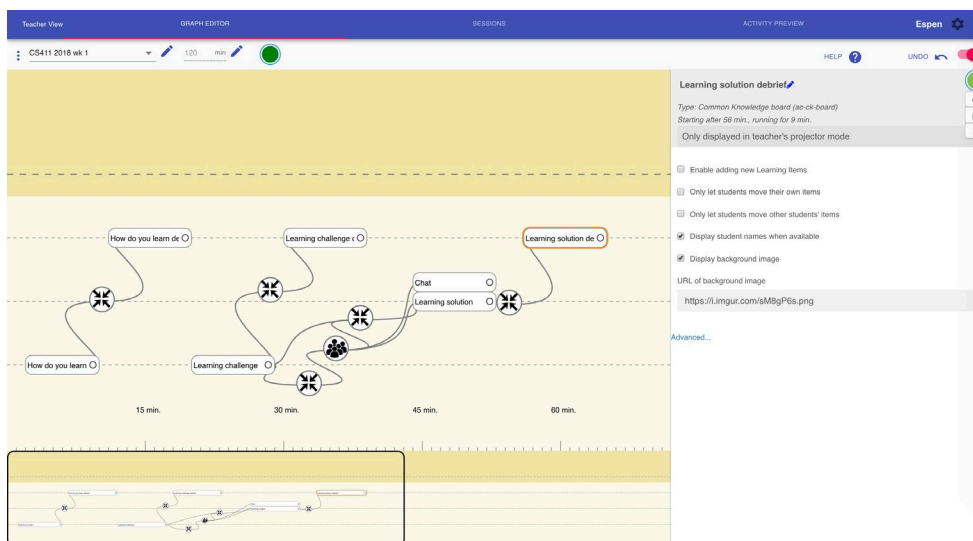


Figure 2. The FROG Graph Editor.

## How the theoretical framework impacts technology design

Although there are other orchestration tools that enable some flow of information between different social planes and different activity types, the OG framework guided us to focus strongly on designing the activity type APIs and operators, as well as the underlying data structures, in a way to maximize flexibility and connectivity. We believe that this principled approach to technology design leads to a framework that is not only very

flexible, but also learnable through some key abstractions. However, there are some tensions inherent in this approach. One is that we necessarily had to make some adaptations to the OG notation when implementing it in an editor meant to output runnable graphs. As we proceed to popularize FROG, we ask ourselves to what extent we should emphasize the OG theory when onboarding teachers, and how to manage the divergence between the theoretical representations and the actual interface (it is of course possible that in the future, we could revise the theoretical representations based on our experiences with implementing FROG).

Because of our desire to maximize flexibility and configurability of scenarios, we have also ended up with a somewhat complex interface, as seen in Figure 2. In the future, we hope to simplify this interface, by implementing better defaults and hiding some of the wiring for very common cases (like having a single group structure persistent throughout a session), while still enabling and exposing the possibilities of doing very complex designs.

## Theory-free use of FROG technology

FROG was from the beginning conceptualized as a pluggable ecosystem, with the goal of having multiple groups contributing activity types (threaded chats, collaborative concept mapping or physic simulations) and operators (group formation, semantic analysis and inferring student progress). Given our focus on synchronous collaborative learning, the FROG engine provides an activity-type API which makes it very easy to build innovative activity types that support synchronous collaboration, and these activity types themselves could be interesting to other learning projects that might not share our theoretical stance (see Figure 3 for an example of an innovative synchronous collaborative activity types in FROG).

The screenshot displays a web application interface. On the left, a rich text editor titled 'CSCL and affordances' is open, showing a discussion about CSCL environments. The editor includes a toolbar with various text formatting options and a text area containing several paragraphs of text, some of which are highlighted with annotations. On the right, a 'Gallery (all)' panel is visible, featuring a search bar and a list of search results. Each result includes a snippet of text and a star icon, indicating that the gallery is searchable and supports annotations.

Figure 3. A searchable gallery with Hypothes.is annotations, and a collaborative rich text editor, which supports embedding rich content (like the annotations).

We are currently prototyping APIs to expose individual FROG activity types to other systems, enabling remote configuration, student grouping, embedding of dashboards, and live-streaming of learning analytics. The Graasp platform is focused around science inquiry spaces (Bogdanov, *et al.* 2012) is currently integrating FROG activity types and making them available to teachers in the EU GoLabz project.

## Conclusion

We have described Orchestration Graphs as an approach to learning design notation, and how it has inspired the FROG platform. We will demonstrate this in practice, letting people experiment with the graph editor, and participate in a graph as learners.

## References

Laurillard, D. (2013). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge.

- Acosta, A. (2018). *Scripting and Orchestration of a Knowledge Community and Inquiry Curriculum for Secondary Biology*. (Unpublished doctoral dissertation). University of Toronto, Canada.
- Prieto, L. P., Sharma, K., Kidzinski, Ł., Rodríguez-Triana, M. J., & Dillenbourg, P. (2018). Multimodal teaching analytics: Automated extraction of orchestration graphs from wearable sensor data. *Journal of computer assisted learning*, 34(2), 193-203.
- White, T. (2018). Connecting levels of activity with classroom network technology. *International Journal of Computer-Supported Collaborative Learning*, 13(1), 93-122.
- Katsamani, M., Retalis, S., & Boloudakis, M. (2012). Designing a Moodle course with the CADMOS learning design tool. *Educational Media International*, 49(4), 317-331.
- Bogdanov, E., Limpens, F., Li, N., El Helou, S., Salzmann, C., & Gillet, D. (2012). A social media platform in higher education. In *Proceedings of the Global Engineering Education Conference (EDUCON)* (No. EPFL-CONF-178720, pp. 1-8).
- Botturi, L. (Ed.). (2007). *Handbook of Visual Languages for Instructional Design: Theories and Practices: Theories and Practices*. IGI Global.



# Mission HydroSci: Meeting Learning Standards Through Gameplay

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**Abstract:** Mission HydroSci (MHS) teaches water systems and scientific argumentation towards meeting Next Generation Science Standards. MHS is a game-based 3D virtual environment for enacting transformational role-playing, wherein students must learn new knowledge and competencies in order to successfully complete the game missions. MHS was developed for middle school science as a replacement unit of about 6 to 8 hours and uses analytics and a teacher dashboard to help support teachers support their students.

## Introduction

Mission HydroSci (MHS) is a game-based 3D virtual environment for teaching and learning key concepts and knowledge of water systems as well as building competencies in scientific argumentation in ways that support meeting Next Generation Science Standards (NGSS). Meeting these new science education goals for middle school students requires rich learning contexts for exploring substantive science ideas through engagement in scientific practices. Our goal is to meet these educational goals for all learners by using online learning to serve those in distance education and rural communities as well as more traditional and well-resourced classrooms, and to use gaming to engage and support students who typically do not see themselves as successful science learners.

MHS is a research and development project funded by grants from the U.S. Department of Education. The grant support has enabled a team of researchers, science educators, learning and game designers, creative arts professionals and software developers to build MHS through an iterative process. The process started with envisioning a powerful fit between emerging technological capabilities and the requirements of teaching and learning to NGSS. Next came conceptualizing a complete system to engage and teach students a robust curriculum and then building and testing each component of the system. The building and testing process has included prototyping, creating design documents, such as requirements specifications and storyboards and building initial versions which then can be taken to usability testing and further refined. Once we felt a substantial portion of MHS was playable and met our requirements specifications for teaching and learning activities through implementation of the curriculum as a game, we conducted usage testing in live classrooms. The usage testing taught us about the practical challenges of using a game in classrooms as well as identifying many areas of gameplay that needed improvement. Our intention and obligation to the funding sources is to undertake a field test using a randomized control trial (RCT) to rigorously evaluate the impact of MHS game play. The RCT will be undertaken in Winter, 2019. However, to test the feasibility of conducting a large field test in classrooms we undertook a feasibility field test in the Spring of 2018. This report and showcase describes MHS and presents some insights about the use of MHS in classrooms from interviews with 12 teachers who participated in the 2018 feasibility testing.

## Rationale for MHS

While MHS is a research project with goals of understanding and testing the potential impacts of a gameplay approach on teaching and learning and of developing gameplay strategies that map to teaching and learning approaches, it is also a product development project aspiring to build a game that middle school science teachers will use to meet important learning objectives in their science curriculum in ways that align with the NGSS. MHS targets general and earth science courses by meeting learning objectives for understanding water systems and building competencies in scientific argumentation. The MHS game provides an active learning environment for meeting these learning objectives by engaging students in a narrative about needing to investigate water resources and use scientific argumentation to complete missions critical to the survival and accomplishments of the members of their scientific enterprise. The enterprise is set on an earth-like planet in the future as the science cadets (our player and a set of non-player characters who serve as guides, partners and sometimes antagonists) explore

mysteries and prepare for survival on the planet. Along with the narrative gameplay MHS includes learning progressions for water systems science and scientific argumentation, a visually exciting environment, substantial interaction and feedback, and applies transformational role-playing as an approach to integrate learning within gameplay.

The theory of transformational play (Barab, Gresfali & Ingram-Goble, 2010) shows how specific design strategies can optimize the potential of games and gameplay to lead to desired learning outcomes. The design strategies to enact transformational play include the student taking on the role of a protagonist, who must use subject matter knowledge to make decisions and take action during play, and having these actions and decisions transform the problem-based situation. In turn the student's understanding of the subject matter is transformed and so is the student's identity. Virtualization and role-playing experiences in MHS are intended to make realistic actions possible and bring about the consequences of actions to dynamically impact the world and the learner.

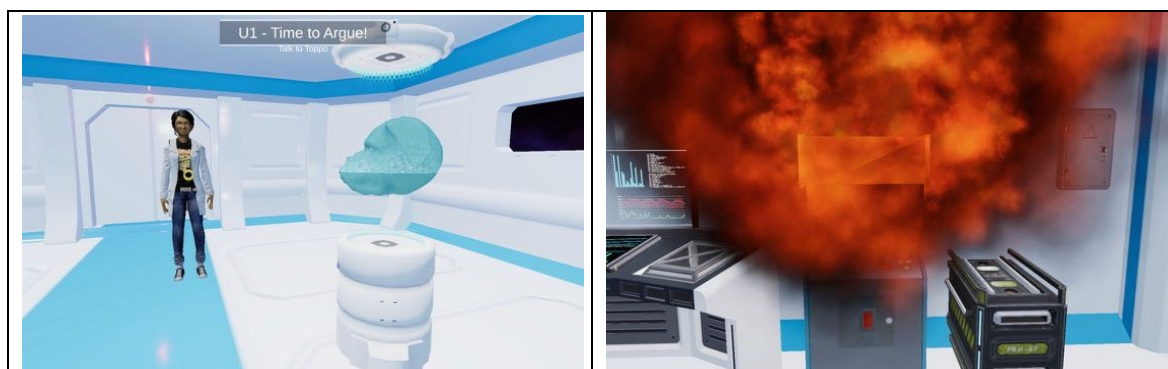
Building competence with scientific practices, such as scientific argumentation, requires learning a progression of competencies, thus multiple practice settings and iteration with feedback must be provided. The game experience helps sustain the student through the many activities as well as makes it OK and natural to fail and try again. MHS is a first person narrative adventure with a sustained learning experience of 6 to 8 hours of instructional time for gameplay and 1 to 2 hours of supplementary classroom or discussion board activity for the teacher to clarify, supplement, and extend the learning from the gameplay.

## Game Play

### Unit 1

Unit 1 introduces students to (1) gameplay including game controls, characters and narrative, (2) scientific argumentation as a process of using evidence to judge between competing claims and (3) the argumentation engine that will be used to conduct arguments during game play. The design task of unit 1 is to help the player get off to a good start, but also to set the stage for engaging at one's own pace, so as to learn how to succeed in the game and not just to move through the game. The tutorial nature of the starting tasks are counter balanced by interesting and fun visuals, learning about interesting NPC characters, and an exciting start to the game.

The unit starts with the player awakening on a space station orbiting an alien but earth-like planet. The player is introduced to ARF who will be an assistant for the player's exploration and activities. ARF is presented as a buddy, given an avatar of a dog, and a high form of artificial intelligence to assist the player. The player also meets Dr. Toppo who is the mission leader and sets up challenges for the player throughout the game. After learning some basics of how to navigate and play MHS as well as being introduced to other NPC's and tools to be used throughout the game, the space-craft is rocked with an explosion and our player must escape the station and fly to the alien planet.



**Figure 1.** Meeting Dr. Toppo and ARF on the spacecraft and the explosion.

### Unit 2

Unit 2 teaches players about topography and using a topographic map as well as understanding watershed and how the relative size of the watershed is related to the amount of water flowing through it. After crash landing on the alien planet our player practices some of the skills they learned in unit 1 while collecting scrap to repair a broken hoverboard and tracking down the communication equipment which they will need to move rapidly on the large terrain and find the rest of their team. In order to find the team they must use a topographic map and respond

to clues and feedback framed using topographic terminology. Once they have located the team, our player is assigned the task of finding which watershed is larger and thus best for setting up the base camp for the expedition. After traveling to key waterfalls and gathering evidence our player engages in an argument where she must use evidence to support the claim of which watershed is largest.



Figure 2. Finding the team and reaching the waterfall to collect data about watersheds.

### Unit 3

Unit 3 teaches about surface water with the learning objectives of having the player be able to predict the spread of a dissolved material through a watershed and identify the direction of water flow based on a map of a watershed. This is enacted narratively through one of the NPCs, Sam, who needs to set up her camp but her supplies are scattered all over the terrain. Our player must find the supplies and figure out which waterways to use in order to float them back to Sam's camp. Upon completing the task, our player returns to the base only to find that Sam's base is polluted and she asks our player to solve what's causing the pollution by tracing the source of the pollution. The player does this by throwing sensors into the nearby river and eventually will find wreckage from the space station explosion. Our player works their way up the river and then must create a good argument using reasoning to connect evidence with a claim in order to get the pollutant removed. Next, our player discovers that the aliens had left irrigation devices to support growing food in gardens, which will be extremely important for the success of the expedition. Unfortunately, the pumps are old and need to be replaced. By succeeding at solving the first of the dungeon-like puzzles the player unlocks new pumps and then must use their knowledge of surface water flow to pick which irrigation systems to restart.

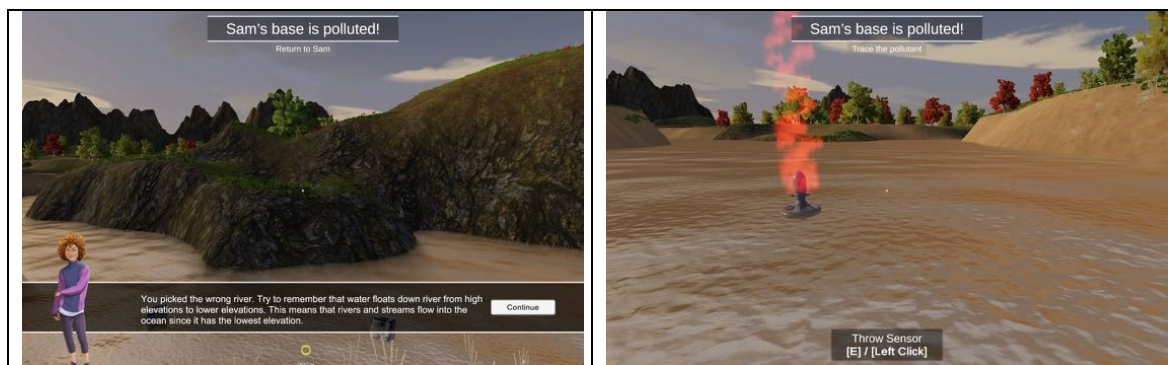


Figure 3. Sam telling you that the crate was tossed in the wrong river and tossing sensor in river to collect evidence for finding the pollution.

### Next Steps

As noted in the introduction, the MHS team is planning a substantial field test of MHS for the winter/spring of 2019. To reach the field test we have prioritized several objectives. First, we need to achieve technical soundness, optimization to perform on as low a performance computer as possible, and clear direction for what systems will

work. Second, improvements across a range of quests and tasks to better achieve learning outcomes. Third, making argumentation a better fit to the rest of the gameplay and providing support for students who are likely to struggle with the competencies. Finally, support for low readers by adding audio for dialog, low experience gamers by adding better feedback, clearer graphics, more tutorials and simplifying some game mechanisms and activities, as well as support for high gamers by enriched graphics and rewards and side quests. More information about MHS can be found at [MHS.missouri.edu](http://MHS.missouri.edu) or by contacting the authors.

## References

- Barab, S., Gresfali, M. & Ingram-Goble, A. 2010. Transformational play using games to position person, content and context. *Educational Researcher* 39, 7 (2010), 525-536.
- Griffin, J., Kim, S. M., Sigoloff, J., Sadler, T. D., & Laffey, J. (2016, August). *Designing scientific argumentation into Mission HydroSci*. Proceedings of the Games + Learning + Society Conference. Madison, WI
- Laffey, J., Sadler, T., Goggins, S., Griffin, J. & Babiuch, R. (2015). Mission HydroSci: Distance Learning through Game-Based 3D Virtual Learning Environments. In Russell, D. & Laffey, J. (Eds.), *Handbook of Research on Gaming Trends in P-12 Education*. (pp. 421-441). Hershey, PA: IGI Global. doi:10.4018/9781-4666-9629-7
- Laffey, J., Griffin, J., Babiuch, R., Sigoloff, J., Kim, S. M., Sadler, T. D., & Goggins, S. (2016, August). *Mission HydroSci: Designing a game for next generation science standards*. Proceedings of the Games + Learning + Society Conference. Madison, WI.
- NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.
- Osborne, J., Henderson, B., MacPherson, A., & Szu, E. (2013). *Building a learning progression for argument in science*. Paper presented at the annual conference of the American Educational Research Association Conference, San Francisco, CA.
- Shulman (Eds.), *Issues in education research: Problems and possibilities* (pp. 399-409). San Francisco: Jossey-Bass Publishers.
- Hawkins, J., & Pea, R. D. (1987). Tools for bridging the cultures of everyday and scientific thinking. *Journal for Research in Science Teaching*, 24, 291-307.
- Lave, J. (1987). *Cognition in practice*. New York: Cambridge University Press.

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# Project Bloks: Embodied and Collaborative Learning with Tangible Interfaces for Young Children

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**Abstract:** This interactive demo presents Project Bloks, a development platform for tangible programming to enable young children to learn programming. The modularity of the platform demonstrates technical and design advances that can benefit not only designers, makers, and educators who can create activities for this platform, but also the children we strive to engage. With this demo, we hope to facilitate new thinking around about embodied and collaborative learning with tangible interfaces for young children.

**Keywords:** children, tangible interfaces, computational thinking, programming, collaborative problem solving

## Introduction

Recent years have seen a steady increase in efforts to teach computer programming in formal and informal learning environments. Organizations and governments, domestic and foreign, have committed in various ways to making computer science education accessible to all students, and new research reveals the promise and challenges of teaching programming (Blikstein, 2018). The idea of computer science education first began in the 1960s with Seymour Papert and Logo (Papert, 1980), and in K-12 education in particular, this movement has since exploded in the number of computer and mobile applications (e.g. Scratch, Kodable, Tynker), building sets (e.g. littleBits, LightUp, MakeyMakey), programmable robots (e.g. Dash & Dot, KIBO, Cozmo), and others (e.g. Robot Turtles, Osmo).

The design space for apps, robots, and other technologies for bringing computational thinking and computer science to children has been in intense transformation during the last five years because of three factors. First, high-profile private and public initiatives and campaigns around coding education drew the attention of design firms, engineers, research labs, and creative educators. Second, the popularization of crowdsourcing platforms gave individuals and groups a viable way to fund and commercialize their ideas for tools to teach computational thinking. Finally, the development of new technologies such as low-power wireless communication, low-cost rapid prototyping, and new types of microcontrollers and microprocessors expanded the design space in unprecedented ways. It became possible to offer higher levels of abstraction using more sophisticated hardware and software, and therefore a more creative mix of digital and tangible interfaces.

However, this rapid design explosion brought about some shortcomings, such as the emergence of many single purpose, proprietary and often expensive designs that were incompatible with each other. Because many of these products were designed for consumption by individuals, they were not designed for schools and formal education, which inherently diminished the designers' focus on collaboration and generating low-cost designs. Therefore, despite the growth of creativity and new products, many design opportunities still remain within the tangible programming space, especially in regards to collaborative classroom activities around coding and particularly for young children.

The development of this platform aimed to address the problems of incompatible designs and increasingly complex hardware and software, while utilizing the learning affordances of an interface that is both digital and tangible. Prior research on tangible interfaces suggests many benefits for learning, including greater accessibility for young children, increased engagement and reflection, and better support for collaborative learning (Marshall, 2007). We drew inspiration from other tangible platforms, such as the Programmable Bricks (Resnick et al., 1998), Tern (Horn & Jacob, 2007), Topobo (Raffle et al., 2004), and Robo-Blocks (Sipitakiat & Nusen, 2012).

## Introducing Project Bloks

Just as Google's Blockly is a platform for the creation of on-screen, block-based languages, the goal for Project Bloks was to be a platform for the creation of tangible programming languages. The design was inspired by Papert, Resnick, and Silverman's idea of low thresholds, high ceilings, and wide walls; to make it easy for novices to get started, but also possible for experts to build complex and diverse creations (Resnick & Silverman, 2005). We also wanted to allow designers, educators, and makers a wide variety of form factors, materials, and feedback channels (haptic, visual, and auditory), rather than having to deal with the technical aspects of developing



technologies for learning. Ultimately, Project Bloks is for children as well as for developers; the components are designed to make sophisticated programming ideas such as conditionals, functions, and recursion accessible to young minds.

One of the key design features of the project is the separation of the (more expensive) hardware blocks and the (inexpensive) “pucks,” which fit on top of the blocks and can be easily customized by educators, developers, and designers. Therefore, the same set of hardware blocks can support the design of multiple sets of special kits of “pucks” (e.g., one for robotics, another one for music, yet another one for cartesian motion). Another key feature is the ability for the system to learn new “functions”, which can be assigned to blank pucks that children can write or draw on to indicate what they do. While existing tangible programming platforms can convey loops and conditionals, Project Bloks is the first to also support functions. Finally, another important feature is the facilitation of classroom collaboration: the system was designed to be used by several children at the same time in a classroom environment. For example, using the “function” feature, an entire classroom might collaboratively generate a solution at the center of the room, with individual groups of children working on their own procedures for this central classroom-wide program.

## Hardware components

The system consists of the following (see Figure 1):

- A central brick, which contains the main source for power and communication. It includes wireless connectivity to support communications with activity software, hardware, and other blocks. It also contains a large green button, which users press to execute their programmed sequences.
- A set of blank bricks, including basic bricks and special bricks (e.g., repeat bricks, if and if-else bricks, function bricks), which can be used in various configurations. Each brick becomes a specific, individual instruction that corresponds with the puck placed on top. These instructions can be programmed by designers to express a wide range of actions, such as “move in a certain direction”, “get flower”, or “turn on or off”. The special bricks can be used to express conditions and functions.
- A set of pucks, which can be customized for different activities. Each puck is an individual tile that represents an instruction. Pucks can be static (“get flower”) or dynamic (“move in a certain direction”); the latter features rotary dials, buttons, and sliders for controlling a setting within an action.



Figure 1. The Project Bloks system, shown with the code.org activity set.

## Supporting hardware

The kit uses a mediator tablet so that an adult facilitator can specify the coding activity and block settings. For activities that require a presentation screen (such as the code.org activity in Figure 1), a web app can be launched on a separate laptop or tablet, which connects to the central brick via Wi-Fi.

## Activities

Three different activities help demonstrate the diversity of applications that Project Bloks currently supports:

- **Code.org:** Children use the blocks and pucks to solve a series of maze puzzles, where the objective for each puzzle is to guide a bee through a maze using code.
- **Mirobot:** In using Project Bloks to control the Mirobot, an inexpensive drawing robot, children are able to create art ranging from simple line drawings to complex patterns.
- **LEGO Education WeDo:** After building a LEGO creation enhanced with a motor, distance sensor, tilt sensor, or LED light, children can use the blocks to control what they built.

## Preliminary studies

Following the development of Project Bloks, we conducted task-based studies with over 40 first- and second-grade children in the U.S. and Brazil. Our research included studies with individuals as well as pairs, as prior work suggests that a key benefit of tangible interfaces is promoting productive collaborative interaction (Marshall, 2007). In general, we observed that the physical cues enabled children to learn how to use the system rather quickly, and also that the tangibility of the tool supported embodied learning in particular. In addition, children were able to engage with complex computational thinking ideas such as loops. Whereas with digital programming languages, children may infinitely duplicate series of instructions, Project Bloks has a limited-block design, such that the practical limitation of having physical blocks created new opportunities for children to learn a key concept (Lin & Blikstein, 2018).

## Expected outcomes and contributions

We hope that demonstrating Project Bloks at CSCL will facilitate a larger conversation about embodied and collaborative learning with tangible interfaces for young children. In particular, one of the main design motivations was to allow better collaboration during programming activities in classrooms. On-screen programming, both on computers and tablets, does not always optimally facilitate collaboration; in order to be engaged, children need to be within reach of and facing the screen, which is especially difficult with small screens. For young children, we believe that Project Bloks can more effectively support collaborative programming. The physicality of the interface not only favors exploratory behaviors because tangibles are natural and intuitive to use (Marshall et al., 2003), but also establishes joint attention between multiple learners and creates a shared space for concurrent interaction (Fernaes & Tholander, 2005; Suzuki & Kato, 1995). In our studies of pairs of children using Project Bloks, we observe that children engage in various strategies to negotiate shared control. Furthermore, while the physicality of the tool increases visibility of the other learners' activity and thinking, both learners also begin to develop a common language for planning and communication.

With the interactive demo at CSCL, we wish to highlight the potential and challenges for tangible interfaces in collaborative learning activities for young children.

## References

- Blikstein, P. (2018). Pre-college Computer Science Education: A survey of the field. Mountain View, CA: Google LLC. Retrieved from <https://goo.gl/gmS1Vm>.
- Fernaes, Y. & Tholander, J. (2005) Looking at the computer but doing it on land: Children's interactions in a tangible programming space. In: *McEwan T., Gulliksen J., Benyon D. (eds) People and Computers XIX — The Bigger Picture*. Springer, London, 3-18.
- Lin, V. & Blikstein, P. (2018). Learning loops: Affordances and challenges of Project Bloks. *ICLS 2018 Proceedings*, 1531-1532.
- Horn, M. & Jacob, R. (2007). Tangible programming in the classroom with Tern. *CHI 2007 Proceedings*.
- Marshall, P. (2007). Do tangible interfaces enhance learning? *TEI 2007 Proceedings*, 163-170.
- Marshall, P., Price, S., & Rogers, Y. (2003). Conceptualising tangibles to support learning. *IDC 2003 Proceedings*, 101-109.
- Papert, S. (1980). *Mindstorms: Children, computers and powerful ideas*. New York: Basic Books.
- Raffle, H., Parkes, A., & Ishii, H. (2004). Topobo: a constructive assembly system with kinetic memory. *CHI 2004 Proceedings*.

- Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., & Silverman, B. (1998). Digital manipulatives: New toys to think with. *CHI 1998 Proceedings*, 281-287.
- Resnick, M. & Silverman, B. (2005). Some reflections on designing construction kits for kids. *IDC 2005 Proceedings*, 117-122.
- Sipitakiat, A. & Nusen, N. (2012). Robo-Blocks: Designing debugging abilities in a tangible programming system for early primary school children. *IDC 2012 Proceedings*, 98-105.
- Suzuki, H. & Kato, H. (1995). Algoblocks: an open programming language. *CSCL Proceedings 1995*, 349-355.

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# The Power of a Network Analysis Tool for Collaborative Learning

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**Abstract:** Net.Create is an open source network analysis software tool that affords simultaneous data-entry and network analysis to help students collaboratively co-construct knowledge about a large corpus of data. In this interactive demo, we demonstrate how the tool uniquely supports collaboration at both the small and large group level in a big lecture format to facilitate discovery, discussion, and reading comprehension in an interactive and engaging way.

## Introduction

The Net.Create tool aims to bring the power of network analysis into university humanities classrooms to support student engagement and collaborative learning. Network analysis is increasingly seen as a powerful computational tool for making sense of big data sets that seek to describe the large network of interdependencies created by the overlap of many localized small networks. Net.Create is an open-source network-analysis software tool that affords simultaneous data-entry, network visualization and analysis to help students collaboratively co-construct knowledge about the text they are representing as a network. Though Net.Create was originally developed specifically for use in history instruction, it can be useful in any context where simultaneous or team-based network data entry is needed. The tool supports students as they enter information about actors (e.g., people and institutions) and the relationships among them. Unlike traditional network visualization tools that are intended for experts to individually enter data and engage in visualization, the Net.Create tool immediately displays the results of the whole network, including students' classmates' work, in a sociography, allowing them to continuously build off of each other's work and ideas. This immediacy and collaborative effort facilitate discovery, discussion, and reading comprehension.

For example, in a history class, Net.Create affords simultaneous data-entry and network analysis to help students collaboratively create the framework for a historical event and fill in its details (see Figure 1). During a Net.Create activity, students collaboratively do network-data entry in small groups who are each assigned a subsection of the larger historical text. As they do this, students can connect to and see the data that their peers are also entering. By dividing up a large, unfamiliar text into smaller pieces and assigning those to small collaborating groups whose work fed back into a whole-class network, the tool leverages the large collaborating group to support students in interpreting an entirely new text. This combination emphasizes both the localized details that make interactions manifest as well as the larger network that makes historical context visible and supports historical argumentation. In this interactive demo, we will demonstrate several student-created networks produced in Net.Create pilot studies and showcase how the specific features of Net.Create can offer a promising collaboration platform to encourage co-construction of knowledge in both the small and large group level. We'll introduce attendees to one of the sources our students have used, provide a short activity that lets attendees try their hands at one of the student activities based on that source, and then do a short debrief that affords time for discussion after the interactive portion of the demo concludes. The Net.Create team is finalizing a version of the software tool and a scaffolded activity that can be downloaded from [www.netcreate.org](http://www.netcreate.org) for computers running MacOS 10.12 or greater.



Figure 1. Students' constructed network of Alexander the Great in Net.Create.

## Using Net.Create to support argumentation and collaborative learning

The vast majority of humanities instructional strategies depends on consuming lengthy texts, both written texts and images as a form of text (Theibault, 2013). Novice students run into a number of common challenges as they read and discuss these texts. For example, novice history learners struggle to consume volume of historical texts because they may not understand the language used in the past, or the context in which events occurred (Craig, 2017). It is particularly difficult for them to grasp the connections between the many participants and events in the text, and these connections may not be explicitly spelled out for students (Wineburg, 1991). Network analysis can support students as they reflect on and explicitly represent the connections within the texts by reducing information in a network to single nodes (an item in the network) and edges (the connections between nodes) then using aggregate information from each node-and edge pairing to interpret the whole network (Carrington, Scott & Wasserman, 2005).

Next, integrating newly acquired network-visualization literacy into the arsenal of tools to present arguments can support students learning as they appropriate disciplinary norms. The gap between novice historians' assumptions about history as a "settled" straightforward linear narrative and expert practice in history as an argumentative discipline is an important consideration in leveraging the notion of *capta* "taken not given, constructed as an interpretation of the phenomenal world" in a history classroom (Drucker, 2014, p. 128). Student assumptions about history as a discipline with established facts are underscored by the lecture environment that is common to many undergraduate history surveys, and it only serves to exacerbate this gap between novice historians' view of history as settled and expert views of history as negotiated. When history is seen *not* as list of facts to memorize but as an interpretive account that collectively holds the cause and meaning of historical interactions supported by evidence, these novice students might more easily understand and remember the historical content (Theibault, 2013). Because of the broad scope contained in many historical texts, collaboration in creating these argumentation-evidence cycles should be encouraged for students, so that they can simultaneously examine the underlying factors that shape their interpretive history accounts and negotiate argument using the resources they have access. Therefore, it is important to foster multiple skills, such as corroboration, sourcing and perspective taking in order to transform the text into contextualized data (Simon, Erduran, & Osborne, 2002).

However, it is challenging to frame history as an interpretive account through collaborative effort in undergraduate history classrooms in part because of the large lecture format that is common to many undergraduate history survey classes and the single-authored nature of the historical document. Moreover, collaborative inquiry activity for novice students is not easy. The students are often asked to simultaneously regulate inquiry processes and activities, negotiate challenges, monitor progress, and articulate their argument as a group (Quintana et al., 2002). Establishing and sustaining mutual understanding via effective communication is a consistent challenge in collaboration. To support these challenges, Dillenbourg, Järvelä, & Fischer (2009) suggested that technology-rich environments should provide groups with a learning environment where they can set shared goals through the repeated negotiation over the course of collaboration and ensure the division of work. It is critical to use the group members as a source for clarifications and to ask relevant questions through productive interaction. Net.Create was designed specifically to support this kind of collaborative co-construction of knowledge.

### **Activity theory: Design framework of Net.Create**

Our design of tool Net.Create is grounded in activity theory (Engeström, 1987). A core assumption in activity theory is that cognition and learning are socially mediated, or transformed by the multiple mediators of the activity, thus, it focuses on how individuals learn within rich activity contexts (Danish, 2014). The activity triangle (see Figure 2) is a representation of the key mediators of activity in the Net.Create context and their relationships with each other, and is intended to help visualize how they are all interconnected (Engeström, 1987). In this design, we positioned Net.Create as a mediating tool to scaffold student collaborative argumentation process across two different levels of learning to develop the necessary skills surrounding historical thinking.

Students within the proposed Net.Create activities are presumed to come to our classroom with some basic knowledge about social networking tools, and with a wide range of ideas about history (the *subject*). Their *object* (or shared motive) will be to make sense of a historical text. To help them accomplish this, we will present them with Net.Create (a new *tool*). Net.Create will fundamentally change how they engage with their motive and with the text (also a *tool*) by providing new ways of looking at the text, and new ways of looking at the information that the students glean from within the text (in the form of network visualizations). We believe that the students are more likely to engage with these tools in productive ways if they work collaboratively. Therefore, we will arrange them in small groups where they will be assumed to support each other by noticing, suggesting, and critiquing alternative elements within the text and resulting visualization (the *division of labor*). Finally, they will be expected to justify their answers within the tool providing significance and using citations (a *rule*) and to share

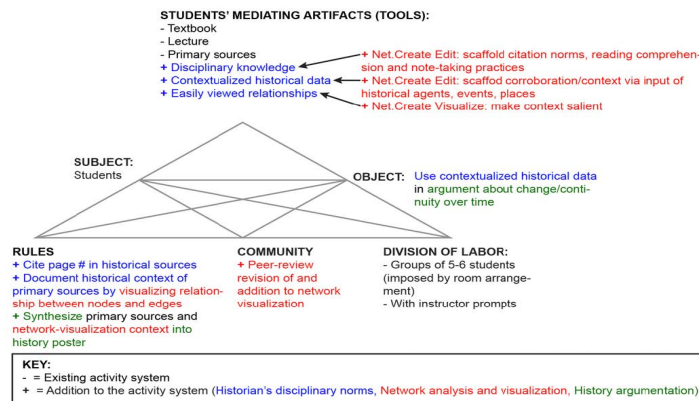


Figure 2. Activity triangle to integrate proposed Net.Create features into a classroom.

their aspects of the network with the entire class, who will also provide feedback. Thus, the community includes the other students in the entire class as well as the instructor who will be present for these discussions. Our assumption is that as students see new aspects of the historical phenomena, they will come to appreciate the value of using a network tool, while also learning how to use such a tool through practice. This appreciation is what we think will drive their appropriation in that they will know both how and why such a tool might be useful, and will be motivated to use one anew in the future.

### Features to scaffold students in Net.Create for network entry and analysis

To use network analysis and visualization as supporting tools for collaborative argumentation, we need to scaffold student encounters with these tools. Most undergraduates do not have high proficiency for understanding, interpreting, and creating data visualizations, particularly network visualizations that are likely unfamiliar to students and have complex visual elements. Fortunately, prior work has shown that even users who are new to network visualizations intuitively understand how the elements of a network visualization represent the actual elements of the network: lines are representative of connections between nodes in the network, and connection distances represent the relative similarity or difference of those nodes within their shared category (Nickerson, Tversky, Corter, Yu, & Mason, 2010). This suggests that Net.Create is still accessible to students with limited data-visualization skills, particularly considering prior successes in two short pilots. However, our pilot also suggests that engaging with network analysis is still challenging, so our aim is to scaffold the necessary skills surrounding network analysis in a number of ways.

First, the history students in small groups can collaboratively enter information from historical texts through a simple data entry form (Figure 3) and see the visualized connection live in a network. The students need

Figure 3. Nodes and edges entry form.

to first review and interpret the text and negotiate the options for recording a historical data point. As they negotiate, the node entry form guides students to consider historical categories for nodes that include person, group, event, or place. Second, students need to determine if the node can be associated with any other nodes. The edge form prompts students to look at the relationship between nodes by asking them to select from a pre-populated dropdown menu (e.g., "has martial or adversarial interaction with", "has peaceful, familial or conversational interaction with", "is a group member of", "makes visit to [a place]", "participates in [an event]"). These options invite students to clearly identify the type of relationships between nodes within the text. They are also encouraged to make their work verifiable by two other features in the edge entry form: a citation field and a significance field. The former means their source material will be readily available to other students engaged in the collaborative process; the latter asks them to be explicit about why they chose to record details and features of a specific edge. The process emphasizes disciplinary norms of citation and historical argumentation and encourages students to interpret and reflect on the historical significance for each detail while reading the text and collaboratively co-construct the historical connections among many possible entries.

Secondly, the tool provides live network visualizations with based on the most recent student input. As students engage in data entry, the tool will calculate the number of times two nodes appear in an edge relationship in order to visualize a “weight” through thickness that tells how strong the edge between two nodes should be (see Figure 1). As students input a new node or edge, instructor tools allow deletion, merging and editing of accidental duplicate entry and the network visualization will adjust to provide students with a clear view of the live network. The immediate effect in the tool can support students to understand the network as a whole rather than looking at the local network built by small groups. For instance, few historical agents in a historical context have no connections. Therefore, as students add new nodes, we can prompt students to draw on elements of the network visualization provided by other students as they determine whether they need to also add more historical context for that node based on the whole network. The network can serve as a reference point for the whole class discussion, leveraging the work of small collaboration groups to support connections only visible in the aggregate. Finally, the tool generates nodes and edges tables (see Figure 4) so that students can seek specific information while reading the text that wasn’t assigned previously and investigate multiple nodes, edges, significance, or citations in one place. In this unique way, the large lecture format that typically limits collaboration options can become a positive feature of the activity by leveraging the large collaborating group to support students in making sense of an entirely new text in a limited time with the small collaborating groups whose work fed back into a whole-class network.

Source	Target	Citation	Significance
Asacus	Neoptolemus		2.1
Neoptolemus	Alexander		2.1
Olympias	Philip		2.10
Olympias	Philip		2.10
Alexander	Syrmus		2.10
Demothenes	Alexander		2.10
Alexander	Diogenes of Sinope		2.14
Alexander	Istimus		2.14
Philip	Alexander		2.3
Olympias	Philip	Source is responsible for leading target project	2.3

Figure 4. Edges table.

## References

- Carrington, P. J., Scott, J. & Wasserman, S. (2005). *Models and Methods in Social Network Analysis*. New York: Cambridge University Press.
- Craig, K. (2017). Analog tools in digital history classrooms: An activity-theory case study of learning opportunities in digital humanities. *Intl Jrl for the Scholarship of Teaching and Learning*, 11(1), 1-9.
- Danish, J. A. (2014). Applying an Activity Theory Lens to Designing Instruction for Learning About the Structure, Behavior, and Function of a Honeybee System. *Journal of the Learning Sciences*, 23(2), 1-49.
- Dillenbourg P, Järvelä S, & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In: Balacheff N, Ludvigsen S, de Jong T, Lazonder A, Barnes S (Eds.) *Technology-enhanced learning* (3-19). Berlin: Springer.
- Drucker, J. (2014). *Graphesis: Visual forms of knowledge production*. Harvard University Press.
- Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki, Finland: Orienta-Konsultit Oy.
- Nickerson, J. V., Tversky, B., Corter, J. E., Yu, L., Rho, Y. J., & Mason, D. (2010). Thinking with networks. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 32, No. 32).
- Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of research in science teaching*, 41(10), 994-1020.
- Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Golan, R., Kyza, E., et al. (2002). *Evolving a scaffolding design framework for designing educational software*. IN P. Bell, R.
- Theibault, J. (2013). Visualizations and Historical Arguments. In Nawrotzki, K. & Dougherty, J (Eds.), *Writing History in the Digital Age (173–185)*. Ann Arbor: University of Michigan Press.
- Wineburg, S. S. (1991). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of educational Psychology*, 83(1), 73.

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# Supporting Collaborative Problem Solving in a Game-Based Learning Environment

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**Abstract:** In this Special Interactive Session demonstration, we present our story-centric game-based learning environment, CRYSTAL ISLAND: ECOJOURNEYS, to highlight how the design is informed by problem-based learning (PBL), a constructivist instructional approach driven by an inquiry framework. We present key features of CRYSTAL ISLAND: ECOJOURNEYS: 1) the interactive story, 2) the whiteboard, and 3) the collaboration scaffolds, and discuss trace data of student interactions as they engage in the story and contribute to the chat and whiteboard tool. In line with CSCL 2019's theme, our design of the game highlights a complex ecosystem that illuminates how aligning tools in the game and a social-constructivist approach to learning, while challenging, was instrumental in supporting student learning.

In problem-based learning (PBL), students work in small groups to address ill-structured problems, drawing on individual's, peers', and instructor's expertise. Game-based learning environments, especially those that feature rich narratives, have the potential to engage students in such problems and support the development of expertise. In line with CSCL 2019's theme of 4E learning, collaborative games provide a complex ecosystem that allow students to learn by doing (i.e., *embedded* learning) and to distribute cognition or *extend* expertise via scaffolds that both support and take on this expertise (Quintana et al., 2004). This, in turn, allows us to understand the *enactive* nature of learning. However, there are some tensions in designing collaborative games that draw upon PBL. One challenge is the relatively open-ended inquiry of PBL environments compared to the well-ordered yet complex problems in traditional games (Adams et al., 2012). Another challenge is how to support synchronous collaboration in the classroom and to augment facilitation through both agent-based and human-based scaffolds. Finally, there is also the issue of aligning tools in the game and our commitment to a social-constructivist approach to learning. How can we account for these epistemological commitments in our design of the tools in the game, such as the narrative or a virtual whiteboard? In this demonstration, we present CRYSTAL ISLAND: ECOJOURNEYS, and share how we addressed these tensions in our design. We highlight how designing for synchronous collaborative interactions can be supported by providing well-ordered interactions that align to the PBL inquiry cycle and provide agency by supporting negotiation in the problem-solving process. By integrating our design with principles of PBL, we were able to leverage advantages associated with the immersive, interactive and narrative nature of games coupled with a pedagogy that has consistently shown benefits for deep learning.

## Theoretical motivations

Problem-based learning is an instructional approach that has its origin in social-constructivist assumptions of learning, namely, the interactional nature of learning, cognitive puzzlement, and social negotiation (Savery and Duffy, 1995). A PBL classroom typically consists of students utilizing peer expertise and instructor facilitation as they work in small groups to solve problems (Hmelo-Silver, 2004). During the PBL process, students define and identify learning issues under the assistance of facilitators. To support inquiry, students often utilize a collaborative tool, a *PBL whiteboard*, that allows them to share ideas and track their progress. Facilitators and tools such as the whiteboard constrain and support students' inquiry and encourage students to take ownership of the learning process and develop solutions.

When designing a collaborative game-based learning environment, designers need to balance student agency, immersive inquiry, and the need for complex but relatively well-defined problems. This is especially salient in story-centric games that poses a 'narrative paradox' (Louchart & Aylett, 2003), which consists of maintaining authorial control over story development while providing players a sense of agency. However, challenges occur when leveraging PBL with game-based learning (GBL). First, while students' individual learning can be negatively influenced by an increased immersion in the narrative (Adams et al., 2012), we do not yet know the extent to which social regulation and collaboration can address this observation. Secondly, because of



documented beneficial outcomes associated with social-constructivist frameworks of learning, it is crucial to support the development of student content expertise in ways that might lead to successful and meaningful problem solving. Moreover, we had to attend to the nature of collaboration: what were the advantages and disadvantages of synchronous collaboration? Further, how can intelligent-based agents support collaboration and the teacher, as well as mitigate the issue of differential student progression as it relates to collaboration? Finally, designing for ill-defined problems also means attending to complex rules that underpin game mechanics, which lead to a delicate balance between the principles of constructivism such as providing agency yet maintaining pre-determined paths to support learning analytics and assessment.

## CRYSTAL ISLAND: ECOJOURNEYS

With these considerations in mind, we developed the CRYSTAL ISLAND: ECOJOURNEYS prototype learning environment, which allows for rapid development of collaborative problem-solving scenarios. In the prototype, students are presented with 2D representations of locations and characters as they progress through the story. Students participate in the story by navigating to locations, interacting with characters through branching dialogue, and completing activities related to the problem-solving scenario (Figure 1). The prototype environment collects fine-grain behavior logs of all student interactions within the environment. For example, trace data recorded by the environment includes information such as how long students spend on each task, which dialogue options were selected while interacting with characters, and whether students completed an activity.

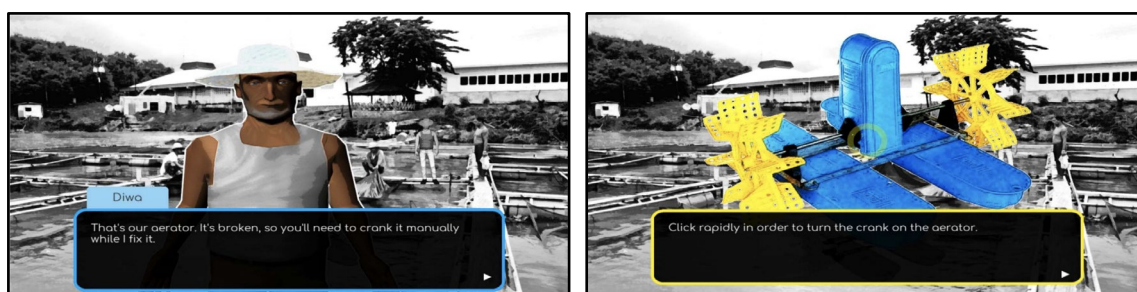


Figure 1. Interacting with character and objects in the prototype learning environment.

To include the PBL inquiry cycle in the design, the team focused on two elements: the narrative and a collaborative PBL whiteboard to support team development of hypotheses linked to evidence. Figure 2 provides an overview of student progression in CRYSTAL ISLAND: ECOJOURNEYS narrative and the interactions that they have through chat and the whiteboard. To ensure that students developed different expertise, we assigned students to interact with various stakeholders within the narrative who had different information to share. To ensure that students all had access to critical pieces of information, critical data was provided to at least two students (i.e., similar data sets and facts).

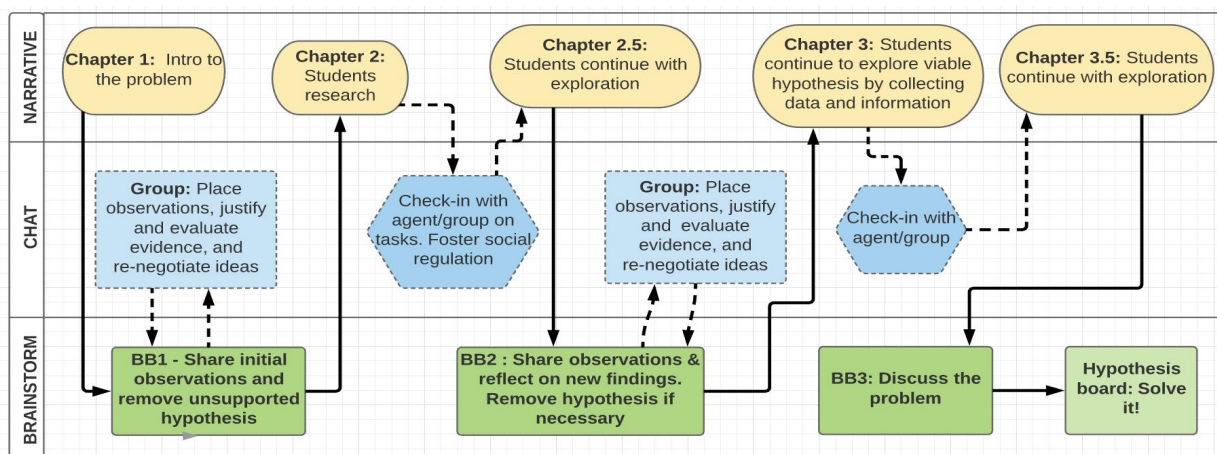


Figure 2. Overview of the narrative structure and activities in CRYSTAL ISLAND: ECOJOURNEYS.

To support students' progression through the narrative, the team also developed an in-game whiteboard (Figure 3). In the game, students interacted with a virtual whiteboard, which was designed to support the following interactions between a small group of students: 1) sharing information, 2) selecting which pieces of information could be used as evidence to support specific hypothesis, 3) evaluating the evidence by stating which pieces of evidence support, does not support, or might support a given hypothesis. These interactions were heavily shaped by the PBL inquiry process. To support sensemaking, we designed an agreement indicator. If all students in the group agree that the evidence supports a given hypothesis, the evidence will turn green. If a piece of evidence has not yet been evaluated, it remains orange, and if there is disagreement, it will turn red. Students must negotiate and resolve any disagreements related to the evidence using in-game chat. Similarly, students must also justify why the team agrees. After each round of data collection (i.e., end of each chapter as depicted in Figure 2), students decide if they should remove any hypotheses that do not have supporting evidence.

It should be noted that the design of the whiteboard took several iterations; we conducted a series of focus group studies and small classroom pilot studies to understand the nature of student interactions with the whiteboard for over a year. In the first iteration, the whiteboard tasked students with generating an explanation by creating a model. In that version, students utilized the Phenomenon-Mechanism-Component framework (Hmelo-Silver, Jordan, Eberbach & Sinha, 2017). This meant that the focus of collaboration was around the content rather than the process of knowledge building. From these studies, we found that students could develop their models but needed a lot support in managing the process of creating the model.

Because the process of inquiry is critical in PBL, we then shifted to using a KWL chart (Know, Want to Know and Learned; Ogle, 1986) in a subsequent classroom study. In this iteration, we also examined how a human facilitator can support student interactions in the chat interface especially as they sort through information and attempt to solve the problem when using the whiteboard. Based on the findings from the classroom study, we sought to support the process at the whiteboard by integrating the PBL steps as part of the whiteboarding experience (i.e., share, discriminate, evaluate, and negotiate). In hindsight, our initial challenge was the lack of alignment in the development of the whiteboard (i.e., model-building rather than integrating the inquiry process). Thus, in our work, one advantage of integrating the PBL inquiry process into the whiteboard was that the current whiteboard design supported collaboration, managed group regulation and provided agency.

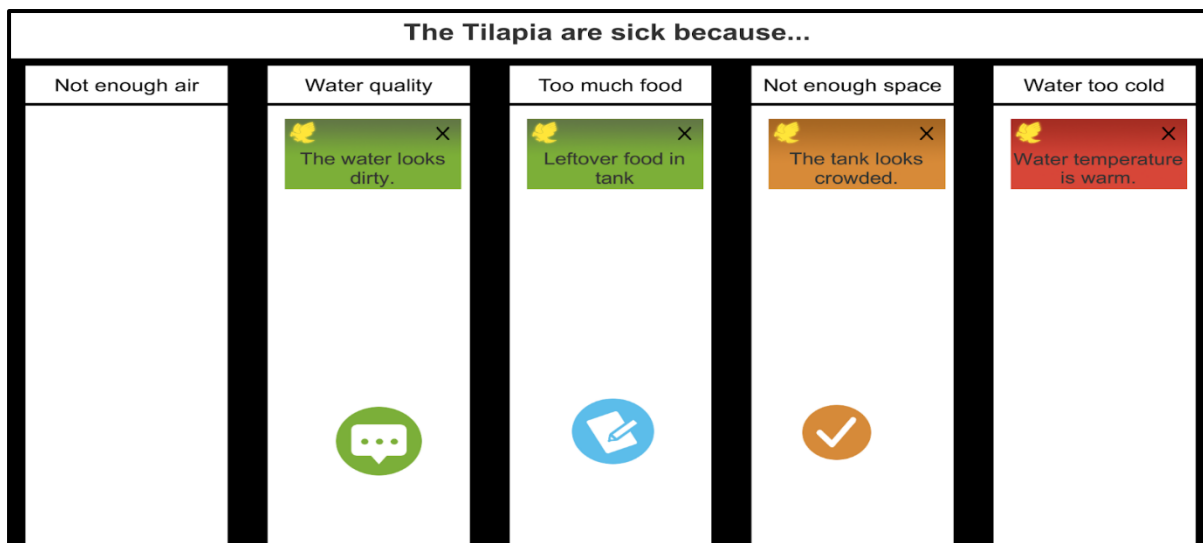


Figure 3. An overview of game features; the whiteboard, chat (green chat icon), student notebook (blue journal icon), and the task list (checkmark icon).

Our approach towards designing the game by supporting agency when using the whiteboard is different than story-centric games. In story-centric games, the focus is to provide players with agency by authoring the narrative in such a way that players' choices have consequences. Our approach was to ensure that students have access to the information that they need in the story, but otherwise allow them freedom to make mistakes as they evaluate different hypotheses when using the whiteboard. As students progress in the relatively linear story, the game does not provide students with any hints about the correct answer. Instead, there are prompts asking students to depend on their peers, by regulating and managing the group goals and learning outcomes. However, it is also critical to note that the game currently tracks students' problem-solving behaviors through trace data, and provide

updates about student collaboration and learning progress via a teacher dashboard that is currently under development. The team is currently in the process of creating the teacher dashboard and hope that the interactive session will allow us to solicit feedback on its design.

Another important element that we have attended to in our design is the attention to the nature of facilitation. In adaptive collaborative learning systems, the focus is to scaffold individual students as they complete tasks. In our design, we extend this system to include the classroom ecology. Although we will be gathering facilitation data to eventually train an automated agent to support collaboration, we also designed specific participant structures in the classroom to provide more support for teachers and students. We adopt a jigsaw approach, wherein students have access to two groups, 1) an expert group in a physical setting and 2) work online with their in-game team. The in-game team consists of students who have met different in-game characters. On the other hand, the expert groups provide additional opportunities for students to engage in group regulation processes and to support them in the fact-finding process. Similar to the brainstorming board interactions, these groups are not explicitly constrained but are instead asked to make sure that students support each other as needed.

## Significance

Our work highlights how we embedded the PBL inquiry cycle into two game elements, the narrative and in-game whiteboard. Because of the value of synchronous interactions in the PBL process, we ensured that progression through the narrative would not hamper students' collaboration at the whiteboard. Specifically, students are encouraged to review the tasks via their task checklist and support re-distribution of tasks as necessary. Moreover, based on our recent data collection, the PBL-inquiry steps that students undertake at the whiteboard also supported students' process management and more importantly, productive discussions without constraining their agency. While there were challenges in designing these interactions, our commitment to PBL, a social-constructivist approach to learning ultimately helped shaped the nature of students' collaborative problem-solving in productive ways.

## Technology platforms supported

Given that CRYSTAL ISLAND: ECOJOURNEYS is delivered through the web and designed to be played in a web browser, we will only need Internet access through a wi-fi access point to demonstrate the game on between 2 to 6 laptops. Further, CRYSTAL ISLAND: ECOJOURNEYS is designed to support wide range of computers, such as Chromebooks, which mean that conference participants can use their own laptops to play the game.

## References

- Adams, D. M., Mayer, R. E., MacNamara, A., Koenig, A., & Wainess, R. (2012). Narrative games for learning: Testing the discovery and narrative hypotheses. *Journal of educational psychology*, 104(1), 235.
- Gee, J. P. (2005, June). Good video games and good learning. In *Phi Kappa Phi Forum* (Vol. 85, No. 2, p. 33). The Honor Society of Phi Kappa Phi.
- Hmelo-Silver, C.E. (2004). Problem-based learning: What and how do students learn? *Educational psychology review*, 16(3), 235-266.
- Hmelo-Silver, C. E., Jordan, R., Eberbach, C., & Sinha, S. (2017). Systems learning with a conceptual representation: a quasi-experimental study. *Instructional Science*, 45(1), 53-72.
- Louchart, S., & Aylett, R. (2003, September). Solving the narrative paradox in VEs—lessons from RPGs. In *International Workshop on Intelligent Virtual Agents* (pp. 244-248). Springer, Berlin, Heidelberg.
- Ogle, D. M. (1986). KWL: A teaching model that develops active reading of expository text. *The Reading teacher*, 39(6), 564-570
- Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., ... & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the learning sciences*, 13(3), 337-386.

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# **Workshops**



## EPCAL: Studying Synchronous Online Collaboration at Scale

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Collaborative problem solving (CPS) is widely accepted as an important 21<sup>st</sup> century skill (Fiore et al., 2017; Griffin, McGaw, & Care, 2012; OECD, 2013; World Economic Forum, 2015). Compute-supported collaboration has made large-scale collaboration possible in the real world and is playing an increasingly important role in academia and the workplace (Stahl, Koschmann, & Suthers, 2006). However, studying the synchronous computer-supported collaboration at scale requires significant technological infrastructure to enable the collaboration and to record the collaboration process data. To carry out studies efficiently, one needs far more than what a communication tool such as Skype or an online meeting tool such as Zoom can provide. For example, to manipulate the team assembly, one needs a participant and team management system to form teams under specific rules. To have participants progress at the same pace, one needs a mechanism to synchronize the progress of each participant. To identify evidence of the skills, one needs all the response and communication data captured and aggregated for further analysis. To provide appropriate scaffolding, one needs a mechanism to send feedback to an ongoing collaborative activity.

Educational Testing Service (ETS) has made a major investment in developing a web-based platform, ETS platform for collaborative assessment and learning (EPCAL, Hao, et al, 2017) to support research studies on computer-supported collaboration. The EPCAL allows multimodal communication, team management, modularized item/task uploading, customizable real-time facilitation/intervention, and captures all the process data during the collaboration. Most importantly, it is integrated with powerful data analytics support from ETS's glassPy data analytics solution (Hao, Smith, Mislevy, von Davier, & Bauer, 2016). All these features make it an ideal tool for computer-supported collaborative research at scale. It is worth noting that the platform is not a commercial product at this stage, but more a research tool that ETS would like to share with the research community for collaboration.

We organized a similar workshop at CSCL 2017 and received tremendous enthusiasm from peer researchers. It also fostered collaborations that lead to several joint submissions of research proposals. Now, we are organizing a workshop at CSCL 2019 again, with our fully upgraded EPCAL platform and a variety of task prototypes in different domains. In particular, we encourage participants to bring in their thoughts and share their own research with other participants. Participants will team up in dyads or triads to work on various collaborative assessment prototypes developed at ETS, by which we want participants to have hands-on experience of using the platform to scale up their studies in future. We will facilitate discussions on common challenges and solutions regarding designing collaborative learning and assessment environments and how the EPCAL platform can be used to support various needs of such designs. The planned activities include the following:

- EPCAL platform, its data analytics and AI-based components
- Example of collaborative prototypes on the EPCAL platform
- Participants will team up into dyads or triads to complete tasks hosted on the EPCAL
- Presentations from participants about their relevant research
  - We planned several slots for participants to introduce their relevant research to other participants.
  - Please respond the form below and we will contact you regarding the arrangement after have a count of the presentations
- Discussions

In the discussion portion of the workshop, we will discuss how EPCAL can help to scale up the research on collaborative learning and assessment and we strongly encourage new ideas and potential collaborations among the participants.

## Experiencing and Analysing Embodied Design Thinking in CSCL

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This pre-conference workshop aims to engage researchers, designers, and practitioners in a design thinking process and then to analyse the workshop activities and solutions using the 4Es of embodied learning.

If you were working with others at a distance on a design problem, what would you need in your digital workspace? Taking this complex challenge as our starting point, we invite you to join us in working through each phase of a design thinking process, learning more about design thinking at each stage of the workshop, and reflecting on how our learning is embodied in artefacts and other representations. These data will be made available for collaborative analysis during and after the workshop, so that workshop participants and presenters can develop research questions of shared interest and jointly author a publication.

We welcome participants from diverse backgrounds to bring a rich variety of theoretical standpoints, workplace experiences and contexts to the “empathy” phase of the design process. If you are interested in design thinking, participatory design, creativity, wicked problems, or the affordances of digitally mediated learning environments for innovative learning strategies, this is the workshop for you.

# Theories and Methods for Researching Interdisciplinary Learning

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We invite you to join us for a full-day workshop “*Theories and methods for researching interdisciplinary learning*” which will take place before the CSCL 2019 conference, on Monday the 17<sup>th</sup> of June 2019. Interdisciplinary learning (IDL) has become widespread in schools, universities, workplaces, and diverse R&D settings. However, it is a highly challenging and dispersed field of CSCL research. This workshop aims to create a more holistic picture of this research field by creating opportunities for CSCL scholars to share their theoretical and methodological tools and practices. Our aim is to establish an agenda for synthesizing the IDL research done by the CSCL community, and to create an integrated theoretical and methodological toolkit that could be shared with other researchers, designers and practitioners (in the form of a special journal issue and the IDL research network). The purpose is to assist scholars in the IDL field to conceptualize and study IDL practices more holistically and robustly. We expect that this will also assist IDL designers and practitioners to design more productive IDL environments and facilitate IDL more effectively.

We invite researchers, designers and other practitioners interested in the following broad research themes:

1. **Concepts and theories:** How do we conceptualize IDL? How do we delineate the scope of IDL and its relationships with other intersecting areas? What are our main objects of investigation? What kinds of theoretical approaches do we use for framing IDL research?
2. **Research methods:** What kinds of methodologies and analytical tools do we use for studying IDL? What kinds of analytical issues do we face? How do we assess IDL processes and outcomes? How do we take into account the extended, embodied, and enacted nature of interdisciplinary work?
3. **Pedagogies and design:** What are the key pedagogical approaches for teaching interdisciplinarity? What are the main design principles for designing IDL environments and courses?
4. **Empirical cases:** What kinds of empirical work is done by the CSCL community developing and investigating IDL? What does it say to us? What kinds of challenges does it reveal?

We welcome different types of contributions ranging from initial ideas, to work in progress, to mature and finished projects. We are looking forward to contributions that have origins in diverse disciplinary perspectives: anthropology, science and technology studies (STS), cognitive science, organizational science, linguistics, design, computer and data science, learning sciences, etc.

## Designing Embedded Phenomena

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Contemporary technologies have the power to transform the physical space of classrooms into interactive spaces in which classroom communities engage in sustained, collective inquiry. In the “embedded phenomena” genre, simulated phenomena are scaled and mapped to classroom space and made accessible through stationary and mobile devices that serve as local portals through which learners interact with and collaboratively construct models of those phenomena to solve problems or address driving questions. In this workshop, participants will engage in design charrettes to envision new phenomena amenable to representation within the genre, and collectively address the theoretical and pragmatic issues surround the design and use of embedded phenomena in learning environments. Through this work, we seek to better understand the affordances and limitations of the embedded phenomena approach, and to engage the CSCL community more broadly in development of the genre.

We invite participation from across the CSCL community, including designers, researchers, and classroom practitioners. We particularly encourage applications attendees who may have an interest in building and using embedded phenomena in their research or practice, and with whom we can share our experiences and resources to help make that happen. We also welcome those with an interest in understanding the potential and limitations of embedded phenomena for creating supportive environments for learning and teaching. The workshop will provide participants with an opportunity to engage in a short collective inquiry activity using an embedded phenomena, to work with others in small groups to envision and prototype new embedded phenomena and learning activities, and to collectively identify research and enactment issues surrounding embedded phenomena within the trajectory of ongoing work of our community.

# Posthumanist Perspectives on Learning

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Where the learning sciences have a long-standing emphasis on tools and materials as important for the study of learning, recent material turn across literacy, early childhood, discourse, and mathematics education studies suggests paradigmatic shifts in how we approach research on learning. To advance our understanding of how these shifts can help uncover ongoing learning and collaborative processes, essential work is needed to clearly articulate the implications of posthuman and materialist views of learning for the learning sciences and CSCL community. To initiate this conversation, this workshop is organized around three themes: (a) reconsidering relationships between humans and the material world, (b) exploring methodological and theoretical implications, and (c) probing how materials shape learning and participation in ways that have been undertheorized in the learning sciences to date.

This full-day workshop seeks to reconsider the relationship between the human and the material world, explore methodological and theoretical implications, and the implications for how materials shape both learning and participation in ways that have been undertheorized to date in the learning sciences. The workshop is organized around three main themes with focal questions that we intend to explore in the workshop:

- Theory: How can we reconcile posthuman and materialist approaches with key concepts in education, including learning, collaboration, development, and agency? How do we leverage skepticism to advance our understandings of posthuman and materialist perspectives on learning? How do these approaches resonate and extend distributed cognition and embodied/situative approaches to learning in CSCL and the learning sciences?
- Methods: How do we capture and analyze onto-epistemological approaches to learning and development, including intra-action as well as broader repetition and transformation patterns that influence the learning process? How can new technological advances for capturing movement of sound, heat cameras, and other machine-readable data points capture learning processes and advance our understanding of the same?
- Design: What would designing within posthuman education look like and what does this mean for the conceptual understanding of design principles? What approaches to child-nature relations can support a holistic understanding of the onto-epistemological nature of learning and development?

# Theorizing and Analyzing Productive Disciplinary Engagement as a Collaborative Phenomenon

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This pre-conference workshop aims to introduce and subsequently apply a multi-dimensional theoretical framework and rubric for evaluating group-level engagement quality observed during collaborative activity. We draw on Engle and Conant's (2002) *productive disciplinary engagement* (PDE), defined as making collective intellectual progress related to core ideas and disciplinary practices during authentic tasks, but extend it to account for engagement in collaborative groups. Evaluating the quality with which students jointly engage is interrelated with their learning of core disciplinary content and practices in STEM. Furthermore, examining group engagement during STEM disciplinary activity is essential for assessing whether students are meeting goals set by national standards documents and instructional design. Participants will be actively involved in applying the rubric to observational data. Through workshop activities, participants will further their understanding and contribute to the developing conversation about the study of disciplinary engagement that moves CSCL research forward, and ultimately informs curriculum design principles.

Come spend the day doing interactive analysis of CSCL collaboration data! The goal of this full-day CSCL workshop is to become familiar with and then apply a rubric for evaluating the quality of group-level engagement observed during collaborative activity. We conceptualize engagement drawing on Engle and Conant's (2002) *productive disciplinary engagement* (PDE), as making collective intellectual progress related to core ideas and disciplinary practices during authentic tasks, but extended to account for engagement in collaborative groups. Evaluating the quality with which students jointly engage is interrelated with their learning of core disciplinary content and practices in STEM. Furthermore, examining group engagement during science, mathematics, and engineering classroom activity, among other disciplines, is essential for assessing whether students are meeting goals of national standards documents, curriculum, or other interventions involving group work.

Following theoretical introduction and rubric training, participants will be actively involved in applying the rubric to data (e.g., video data, transcripts, asynchronous discussion). In addition, participants can choose to code their own data or data shared by other workshop participants and/or co-organizers. The data to be made available from the co-organizers involves middle schoolers collaborating during STEM curricular units. Through workshop activities and discussion, participants will further their understanding of disciplinary engagement, and contribute to the developing conversation about the study of disciplinary engagement that moves CSCL research forward, and ultimately informs curriculum design principles.



# Making the Learning Sciences Count: Impacting Association for Computing Machinery Communities in Human-Computer Interaction

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At CSCL 2013, a workshop proposed that a relationship develop between the learning sciences (LS) and human-computer interaction (HCI). In the past six years, growth has been occurring in the Association of Computing Machinery (ACM) conferences in HCI. Flagship conferences such as Computer-Human Interaction (CHI), Computer-Supported Collaborative Work (CSCW), and Interaction Design and Children (IDC) all have seen integration and participation of LS researchers into leadership and community positions. We believe it is time to evaluate this growth, but also to explore, challenge, and critique the development between LS/CSCL and the ACM conferences in HCI. This workshop focuses on the interdisciplinary examination between the norms, expectations, goals, and awareness of the two communities. We intend to extend the CSCL 2013 workshop by reflecting on this past growth, exploring present awareness of the two communities, and setting up future goals, such as developing effective strategies for publications and participation in both fields.

Our workshop will be a full day event with an agenda that focuses on building community among scholars that bridge LS and HCI. The intended audience is learning scientists and computer-supported collaborative learning researchers who are interested in making an impact in Association for Computing Machinery (ACM) communities and conferences in HCI, such as CHI, Computer-Supported Collaborative Work (CSCW), Interaction Design and Children (IDC), International Computing Education Research (ICER), and Ubiquitous Computing (UbiComp), CHIPlay, and others that complement the learning sciences.

The workshop will begin with participants brainstorming potential ACM and learning focused research communities and venues, comparing and contrasting complementary and/or conflicting goals, values, and disciplinary affiliations across the two communities, writ large. Participants will ideate on these results through participatory design activities such as storyboarding design fictions and card-sorting to identify options for increasing awareness and presence between the two communities. Our focus will be on taking concrete steps toward more seamless interdisciplinary dialogue. For example, a special issue on LS and HCI in the ACM Communications magazine may be an initial step for highlighting LS work to the HCI community.

A critical component of our conversation will address publication expectations and processes followed in the ACM and learning sciences and how best to publish in both communities. We will spend time breaking down how some HCI learning papers are written, examine the review process (all authors have been Associate Chairs at CHI and IDC; June Ahn has been a Papers Chair at CHI), and highlight similarities and differences between a LS / CSCL paper and an ACM paper in HCI.

Our final workshop activity will catalog HCI design practices, research methods, and pedagogy that might benefit from LS theory and insights. To bring these opportunities to light we will brainstorm learning theories (i.e. zones of proximal development, transfer, or scaffolding) and design practices, research methods and learning goals in HCI classes, then use a matching activity to pinpoint future opportunities for LS to inform HCI.

## Creating, Refining, and Validating Automated Discourse Codes: An Introduction to nCoder and Rho

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Creating, Refining, and Validating Automated Discourse Codes is an interactive CSCL 2019 half-day pre-conference workshop where participants will work together to analyze *their own data* using the nCoder and rho toolkits.

The goals of the workshop are for each participant to:

1. Understand how to combine qualitative and quantitative perspectives for text analysis and use two key tools for conducting such analyses,
2. Create codebooks for code validation and publication,
3. Develop, test, and validate automated classifiers to code text data, and
4. Find a meaningful result from their own data that they can refine in future work, ideally leading to the publication of a special issue on current approaches to automated text analyses.

This workshop will provide an overview of the methodology and hands-on experience with two tools:

1. *nCoder*, which helps researchers develop, refine, and validate automated coding schemes, and
2. *Rho*, a statistical method for establishing the generalizability of inter-rater reliability metrics.

This is a data-intensive workshop where you get to develop codes for your own data, and discuss your process and results with other participants and with experts in automated data analysis.

The workshop will first introduce you to the theoretical background of these methods. Afterward, you will work in small groups with other participants to analyze your own data or sample data using nCoder and rho; workshop organizers will be on hand to answer any questions and assist with analyses. The workshop will culminate in each group presenting one result of their analyses to the rest of the participants.

# Creating Common Ground for Teaching Designs in Learning Sciences Programs: Building on CSCL Research and Practice

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Are you interested in teaching the Learning Sciences in PhD or Master's degree programs? Do you have expertise in research and pedagogies in the area of Computer-Supported Collaborative Learning? In this workshop we would like to bring together the aspirations to shape teaching of the Learning Sciences in the future and the latest developments and research outcomes in the field of CSCL. We particularly invite academics from Learning Sciences programs that are or are planning to become NAPLeS members. We also wish to encourage everyone from the CSCL community who is interested in shaping pedagogies for teaching the Learning Sciences to participate in this workshop. Throughout the workshop we will exchange content and pedagogies currently used in the participating Learning Sciences programs, discuss how to design the teaching of the Learning Sciences utilizing current innovations from CSCL research, and finally collect ideas about how NAPLeS can support future exchange of innovative pedagogies between Learning Sciences programs.

The proposed workshop intends to strengthen the exchange between academics involved in the organization and teaching of academic Master's and PhD programs in the Learning Sciences from different universities and countries. The main goal of the workshop will be to identify how CSCL practices can be designed to teach the Learning Sciences in their programs and across different programs, starting point with the CSCL the workshop organizers and participants can contribute. In addition, the workshop aims to provide an arena for discussing how the NAPLeS network can serve the needs of academic Learning Sciences programs to maintain exchange and realize innovative pedagogies for learning in the future. Particularly, the participants will introduce their programs and specific thematic areas addressed in their programs, will discuss commonalities and differences of the various pedagogies, and will identify areas for potential joint endeavors. The workshop will be concluded by listing future learning design activities for which NAPLeS can support its members to be engaged in and benefit from.

1. The first 60 minutes of the workshop will be dedicated to the presentation by the workshop participants of the content and the pedagogies in their respective programs. Depending on the number of participants, each participant will have up to five minutes to present content and pedagogies of their program;
2. In the second part, for about 120 minutes, small special interest groups will be formed of participants from different programs and will brainstorm on latest innovations from CSCL research and how these could be implemented to teach the Learning Sciences within and across different programs;
3. In the last 60 minutes, we will discuss about what NAPLeS can do to support the implementation of CSCL pedagogies in joint teaching endeavors. We will further discuss how NAPLeS can facilitate the exchange of content and pedagogies, joint teaching and learning, working on teaching innovations, or facilitating scholarly visits between Learning Sciences programs.

## International Workshop on Collaboration Analytics: Making Learning Visible in Collaborative Settings

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We use the term *collaboration analytics* to refer to methods for collecting and analysing multiple sources of evidence from collaborative settings with the purpose of i) generating a deeper understanding of collaboration and learning; or ii) supporting learning and the development of collaboration skills by making key traces of activity visible to learners and their instructors or available to computational analysis.

This half-a-day workshop brings together researchers and practitioners from different disciplines to discuss the breadth and depth of the emerging concept of collaboration analytics.

The goal of this workshop is to build upon the promising sensing technologies, collaborative tools and emerging data analytics techniques to address the need for tools that provide automated assessment and feedback on group activities. The workshop targets both *remote* and *collocated* CSCL situations focusing on the shared complexity of human activity and its environment, looking particularly at the major role that data can play to enhance evidence-based reflective practices in CSCL teaching and learning.

# Understanding New Assessment and Environment for Knowledge Building: Triangulating Features of Discourse Platform, Multimodal Learning Analytics and Text-based Learning Analytics

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This workshop aims to engage participants in discussing and deriving the problem-space surrounding assessment and environment for knowledge building. The problem-space aims to map the types of data (text-based and multimodal data), hypotheses of the learning attributes (visible and invisible) to be derived from these data, and the related annotation and coding specific to the 21st Century Competencies of communication and collaboration skill. The discussion will revolve around different collaborative scenario in a knowledge building classroom, e.g. knowledge building talk, small group discussion with or without computers.

The workshop will first acquaint participants with a number of innovative design of KB environment, as well as text-based and multimodal learning analytics already in progress but the team will also focus on challenges yet to be met. Participants will then work (in groups) on different sets of collaborative scenario to generate possible hypotheses afforded by the multimodal data to surface different learning attributes of students, along with suggested coding and annotation.

Over the years, knowledge building research and innovation have endeavoured to change the teaching landscape, providing theories, models and technology to shift from teacher-centric to student-centric and idea-centric practices. The on-going adoption of knowledge building by schools across different continents is motivated by the need to engage students in knowledge creation practices. Knowledge building is a well-established field in education research, and the advocacy of knowledge building continues to gain momentum. However, it has often been termed as one of the most different learning sciences theory to tackle in practice.

A principled-based solution of multimodal learning analytics (MMLA) that teachers can easily access to support their design of the environment and assess along with feedback mechanism conducive to the enactment idea-centric pedagogy is the critical piece of scaling and sustaining knowledge building practice in schools. Toward this end this half-day design workshop is proposed to inform the design of such MMLA solution. It is essential to continue to explore how advanced digital technologies and LA can mitigate the relationship between epistemic practice and interaction pattern between students in order to reinforce productive collaboration patterns.

The goal of this workshop is to produce a classification table of the problem spaces framed onto a developmental trajectory to distinguish between different types of collaborative practice in school. This problem-space table attempts to explain the following: (i) classroom collaborative practice; (ii) the design features of online discussion forum; and finally (iii) the design and adaptation of text-based and multimodal learning analytics.

More importantly, we hope to brainstorm on a robust feedback mechanism that can be adopted in class through the understanding of the annotation and coding mode in the problem-spaces classification table. Such holistic understanding will be useful in supporting teachers in the facilitation of online and face-to-face knowledge building environment focusing on emerging ideas, leading to a better characterization of teachers' design practice to inform professional development.

The workshop is designed to engage interested participants in exploring these problem spaces and figuring how the implementation of MMLA in authentic classroom settings. Please fill in the survey so that workshop organizers can fine-tune the workshop in line with interests and talents of participants.

The expected outcomes of this workshop will be a draft problem spaces classification table with design features that can be integrated into classroom. We also hope to establish a working groups to continue to advance the objectives set out in these workshop, even after the workshop.

The workshop will proceed in 3 phases.

- Phase 1: Introduction and orientation. The organizers will present an overview of the present state of design and research on knowledge building environment and assessment through multimodal and text-based analytics. The major challenges for these initiatives as research and practice will also be discussed.
- Phase 2: Work, in groups, on unpacking different collaborative scenario, working through the data types, the hypotheses of how these data can inform 21<sup>st</sup> century collaborative and communication competencies, formulating the problem spaces classification able.
- Phase 3: Group report on discussions, clarify the problem spaces, propose design solutions, and outlines future work needed to consolidate the proposed solution.

## Publishing in the Learning Sciences: A Journal Writers' Workshop

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Editors and Fellows of ISLS will conduct a half-day workshop that fosters a writing culture among a cohort of learning scientists. Selected participants must be actively working on a manuscript poised for submission to an ISLS journal, and lacking the appropriate mentoring resources. The workshop activities address general journal writing tips and review process information, as well as one-on-one and small group time spent between participants and their mentors focused on participants' specific writing projects. Outcomes include participation in a journal writers' support network and a mentoring relationship that can extend beyond the conference.

Although ISLS is an international society, which holds its annual conferences in countries around the world, there are very few international or non-native English-speaking scholars published in ISLS journals. There are several reasons for why this situation has persisted. First, relative to the membership, there are comparatively few manuscripts submitted from regions in which English is not the academic language. Second, the manuscripts that are submitted from these regions often do not follow the norms and standards of high quality academic writing that are required to be published in ISLS journals. Third, in many cases, we know that scholars in these regions do not have access to mentors and research environments that can support their writing.

A powerful technique used by English as a Second Language (ESL) adults learning to improve their writing is collaborative writing (Storch, 2005). Those working in pairs produced texts that were more concise, had fewer grammatical errors, and better matched the task goals. Several processes in the collaboration contributed to this, including more frequent and useful feedback by their writing partner and the opportunity to pool relevant ideas together to improve the document.

## **Mid-Career Workshop: Empowering Women in the Learning Sciences**

### **New Format, New Mission**

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The 2019 Mid-Career Workshop has refocused its conference-related activities to serve as community-building opportunity for those who have achieved tenure or a related professional milestone (e.g., learning scientists with positions in industry, non-profits, museums, and other learning-oriented organizations). Organized and facilitated by senior scholars, this pre-conference session will cover a diverse array of topics of concern to the mid-career community in parallel break-out sessions of approximately 30 minutes each. Participants can rotate through multiple break-out sessions.

The parallel break-outs cover issues mid-career members typically encounter, including the following:

- navigating post tenure responsibilities and opportunities, balancing work and life
- identifying and evaluating leadership opportunities and surviving these roles
- learning to delegate
- engaging in effective self-promotion
- managing interpersonal relationships in academia (“Me too” in the academy)/ supporting colleagues and students/ making oneself heard
- surviving the publication process
- managing preconceived beliefs about who “belongs” in the community

The specific topics will be tailored to those of greatest concern to the workshop attendees.

At the workshop we will be introducing a new initiative: The Mid-Career One-to-One Mentoring Program, a post-conference activity to meet the individual needs of ISLS’s Mid-Career members on an ongoing basis.



# **Early Career Workshop**



# CSCL 2019 Early Career Workshop

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## Summary

The purpose of the CSCL Early Career Workshop is to provide a high quality learning and networking opportunity for early career researchers doing work related to computer-supported collaborative learning and the learning sciences. Within the workshop, participants will share their research with peers and experienced CSCL researchers serving as mentors. Participants will engage in collaborative inquiry and scholarly discourse to improve their research work and prepare for a future career as a CSCL / Learning Sciences researcher. 13 Early Career Scholars were chosen through a competitive application process for participation.

## Objectives and Design

The workshop aims at supporting participants in:

- Defining innovative and productive programs of research that lead toward an impressive record of inquiry;
- Focusing learning on high-yield professional activities such as grant-writing, peer editing, and building a publishing trajectory;
- Supporting strong data analysis skills and evidence-based arguments in their research projects; and
- Expanding the professional networks of workshop participants through interactions with other early career scholars, mentors, and journal editors

The CSCL Early Career Workshop will involve a two-day event on June 17-18, 2019, just prior to the 2019 CSCL conference in Lyon, France. In the workshop, we will focus on collaborative inquiry and scholarly discourse with peers and a panel of experienced faculty serving as mentors. Main workshop activities include:

1. Sharing and discussing current research with peers and mentors.
2. Small group career path consultancies with peers and mentors
3. Meeting with Journal Editors to discuss the writing and reviewing process in Learning Sciences journals including JLS and ijCSCL.
4. Opportunities for group and individual consultation and networking between Early Career Scholars as well as with Doctoral Consortium Scholars and senior colleagues.

# An Embodied Conjecture Approach Towards Designing Games Using Problem-based Learning

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**Abstract:** While problem-based learning (PBL) is an effective instructional approach, it is unclear how to translate its principles into a game-based learning environment. Additionally, it is also necessary to balance several factors when designing games using PBL, such as group regulation, agency, motivation and content learning. To address these issues, the paper utilizes Sandoval's (2014) conjecture mapping to articulate how the design of branching narratives and a whiteboard tool fosters agency and in turn, support group regulation and learning.

Problem-based learning (PBL) is an instructional approach that engages students in ill-defined problems and supports them in the process of collaborative inquiry by developing individual expertise and providing just-in-time expert facilitation (Hmelo-Silver, 2004). As complex learning environments, narrative-rich games complement PBL by similarly engaging learners in well-defined problems while also providing free choice. Taken together, principles of PBL can scaffold collaboration to help students deal with the complex learning issues embedded in a game environment. When integrating PBL with narrative games, several challenges arise. First, it is necessary to support group regulation processes as part of the PBL cycle while maintaining a sense of agency and motivation. Secondly, designing rich narratives for the game must promote interest without compromising individual learning outcomes (Adams et al., 2012). With these considerations in mind, the paper utilizes Sandoval's (2014) conjecture mapping to articulate our hypotheses for how we designed PBL in the context of a narrative game, *Crystal Island: Eco Journeys*.

## Conjecture mapping and problem-based learning

Conjecture mapping (Sandoval, 2014) involves empirically validated assumptions that are derived from literature. In the case of the current design, these conjectures are based on the PBL literature and are designed in such a way that they can be empirically tested and refined. Here, I highlight elements of the PBL process and later, articulate how these principles are instantiated in the design. The PBL process includes 1) problem identification and fact finding, 2) hypothesis generation, 3) identifying knowledge gaps, 4) engaging in self-directed learning and 5) applying facts and evaluation of current understanding (Hmelo-Silver, 2004). While this process appears linear, it is more dynamic and iterative in nature. In the problem-identification step, each student can focus on specific learning issues, which then support the development of their expertise in the content area of choice. In a typical PBL process, students also use a whiteboard to regulate their learning. In the context of collaborative games, supporting collaboration means scaffolding socially shared regulation of learning (Hadwin, Järvelä & Miller, 2011). In both PBL and the socially shared regulation literature, the differentiation of roles in relation to a socially shared goal or problem and regulatory processes in learning were critical in ensuring productive collaboration.

## Development of the design

While designing for learning is often a key element in educational design, the project's focus was to support students in group regulation and collaboration. However, before we could even begin to embody our design for the game, we had to first refine our understanding about two key elements. First, the team focused on the development of the game narrative, especially as it pertains to the characters and setting (i.e., the problem, location). This was because we had to ensure that the problem-based narrative was engaging to students and remained rooted in a real-world context (Savery & Duffy, 1995). Additionally, given that the aim of PBL was the development of expertise among students, the team adopted a multi-perspective approach to the narrative. Four different but interdependent narrative paths were designed so that each student in group could engage in the problem from unique perspectives. This in turn, allowed each student to be an expert in their own right. Secondly, the team attended to the nature of students' collaboration as they used a whiteboard tool to problem-solve. The team focused on design efforts on the whiteboard tool since it is a tool in PBL used to help students share ideas and regulate their learning. In conjunction with the use of chat in the game, students negotiate their ideas and decide which hypotheses are worth pursuing when using the whiteboard. Thus, our high-level conjecture was that successful group regulation depended on the development of expertise in the group and awareness of group goals (figure 1).

Due to space constraints, I will only highlight the first year's iteration since it allowed us to attend to the high-level design issues. Six focus group studies were conducted with 6th grade students (N=19) over the course of six months to refine the initial design (Saleh et al., 2018a). In this instantiation of the shared whiteboard, students were using a modeling tool that allowed them to represent the relationships among components and mechanisms of a system, and use corroborating evidence to support their explanations. Three groups of students used a digital whiteboard to model while another three used pen and paper to model their explanations.

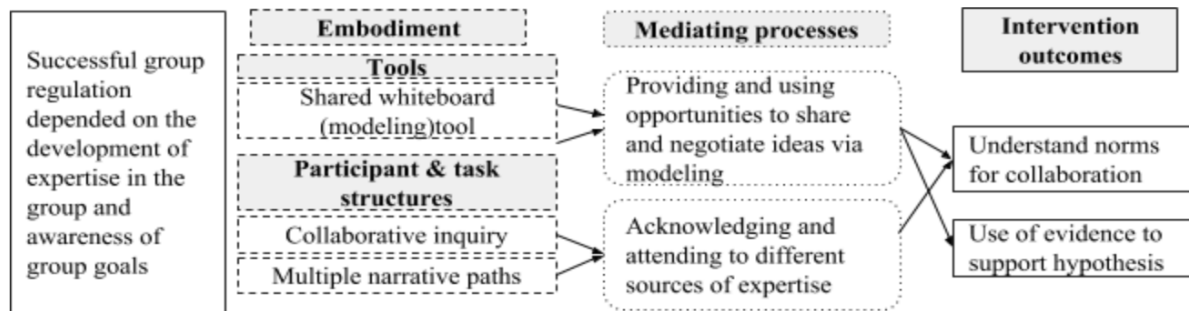


Figure 1. Initial embodied conjecture.

We found that students who participated across multiple focus groups took on more leadership roles, helped managed the group goals and often kept the group on task, especially in the face to face interactions. When using the digital modeling tool, students did not use chat to either engage in shared understanding of the task or negotiate group regulation strategies. Instead, students performed parallel work that was often duplicative of their peer's efforts. Thus, a more explicit tool was needed to manage the process of hypothesis testing and group regulation. To that end, we utilized a KWL (Know, Want to Know and Learned) chart, a common PBL tool used to share ideas and monitor progress. The next iteration included a KWL chart and a jigsaw approach towards collaboration. The jigsaw approach was utilized to further support students' development of expertise as they learn about the problem in the game. Subsequent implementation highlighted that the subsequent design embodiment did support students' collaboration and agency by offering more opportunities to engage in group regulation and negotiation (Saleh et. al, 2018b).

## Implications

Given that it is not clear how to instantiate PBL in a game-based learning environment, the paper articulates initial design principles for integrating PBL in games. Specifically, the design attended to multiple- narrative path and a whiteboarding tool to support the development of both individual and group expertise. Taken together, these designs encouraged student agency in the game while ensuring support for group regulation.

## References

- Adams, D. M., Mayer, R. E., MacNamara, A., Koenig, A., & Wainess, R. (2012). Narrative games for learning: Testing the discovery and narrative hypotheses. *Journal of educational psychology, 104*(1), 235.
- Hadwin, A., Järvelä, S., & Miller, M. (2011). Self-regulated, co-regulated, and socially shared regulation of learning. In B. Zimmerman & D. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 65–84). New York, NY: Routledge
- Hmelo-Silver, C.E. (2004). Problem-based learning: What and how do students learn?. *Educational psychology review, 16*(3), 235-266.
- Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the learning sciences, 23*(1), 18-36.
- Saleh, A., Shanahan, K., Chen, Y., Georgen, C., Hmelo-Silver, C., Glazewski, K. & Lester, J. (2018) Scaffolding middle-schoolers construction of scientific models. Paper presented at the American Educational Research Association, New York.
- Saleh, A., Shanahan, K., Chen, Y., Hmelo-Silver, C., Rowe, J. & Lester, J. (2018b) Scaffolding Peer Facilitation in Computer-Supported Problem-based Learning Environments. *Proceedings of the Thirteenth International Conference of the Learning Sciences (ICLS-2018)*, pp. 1831-1834, London.

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# Supporting Youth in Exploring and Expressing Disciplinary Identities With Learning Technologies

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**Abstract:** My research focuses on designing and developing innovative learning technologies to support youth in exploring and expressing disciplinary identities with the goal of exposing them to career options and preparing them for future career engagement. This summary presents two projects that set the foundation of my research agenda.

## Overview

As an educational technologist and learning scientist, I am driven by a passion for addressing educational challenges with the design and development of innovative learning technologies. My work focuses on examining how technology can be used to broaden youth's participation in integrated STEM+L (Science, Technology, Engineering, Math, and Literacy) practices and engage youth in career exploration. In the following, I will briefly explain two projects that set the foundation for my career goal.

## PhD research

My doctoral research (Jiang et al., 2016, 2018, 2019; Smith et al., 2018) seeks to uncover youth's collaborative learning processes and identity development, and in particular the connection between the two in collaborative multimodal composing environments. This work addresses the knowledge gap of integrating multimodal composing practices (Kress, 2010) in STEM education. As an example, my dissertation, *STEM+ L: Investigating Adolescents' Participation Trajectories in a Collaborative Multimodal Composing Environment*, is situated in an NSF-funded project (STEM+L, PIs: Drs. Ji Shen and Blaine E. Smith). In this project, sixth to eighth graders formed groups of three to five to create multimodal science fiction books (see Figure 1) in iKOS (a CSCL platform; ikos.miami.edu). In this study, we explored youth's participation in STEM+L practices through two theoretical perspectives: disciplinary identity development (Van Horne & Bell, 2017) and community of practice (Lave & Wenger, 1991). This study demonstrated that integrated STEM+L practices mediated by multiple modes can not only offer students flexibility in moving across forms of participation, but also open space for them to demonstrate their expertise as knowledge producers and explore future careers. Important implications were suggested regarding learning technology and environment design to facilitate the cultivation of positive disciplinary identities and the extension of participation in integrated STEM practices.

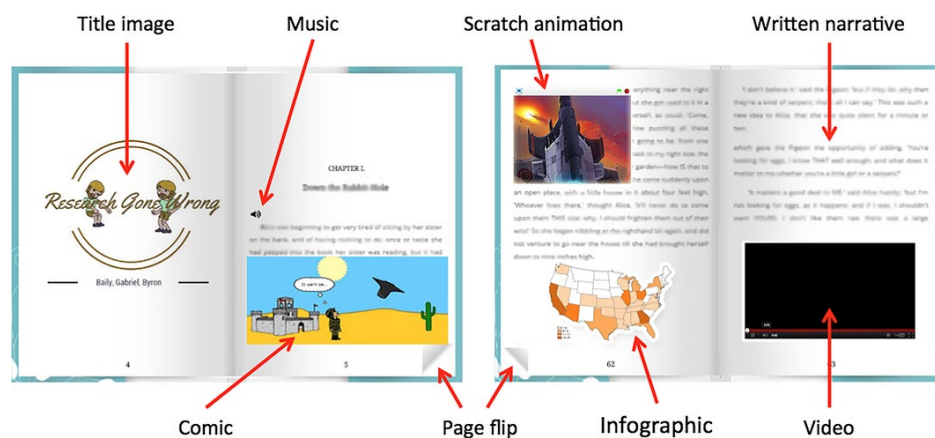


Figure 1. Multimodal science fiction book.

## Postdoctoral research

My postdoctoral work at Carnegie Mellon University addresses the need of providing students with automated structural writing feedback, leveraging cutting-edge deep learning technologies. Funded by the Schmidt foundation and supervised by Dr. Carolyn P. Rosé, I am applying the Rhetorical Structure Theory (Mann & Thompson, 1988) and deep learning technologies to predict the structure of student essays. The current focus is on technology development, but at the same time we are planning a large classroom study with our collaborators

at TurnItIn.com. The goal of the technology-enhanced collaborative writing deployment study will be to provide automated feedback towards enhancement of rhetorical structure in student writing.

## Future directions

Moving forward, I plan to integrate my doctoral and postdoctoral research to explore how to use deep learning technologies in addressing the need of supporting youth in developing positive disciplinary identities. In the STEM+L project, youth explored and expressed disciplinary identities in collaborative multimodal composition. Some students presented the conflict between how they and others saw their future professions in multimodal artifacts while some students explored what they wanted to be in the future in the multimodal composing process. Deep learning technologies have the potential of identifying identity expression and exploration and support the cultivation of positive disciplinary identities. I am looking forward to examining how deep learning technologies can be used to engage youth in profound STEM learning and STEM career exploration in different contexts.

Furthermore, I utilize my expertise in data visualization to examine how data visualization technologies can be used to 1) engage youth in disciplinary learning through creating interactive data visualizations (Jiang, 2016; Jiang & Kahn, 2019), 2) facilitate online adult learners to understand and improve learning processes (Jiang et al., 2015), and 3) support communication and decision making in professional domains. For instance, I worked with Dr. Jennifer B. Kahn to examine how youth used big data visualization technologies to build models of family migration narratives. Our work demonstrated that data visualization technologies were valuable instructional tools for supporting learning and communication with others about important and scientific issues and the family migration context positioned minorities as having agency and authority over big data, which addressed the tension of confirming data in the literature. Looking forward, I will continue to leverage the power of data visualization in different learning and professional contexts.

Interdisciplinary collaboration has been essential to my research. In addition to research interests explained above, my areas of study will include a wide range of technologies, approaches, and application areas. I anticipate collaborating with researchers and practitioners from different fields to use technology to address pressing challenges in education and other contexts.

## References

- Jiang, S. (2016). A technology-enhanced curriculum: Integrating STEM learning with data visualization, published online ([www.wise.berkeley.edu](http://www.wise.berkeley.edu)).
- Jiang, S., & Kahn, J. (2019). Data wrangling practices and processes in modeling family migration narratives with big data visualization technologies. *Proceedings of the 13th International Conference of the Computer Supported Collaborative Learning (CSCL)*, Lyon, France.
- Jiang, S., Shen, J., & Smith, B. E. (2019). Designing discipline-specific roles for interdisciplinary learning: two comparative cases in an afterschool STEM+ L programme. *International Journal of Science Education*, 1-24.
- Jiang, S., Shen, J., & Smith, B. (2016). Integrating science and writing in multimedia science fictions: Investigating student interactions in role-taking. *Proceedings of the 12th International Conference of the Learning Sciences (ICLS)*, Singapore.
- Jiang, S., Shen, J., Smith, B., & Kibler, K. (2018). Examining Science Identity Development in a Disciplinary Role-taking Multimodal Composing Environment. *Proceedings of the 13th International Conference of the Learning Sciences (ICLS)*, London, UK.
- Jiang, S., Shen, J., Sun, Y. (2015). Conceptualizing, analyzing, and visualizing massive data on student engagement in MOOCs: A literature review. *Proceedings of the 11th International Conference of the Computer Supported Collaborative Learning (CSCL)*, Gothenburg, Sweden.
- Kress, G. (2010). *Multimodality: A social semiotic approach to contemporary communication*. New York: Routledge
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.
- Mann, W. C., & Thompson, S. A. (1988). Rhetorical structure theory: Toward a functional theory of text organization. *Text-Interdisciplinary Journal for the Study of Discourse*, 8(3), 243-281.
- Smith, B., Shen, J., Jiang, S., Chen, G., Hamaoui, M., & Torralba, J. (2018). Multimodal Reflection: Adolescents Remixing and Sharing their Experiences in an Informal STEM+L Academy. *Proceedings of the 13th International Conference of the Learning Sciences (ICLS)*, London, UK.
- Van Horne, K., & Bell, P. (2017). Youth disciplinary identification during participation in contemporary project-based science investigations in school. *Journal of the Learning Sciences*, 26(3), 437-476.

# Cultivating an Orientation to Care in Computing Education

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**Abstract:** This paper summarizes one particular research project that is developing digital mapping activities and new computational tools to cultivate an orientation to care in computing education. Specifically, this paper introduces a project that is developing activities and a set of tools for students to dynamically visualize and study their physical movement over digital maps and large-scale data sets about their local geography in ways that allow them to explore concepts foundational to an ethic of care.

## Background and research goals

The project summarized in this paper reflects how my research agenda is situated at the intersection of the learning sciences, information visualization, and architecture and aims both to study the relation between the physical environment and human learning and to design dynamic visualization environments for computing education.

The project described in this paper is a collaborative effort with Amanda Meng at the Georgia Institute of Technology and draws from research inside and outside of education that aims to develop “an orientation to care in the practice of data science” (Zegura, DiSalvo & Meng, 2018) and to leverage personal mobility in teaching activities as both the means and content for learning (Taylor & Hall, 2013; Abrahamson et al., 2018). Importantly, this research advocates for the development of learning environments that allow students to attend to and understand data in relation to the local contexts in which it is collected or is about, particularly by establishing personal relationships to data (see Kahn, 2017; Craig, 2017; Lee, 2019; Roberts et al., 2014; Shapiro et al., 2018). This project also adapts tools that comprise a new approach to visualizing and interpreting human activity I have developed and call interaction geography (Shapiro, Hall & Owens, 2017; Shapiro & Hall, 2018). This approach integrates and extends methods of interaction analysis (Jordan & Henderson, 1995) with methods of time geography (Hagerstrand, 1970). Altogether, this project broadly seeks to understand: 1) how can the influence of computing on society be made visible for critical analysis and discussion by building environments that leverage interaction geography? and 2) What learning opportunities do these environments provide for computer science students to foster a sense of relational responsibility to how our society is evolving as a result of computing?

## Methodology and project design

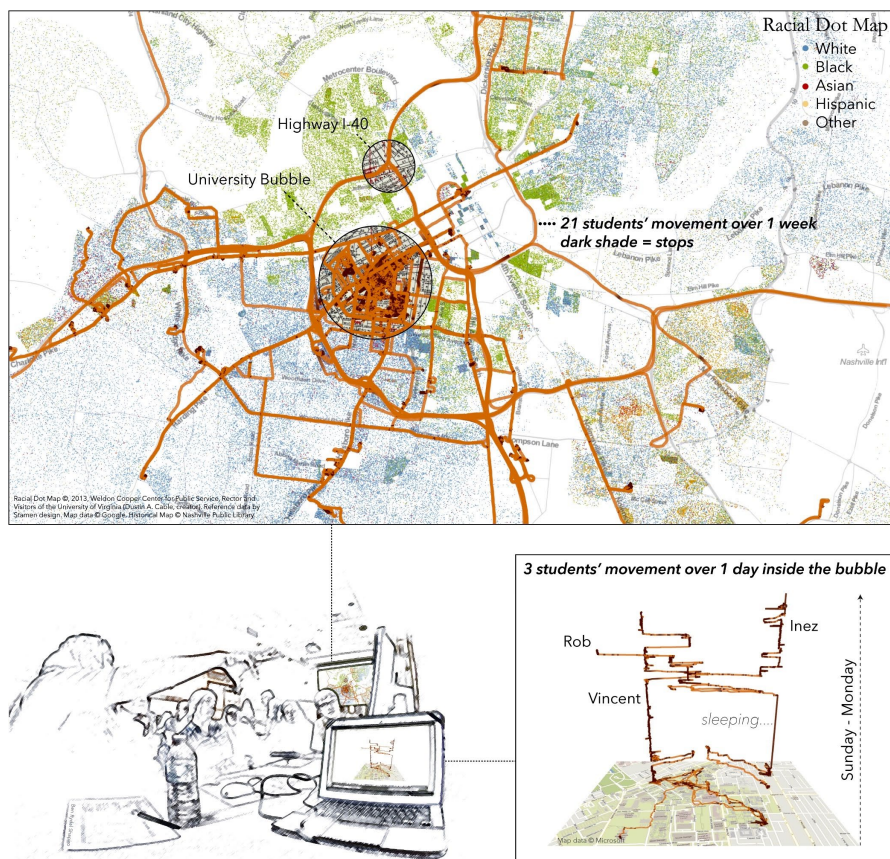
In this particular project, I am developing and studying a learning environment for general use in different computer sciences courses. This environment allows students to collect their physical movement typically over a period of one week and to use a dynamic visualization tool I have developed and call the Interaction Geography Slicer (IGS) to collaboratively study their movement over different types of digital maps and large-scale data sets about their local geography (e.g., maps of racial distribution, urban planning, social media and technology use). This environment engages students in dynamic learning experiences and activities, allowing them to embody data and become newly attentive to their local geography. Likewise, these experiences and activities foreground care ethics, a feminist theory currently underutilized at schools of computer science but one that is emerging as critical to understanding and fostering a sense of relational responsibility to how our society is evolving as a result of computing. Figure 1 provides a snapshot of this learning environment being used in one particular classroom.

This project will iteratively use, further develop, and evaluate this environment in three different computer science courses at the Georgia Institute of Technology to develop generalizable and open source curricula and computational tools for use in other university/computing contexts. Data collected will include audio/video data, surveys, and course evaluations before/after students use this learning environment, and I will analyze this data using mixed methods approaches that particularly draw from and extend methods of conversation and interaction analysis. Altogether, this project reflects my use of design-based research and participatory design methods in order to study learning primarily from socio-cultural and social practice perspectives.

## Expected findings and contributions

I expect this work will provide new ways to incorporate ethics across courses at schools of computer science while advancing work in the CSCL and Learning Sciences communities that focuses on how to leverage personal data and digital mapping technologies to support learning environment design. Likewise, I expect to develop open-source software, curricula, and evaluation instruments for other researchers, teachers, and practitioners working in computer science but also other disciplines such as social studies.





**Figure 1.** Students use the IGS in class to dynamically visualize their physical movement over digital maps and large-scale data sets such as the racial dot map (see: [https://www.youtube.com/watch?v=H8vd\\_HX9RVs](https://www.youtube.com/watch?v=H8vd_HX9RVs))

## References

- Abrahamson et al. (2018). Moving Forward: In Search of Synergy Across Diverse Views on the Role of Physical Movement in Design for STEM Education. In *Proceedings of the 13th International Conference of the Learning Sciences*. London, UK: International Society of the Learning Sciences.
- Craig, K. (2017). Analog Tools in Digital History Classrooms: An Activity-Theory Case Study of Learning Opportunities in Digital Humanities. *International Journal for the SoTL*, 11(1).
- Hagerstrand, T. (1970). What about people in regional science? *Papers in regional science*, 24(1), 7-24.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, 4(1), 39-103.
- Kahn, J. B. (2017). At the intersection of self and society: Learning, storytelling, and modeling with big data. Vanderbilt University.
- Lee, V.R., (2019). On researching activity tracking to support learning: a retrospective, *Information and Learning Sciences*, Vol. 120 Issue: 1/2, pp.133-154.
- Roberts et al. (2014). Interpreting data from within: supporting human data interaction in museum exhibits through perspective taking. In *Proceedings of the 2014 conference on Interaction design and children (IDC '14)*. ACM, New York, NY, USA, 7-16.
- Shapiro, B.R. and Hall, R. (2018). Personal Curation in a Museum. In *Proceedings of the ACM on Human-Computer Interaction*, Vol. 2, CSCW, Article 158 (November 2018). ACM, New York, NY.
- Shapiro, B.R., Hall, R. and Owens, D. (2017). Developing & Using Interaction Geography in a Museum. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 377-399.
- Shapiro, R.B., Fiebrink, R., and Norvig, P. (2018). How machine learning impacts the undergraduate computing curriculum. *Commun. ACM*, 61, 11, 27-29.
- Taylor, K. H., & Hall, R. (2013). Counter-mapping the neighborhood on bicycles: Mobilizing youth to reimagine the city. *Technology, Knowledge and Learning*, 18(1–2), 65–93.
- Zegura, E., C. DiSalvo, & A. Meng. (2018). Care and the Practice of Data Science for Social Good. In *Proceedings of the 1st ACM SIGCAS Conference on Computing and Sustainable Societies (COMPASS '18)*.

# Talking to Learn Across Digital and Face-to-face Settings in a High School English Classroom

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**Abstract:** This study reports on a design-based research collaboration with a high school English teacher that aimed to encourage dialogic discourse across face-to-face discussions and discussions embedded in an interactive e-reader. Findings suggested connections between digital and nondigital discursive practices that influenced collaborative meaning making opportunities among students, as changing practices around digital discourse required a reorganization of rules and tasks in both digital and face-to-face learning environments.

## Background

Over the past 40+ years, studies have established the central role of high-quality discussion in the developing understandings of learners (e.g., Michaels, O'Connor, & Resnick, 2008; Nystrand, 1997). In particular, research has emphasized the promise of dialogic instruction, which provides students with opportunities to engage in “talking to learn” (Britton, 1969) by collectively building on and responding to others’ ideas. With the increasing popularity of interactive technologies in K-12 spaces, classroom discussion has expanded into digital settings, but the relation between learning and digital discourse—what I refer to as the interactive written communication that occurs in networked online spaces between two or more participants—is less clear. On one hand, digitally mediated communication in K-12 classrooms fosters critical thinking, collaboration, and new spaces for productive dialogue (e.g., Resnick, Asterhan, & Clarke, 2015). Yet, teachers struggle to use digital tools in ways that support interactive learning, even though they often adopt these social technologies to support students’ dialogic meaning making (e.g., Reich, Murnane, & Willett, 2012).

Framed by sociocultural theories of learning (Engeström, 1999; Vygotsky, 1978) and theories of dialogism (Bakhtin, 1981), this study examined the relation between learning and digital discourse through a three-month design-based research collaboration with a high school teacher. The teacher and I worked together to design and implement practices aimed at encouraging dialogic discourse across face-to-face class discussions and class discussions embedded in a popular K-12 interactive e-reader, Subtext. The following research questions guided this study: 1) What kinds of learning opportunities are mediated by digital discourse in a high school English classroom? 2) How can learning be organized to support dialogic digital discourse?

## Method

I collaborated with Peter, a veteran English teacher in a socially and culturally diverse high school, in a design-based research experiment to build working theories about digital discourse as a mediating learning tool and to uncover variables that shape teaching and learning with digital discourse. Peter was interested in transforming digital discourse from a perfunctory exercise to a meaningful learning tool for his students. We focused on his Period 1 English 11 class (27 students), which used Subtext to read and engage in discussions about almost all assigned texts.

I collected a variety of qualitative data over two phases. Data sources included semi-structured teacher interviews, class observations, informal conversations with Peter and students, digital discourse data, design and reflection sessions, classroom documents, transcriptions of audio and video recordings, field notes, and memos. In the first phase, I observed in Period 1 for three weeks to gain a better understanding of everyday classroom life, class practices, and how digital discourse was used. During the second phase, the design collaboration with Peter, I collected data related to our design cycles as we attempted to shift digital discourse practices.

Analyses during design collaborations were concurrent and continuous with data collection. Peter and I examined student data to assess movement toward learning objectives and used our analyses to design subsequent lessons. For the qualitative retrospective analysis of the entire data set, I applied deductive and inductive descriptive codes to Phase 1 data to summarize the basic topics of data passages. I further reduced data through pattern codes that identified themes related to classroom talk and mediation of learning. For talk-related practices, I used deductive codes drawn from Nystrand’s (1997) typology of classroom talk. For Phase 2 data, I applied inductive and deductive descriptive codes guided by my research questions, theoretical frames, and research literature. I then re-coded the data for process (Strauss & Corbin, 1998) to focus attention on discourse practices in which students and teachers engaged, and on design collaboration activity. I further reduced data through pattern codes that categorized student discourse practices and teacher discourse practices

within iterative design cycles. I then compared these patterns across the design cycles and coded for shifts in student and teacher participation.

## Results

Findings highlighted how “talking to learn” in the 21st century happens in and across complex social ecologies (Cole, 1996). Changing how Period 1 engaged with the tool of digital discourse required a reorganization of not only the digital activity system but of the face-to-face system as well. Peter and I began by shifting rules and tasks in the digital Subtext environment to influence digital discourse. However, our designs revealed the tensions between the classroom’s digital learning environment and established face-to-face talk practices. Peter wished to leverage digital discourse for collaborative knowledge building, but our design work instead revealed the contradictions between intended uses of digital discourse as a learning tool and the established talk practices, shaped by community rules and roles, of the teacher and students (Engeström, 1999). It was only after considering the broader classroom ecology and the affordances and constraints of available tools—digital and nondigital—that we were able to reorganize practices to support more dialogically oriented learning across face-to-face and digital learning contexts.

Over two design cycles in Peter’s English 11 class, the following theories emerged about digital discourse and the facilitation of dialogic digital exchange around literary texts: (a) learning opportunities mediated by digital discourse depend on how practices around it are socially organized, and (b) in order to support dialogic digital discourse, organization of learning must account for the mutually influential nature of digital discourse and face-to-face talk.

## Implications

In addition to suggesting important connections between digital and nondigital discourse that influence meaning-making, the study findings highlight the critical role teachers continue to play in our digital age. The connections between digital and face-to-face discourse suggested by this study’s findings call for more attention to the preparation of teachers regarding classroom talk in its various guises. Instead of isolating face-to-face talk opportunities from the digital, perhaps it would be more productive to help teachers think about how these different talking-to-learn opportunities travel and interact across the discursive spaces that are now available in many classrooms.

## References

- Bakhtin, M. M. (1981). *The dialogic imagination: Four essays*. (C. Emerson & M. Holquist, Trans.). Austin, TX: University of Texas Press. (Original work published 1975).
- Britton, J. (1989). *Language, the learner, and the school*. Portsmouth, NH: Heinemann (Original work published in 1969).
- Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.
- Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R. Punamaki (Eds.), *Perspectives on activity theory* (pp. 19-38). New York, NY: Cambridge University Press.
- Michaels, S., O’Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in Philosophy and Education*, 27(4), 283-297.
- Nystrand, M. (1997). *Opening dialogue: Understanding the dynamics of language and learning in the English classroom*. New York, NY: Teachers College Press.
- Reich, J., Murnane, R., & Willett, J. (2012). The state of wiki usage in US k–12 schools leveraging web 2.0 data warehouses to assess quality and equity in online learning environments. *Educational Researcher*, 41(1), 7-15.
- Resnick, L. B., Asterhan, C. A., & Clarke, S. N. (2015). *Socializing intelligence through academic talk and dialogue*. Washington, DC: American Educational Association.
- Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Procedures and techniques for developing grounded theory*. Thousand Oaks, CA: Sage Publications.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

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# Improving Feedback for Learning Real-world Design

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## Goals of research: Teaching and learning real-world design

In my research, I create and study technologies, pedagogies, and organizations to promote more effective teaching and learning of real-world design. I work at the intersection of Learning Sciences, Computer-supported Collaborative Learning (CSCL), and Human-Computer Interaction (HCI) to investigate how to support teachers, professional designers, students, and other community stakeholders involved in teaching real-world design problems. Across the world, we face pressing social problems, such as educational inequality and homelessness; these societal challenges are design problems (Jonassen & Hung, 2015)—problems with no clear solutions, solution path, or goals. Furthermore, design problems require integrating different disciplines and balancing the needs of multiple different stakeholders. We can prepare students to solve societal problems by teaching them to take on real-world design problems. For example, one team of university students we worked with tackled the challenge of reducing the 100,000 annual deaths across the US from hospital-acquired infections. The team worked with hospital staff, administrators, and patients to create a portable hand-hygiene device. However, teaching real-world design is challenging as no one stakeholder, including the teacher, knows the ‘correct’ solution or solution path, so teachers have limited ability to anticipate student needs (Jonassen & Hung, 2015). Students must learn to communicate with, understand and balance the needs of multiple real-world stakeholders, while also defining the problem and building solutions (Schön, 1983). Furthermore, real-world design involves numerous other stakeholders, including volunteer experts, users, and clients—causing an orchestration burden for teachers and students.

My research program takes a design-based research approach, drawing on theories from the Learning Sciences, cognitive science, design studies, HCI, and CSCL. I employ qualitative research methods, including interviews, surveys, participant observation, video analysis, and log data analysis. By combining these approaches I am able to (a) understand the nature of, and practices in, teaching and learning real-world design, and (b) create and evaluate novel technologies, pedagogies, and organizations to support teaching and learning real-world design.

## Understanding teaching and learning in real-world design

To better understand the challenges in design education, I ask, what is the nature of teaching and learning in real-world design? That is, what are common practices, challenges, appropriate learning goals, and assessments in design education that can inform more effective pedagogies, technologies and organizations. In one study, I investigated what teachers of real-world design experience as their most pressing challenges (Rees Lewis et al., in review; Rees Lewis et al., 2017); I conducted 47 semi-structured interviews with university design teachers in the US. I found that design teachers experience the challenges of: (1) monitoring teams as problem definitions change; (2) providing regular tailored feedback to help students create more effective and viable solutions; (3) scoping problems and working with clients before the class; (4) designing curriculum flexible enough for changes in problem and solution understanding; and (5) orchestrating co-educators, clients, and other stakeholders to support learning. In another study, my colleagues and I explored expert feedback on student design practice to define risk assessment as a core area of expertise (Carlson, Maliakal, Rees Lewis, Gorson, Gerber, & Easterday, 2018)—risk assessment is the practice of identifying what might lead to creating ineffective or undesirable solutions (e.g. not knowing user needs).

I aim to extend this work by (a) understanding student struggles in real-world design classrooms, (b) creating assessments for planning in real-world design, and (c) understanding student epistemologies in real-world design—how students reason about evidence pertaining to the nature of problem or the viability of their solution.

## Design-based research for real-world design classrooms and organizations

To better understand how to create more effective interventions, I build and study technologies, pedagogies, and organizations for supporting teaching and learning in real-world design learning environments. In one set of studies, I looked to support teachers who sought to provide students with coaching by pairing them online with professional designers who could rarely meet face-to-face. In a preliminary intervention, I found students and professionals rarely maintained a coaching relationship online because students rarely surfaced their thinking and activities in a way that helps professional designers coach (Rees Lewis et al., 2015). In response, I created *StandUp*, a CSCL pedagogy and technology based on socially shared regulation of learning principles (SSRL, Järvelä & Hadwin, 2013) that regularly prompts student teams to surface their activities and planning to coaches

online. Through interviews, participant observation, and analysis of log data, I found that using SSRL technologies, we can dramatically increase online coaching interactions which in turn help the teams enact professional design practices (Rees Lewis et al., 2017; in press). In another study, I sought to help students to enact the design practice of frequent iteration—testing and revising solutions to avoid creating ineffective or undesirable solutions. I created *Planning-to-Iterate*, an approach that scaffolds students in (a) defining important aspects of their project, such as client needs or existing solutions, (b) assessing risk in their projects (what might lead to ineffective or undesirable solutions), and then (c) testing their solutions to reduce risk (Rees Lewis et al., 2018). I compared *Planning-to-Iterate* to a condition in which teams didn't have the *Planning-to-Iterate* scaffolding, but did receive 2 extra hours of face-to-face teacher coaching each week. I conducted participant observation and analysis of classroom video and audio data across the two conditions. I found that compared to the coaching condition, students using *Planning-to-Iterate* doubled the frequency in which they tested and drew conclusions about how to make their solutions more effective and desirable. In other work, to provide useful feedback to student design teams, we built computer-supported group critique technology that increased peer feedback quantity and quality (Easterday, Rees Lewis & Gerber, 2017).

I aim to extend the ways we can support students to enacting design practices, including (a) defining coaching strategies in real-world design that can support student planning, and (b) combining *Planning-to-Iterate* with coaching strategies to understand how to better support student planning in real-world design.

I also seek to build and study organizations that support learning real-world design. To fully address a real-world design problem, it typically takes more time and resources than a classroom can provide—as such, organizations have tremendous potential to support real-world design learning (Easterday, Gerber, & Rees Lewis, 2018). I am currently building technology to support design collaboration across the CANMEE network—a lesson study network of 100+ maths teachers across California who are engaging in an equity-based lesson study; the teachers redesign and share maths curricular materials to reduce educational inequality.

## Conclusion

My work advances theory about how to better support the teaching and learning of real-world design problems. This in turn can increase our ability to prepare students to tackle pressing societal problems. I will continue to work towards this goal through a robust research program, through the training of practitioners and the dissemination of curriculum and technology. Ultimately, I aim to increase our capacity to solve pressing societal problems by preparing more people to be pro-social expert designers.

## References

- Carlson, S. E., Maliakal, L. V., Rees Lewis, D. G., Gorson, J., Gerber, E. M., & Easterday, M. W. (2018). Defining and assessing risk analysis: The key to strategic iteration in real-world problem solving. *Proceedings of the 2018 International Conference of the Learning Sciences*. London, UK.
- Easterday, M. W., Gerber, E. M., & Rees Lewis, D. G. (2018). Social innovation networks: A new approach to social design education and impact. *Design Issues*, 34(2), 64–76.
- Easterday, M. W., Rees Lewis, D., & Gerber, E. M. (2017). Designing crowdcritique systems for formative feedback. *International Journal of Artificial Intelligence in Education*, 27(3), 623–663.
- Järvelä, S., & Hadwin, A. F. (2013). New frontiers: Regulating learning in CSCL. *Educational Psychologist*, 48(1), 25–39.
- Jonassen, D. H., & Hung, W. (2015). All problems are not equal: Implications for problem-based learning. *Essential Readings in Problem-Based Learning*, 7–41.
- Rees Lewis, D. G., Easterday, M. W., Harburg, E., Gerber, E. M., & Riesbeck, C. K. (2018). Overcoming barriers between volunteer professionals advising project-based learning teams with regulation tools. *British Journal of Educational Technology*, 49(3), 354–369.
- Rees Lewis, D. G., Gerber, E. M., Carlson, S. E., & Easterday, M. W. Planning to Iterate: Supporting iterative practices for real-world ill-structured problem-solving. *Proceedings of the 2018 International Conference of the Learning Sciences*. London, UK.
- Rees Lewis, D.G., Carlson, S.E., & Gerber, E.M., & Easterday, M.W (in review). Opportunities of educational innovations in authentic PBL: Understanding instructor perceived challenges to design for adoption.
- Rees Lewis, D.G., Carlson, S. E., Easterday, M.W., & Gerber, E.M., (2017). Empirical investigation of challenges for PBL stakeholders in engineering education. *Poster presented at EARLI*. Tampere, Finland.
- Rees Lewis, D., Harburg, E., Gerber, E.M., Easterday, M. (2015). Building help-seeking tools for novice designers. *Proceedings of ACM Conference on Creativity & Cognition* (pp. 43–52). New York: ACM.
- Schön, D. A. (1983). *The reflective practitioner: how professionals think in action*. New York: Basic Books.

# Supporting Student Understanding of Engineering: Using Hands-on Projects and Interactive Computer Models

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**Abstract:** This research investigates two ways of framing design projects and their impacts on learning. In an *engineering* condition, students learn the necessary science concepts during a design project. In a *science* condition, students learn science concepts first, then apply them during a design project. I used three types of pre/post assessment items: *science* concepts, *engineering* practices, and a *combination* of the two. I found benefits for each condition, but results favored the *engineering* condition.

## Introduction

Engineering projects are becoming more common in K-12 schools, but while it is often claimed that engineering projects improve student achievement in mathematics and science, research on this topic has shown that many projects do not live up to the claim (Teacher Advisory Council, 2009). While engineering projects may generate more student interest and engagement (Hmelo et al., 2000; Cantrell et al., 2006) than typical science curricula, they often fall short on developing science concepts. Ideally, undertaking a science project should be motivating, while also helping students to understand the interplay between science concepts (like energy transformation) and engineering design decisions. However, the framing of goals can impact what aspects of the project are emphasized.

Often, in science the goal is to develop knowledge, while in engineering the goal is to develop a solution (Lewis, 2006; Purzer, et al., 2015). This tension carries into curriculum: in projects framed around science goals, students learn the science concepts and then do a design project to apply those concepts (*science* condition). In projects framed around engineering goals, students learn the science concepts during the process of completing a design project (*engineering* condition). I investigate ways these two goal frameworks impact student learning. In addition, I use the Next Generation Science Standards (NGSS) focus on science and engineering practices, specifically the practice of “constructing explanations (for science) and designing solutions (for engineering)” (NGSS Lead States, 2013) to inform our conditions.

## Project background and methodology

This study was implemented in a curriculum module entitled *Solar Ovens* in the Web-based Inquiry Science Environment (WISE) platform. The goal of the unit was to familiarize students with the way energy transforms. Students use an interactive model of a solar oven, designed using NetLogo, to test features in the solar oven and understand how solar radiation transforms into infrared energy (Figure 1), in addition to building and testing a physical solar oven.

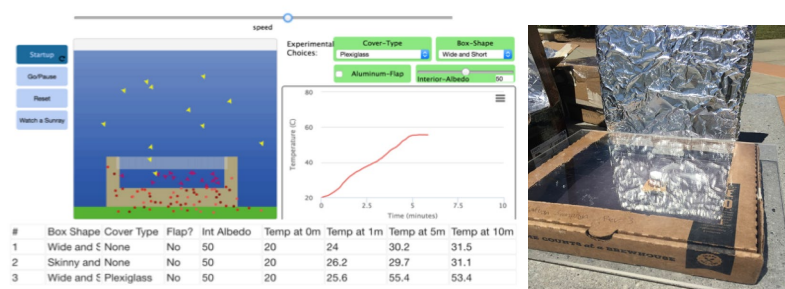


Figure 1. *left*: Screenshot of solar oven model, *right*: image of physical solar oven, built by a student.

Conditions did not differ in content, only in the order the content was presented and in the framing of questions or activities. In the *engineering* condition students were introduced to the design project in the first step, then were prompted to learn or consider science concepts during the design process. In the *science* condition, students learned all the science concepts at the beginning of the project in a module about the energy, then were introduced to the design project as a way to apply what they had just learned.



One teacher and her 153 students participated in this study. Out of these students, 139 students completed a pretest, (some part of) the curriculum, and a posttest. The pretest was conducted one day before beginning the unit, and the posttest was conducted one day after finishing the unit. Both the pretest and posttest were administered to students individually. Pairs, or in some cases triads, of students were assigned to collaborative workgroups by their teacher to work on curriculum. Workgroups were randomly assigned to a condition (*science* or *engineering*) by the software. All students received the same curricular content, but activity focus and order varied by condition.

The pre- and posttest assessments consisted of 9 assessment items. These items fell into three areas: science concepts, engineering practices, and the integration of science and engineering. All items use short response format, and are scored using knowledge integration rubrics; the rubrics are based on a 5-point scale that rewards students for connecting ideas (Linn & Eylon, 2011). Of these 9 items, 5 items measure integration of science concepts, 3 items measure integration of engineering design ideas and practices, and 1 item measures the integration of design practices with science concepts. I also use the automatically generated table from students' interactions with the interactive computer model (Figure 1) to analyze how many trials students ran during the project, based on log data.

## Results

There were no overall differences between the *science* and *engineering* conditions. When considering the groups of science and engineering assessment items, there were non-significant differences in condition differences. Students in the *science* condition made slightly greater gains on the science assessment items between pretest and posttest and likewise students in the *engineering* condition made slightly greater gains on the engineering assessment items between pretest and posttest; neither of these differences were significant. When considering the integration assessment item, there was a significant impact of condition in favor of the *engineering* condition ( $\beta = 0.18, p < 0.01$ ). I also analyze the number of trials students run in the interactive computer model during the design phase of the project. Groups in the *engineering* condition ran significantly more trials than those in the *science* condition ( $\beta = 0.33, p < 0.02$ ). In previous work, the interactive model has been shown to be a place for students to integrate their science ideas with their design work, since the model integrates the process of energy transformation with design decisions.

## Expected contributions

This work finds differences in student use of tools, specifically an interactive computer model, based on the framing of the project. These results also indicate that there are benefits for each type of framing. This is important to recognize in aligning the design of the curriculum with teachers' learning goals for their students. I have replicated this study in another hands-on project that includes an interactive computer model, but is focused on self-propelled (balloon-powered) vehicles. This study will help us understand if the differences between framings found in this study are consistent with those found in other contexts.

## References

- Cantrell, P., Pekcan, G., Itani, A., & Velasquez-Bryant, N. (2006). The effects of engineering modules on student learning in middle school science classrooms. *Journal of Engineering Education, 95*(4), 301.
- Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational psychology review, 16*(3), 235-266.
- Lewis, T. (2006). Design and inquiry: Bases for an accommodation between science and technology education in the curriculum?. *Journal of Research in Science Teaching, 43*(3), 255-281.
- Linn, M. C., & Eylon, B.-S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. New York: Routledge.
- Teacher Advisory Council. (2009). *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*. National Academies Press.
- NGSS Lead States. (2013). Next Generation Science Standards: For States, By States.
- Purzer, Ş., Goldstein, M. H., Adams, R. S., Xie, C., & Nourian, S. (2015). An exploratory study of informed engineering design behaviors associated with scientific explanations. *International Journal of STEM Education, 2*(1), 9.

# Devising an Interactive Social Learning Analytics Tool to Foster Online Collaborative Learning

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**Abstract:** I propose a design-based research study to devise a real-time interactive social learning analytics tool in order to foster students' interaction, discourse and cognition processes during online collaborative learning. I will empirically investigate the influence of this tool on students' collaborative learning with pedagogical supports in online learning contexts. Expected outcomes include an interactive tool, empirical knowledge, and implications for collaborative learning and instruction.

## Background

In computer-supported collaborative learning (CSCL), learners interact, communicate and collaborate with each other to achieve shared learning goals with technological and instructional supports (Dillenbourg, 1999; O'donnell & Hmelo-Silver, 2013; Stahl, Koschmann, & Suthers, 2014). Inspired by this social perspective of learning, researchers design and implement learning analytics tools, representations, and dashboard systems to demonstrate interactive, dialogic, collaborative aspects of online learning (e.g., Chen, Chang, Ouyang, & Zhou, 2018). However, empirical studies showed that those learning analytics implementations serve as both facilitators and constraints for CSCL learning (Chen et al., 2017; Jivet, Scheffel, Drachslar, & Specht, 2017). One of the primary reasons that caused this complexity is that most existing tools merely provided relation-related information such as social interaction information (e.g., network visualizations, centrality metrics), or behavior-related information (e.g., time spent online, number of messages); they did not provide students with a holistic picture of learning processes which may increase social comparisons, and discourage further student engagement (Jivet et al., 2017; Ouyang & Chang, 2018). Devising learning analytics tools or representations that can demonstrate social, knowledge, and temporal information about learning can better serve CSCL learning and instruction.

## Research purposes and questions

My research goal is to foster interactive, collaborative learning in online discussions and discourses with the support of interactive learning analytics implementations and relevant pedagogical strategies. To achieve this goal, I plan to (a) devise a real-time interactive social learning analytics tool named *IntVisRep* to help participants become aware of their interaction, discourse and cognition processes, (b) empirically investigate students' collaborative learning processes with the technological support of this tool, and (c) develop more inclusive pedagogical supports to help students better use this tool to foster collaborative learning.

## Methodology

This study will use the design-based research methodology (McKenney & Reeves, 2012) to iteratively design and implement an interactive learning analytics tool and analyze how the use of this tool and relevant pedagogical supports can influence online collaborative discussions.

My doctoral dissertation research served as the first iteration. I used a mixed-method approach (social network analysis, content analysis and temporal analysis) to examine the collaborative learning processes within an online course in higher education context in the United States. I found that to support collaborative learning, the instructor manifested different participatory roles throughout the course (Ouyang & Scharber, 2017). She evolved from a leader in the early stage, to a facilitator or a collaborator at the middle stages, and to an observer in later stages. With her course design and facilitation, students developed an equally-distributed social network, where they achieved a high-level individual and collective knowledge construction. Students, with different participatory roles, contributed to different levels of knowledge construction. Particularly, leader students made the most contribution to the collective-level knowledge construction (Ouyang & Chang, 2018). Based on the results, this research proposed methodological frameworks to analyze different aspects of collaborative learning, and provided pedagogical strategies that can enhance collaborative learning. This research also provided suggestions for future learning analytics tool design, that is, providing both social and cognitive information may decrease social comparison and increase collaboration (Ouyang & Chang, 2018).

In the second iteration, a participatory design approach (Schuler & Namioka, 1993) will be used to iteratively refine the interactive learning analytics tool *IntVisRep*. Based on the suggestions from the first iteration, I developed an initial prototype of *IntVisRep* through a ShinyApp (a short introduction video and the app's Github



repository). The *IntVisRep* prototype demonstrated three types of interactive, visualized representations: interaction network, keyword flow, and temporal engagement. In the participatory design workshop, I will recruit instructors, students and designers and share this initial prototype to them, ask them to respond, reflect, and critique on the design of this tool. Based on their feedback, the design team and I will revise this tool to better reflect students' collaborative learning during online discussions. Another goal is to collect real-time participant data and demonstrate visualized representations directly. A challenge is that currently *IntVisRep* includes some intensive post hoc analyses which can only provide delayed information to participants; to achieve real-time data analytics and representations, application program interface (API) could be used. How to automatically demonstrate content-related data analytics and representations is a big challenge for this study.

In the third iteration, I will use the revised *IntVisRep* tool in an online or blended course in Zhejiang University to empirically investigate the effect of the use of *IntVisRep* tool on students' collaborative learning. I will engage instructors to together develop more inclusive pedagogical supports to better use this tool to foster collaborative learning. A quasi-experimental design will be adopted to examine the influences of technological and pedagogical supports have on collaborative learning. Research question is: *whether, to what extent, and how does the IntVisRep tool and relevant supporting pedagogies foster individual knowledge construction, social interaction and group knowledge advancement?* Data analysis methods will include social network analysis, content and discourse analysis, and temporal-oriented sequential analysis.

### Expected outcomes and contributions

Expected outcomes include an interactive tool, empirical knowledge, and implications for collaborative learning and instruction. The first outcome is a social, interactive tool that can interactively demonstrate real-time information about students' social interaction, knowledge flow and online engagement. The second outcome is empirical knowledge about students' use of this tool to sustain collaborative learning and instructors' pedagogical supports of collaborative learning. The third outcome is supporting pedagogical strategies that can be used to help students better understand their collaborative learning processes when using this tool. Taking together, this work will contribute to the advancement of the design, practice, and research of collaborative learning, particularly collaborative discussions in online learning environments. Specifically, this project's implications for future design is design principles, techniques and processes for real-time information analytics and representations. Implications for practice will focus on recommendations for instructors to use technological and pedagogical supports to foster collaborative discussions. Implications for research will highlight the design, use, and development of learning analytics implementations in collaborative learning research.

### REFERENCES

- Chen, B., Chang, Y. H., Ouyang, F., & Zhou, W. Y. (2018). Fostering discussion engagement through social learning analytics. *The Internet and Higher Education*, 37, 21–30.
- Dillenbourg, P. (1999). What do you mean by “collaborative learning”? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (pp. 1-19). Oxford, UK: Elsevier.
- Jivet, I., Scheffel, M., Drachsler, H., & Specht, M. (2017). Awareness is not enough: Pitfalls of learning analytics dashboards in the educational practice. In E. Lavoué, H. Drachsler, K. Verbert, J. Broisin, & M. Pérez-Sanagustín (Eds.), *Data Driven Approaches in Digital Education* (Vol. 10474) (pp. 82-96). Tallinn, Estonia: Springer.
- McKenney, S., & Reeves, T. C. (2012). *Conducting educational design research*. New York, NY: Routledge.
- O'donnell, A. M., & Hmelo-Silver, C. E. (2013). Introduction: What is Collaborative Learning? An Overview. In C. E. Hmelo-Silver, C. A. Chinn, C. K. K. Chan and A. M. O'Donnell (Eds.), *The international handbook of collaborative learning* (pp. 93-111). New York, US: Routledge.
- Ouyang, F. & Chang, Y. H. (2018). The relationship between social participatory role and cognitive engagement level in online discussions. *British Journal of Educational Technology*. doi: 10.1111/bjet.12647.
- Ouyang, F. & Scharber, C. (2017). The influences of an experienced instructor's discussion design and facilitation on an online learning community development: A social network analysis study. *The Internet and Higher Education*, 35, 33-47. doi: <https://doi.org/10.1016/j.iheduc.2017.07.002>
- Schuler, D., & Namioka, A. (1993). *Participatory design: Principles and practices*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Stahl, G., Koschmann, T., & Suthers, D. D. (2014). Computer-supported collaborative learning. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 479-500). New York, NY: Cambridge University Press.

# Combining Machine Learning and Learning Analytics to Provide Personalized, Adaptive Scaffolding

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**Abstract:** This work aims to propose a methodological framework to provide personalized and adaptive scaffolding to students who engage with computer-supported learning activities. Bridging the gap between pedagogical theories and established practice, my particular aim is to answer the following research questions: what makes scaffolding more beneficial for some students than others, why do some students give up even when supported, how can we prevent dropouts and turn them into successful learning episodes? My goal is to explore how theoretical frameworks on scaffolding can guide computational models in order to address student needs. My research hypothesis is that we can use Learning Analytics to model students' cognitive state and to predict whether the student is in the Zone of Proximal Development. Based on the prediction, we can plan how to provide scaffolding based on the principles of Contingent Tutoring.

## Goals of research

The main goal of my research is to study how we can combine computational models informed by learning analytics (LA) with established pedagogical theories in order to provide personalized and adaptive scaffolding to students, targeting their specific needs. In particular, I am working on a project that aims to provide personalized guidance and feedback to students by adapting scaffolding to their background knowledge and cognitive state (1). To that end, I propose the use of machine learning in order to design models to assess students' knowledge and cognitive state with respect to students' prior practice. To monitor prior practice, I propose the use of computational learning analytics (LA). To maintain the most up-to-date representation of students' knowledge and cognitive state, student models will be dynamically updated during students' practice. In order to provide guidance and feedback with respect to student's specific needs, I follow the Vygotskian construct of the Zone of Proximal Development (ZPD) (Vygotsky, 1978) and adapt scaffolding with respect to the principles of Contingent Tutoring (Wood, 2001).

## Background

The adoption of technology in education has led to the development and adoption of new tools and methods to support learning and teaching. These tools and methods provide us with the unique opportunity to employ cutting-edge computational approaches for addressing fundamental pedagogical challenges that remain open: how to adaptively guide students and how to provide appropriate scaffolding to facilitate learning and to improve the learning outcome. Empirical research suggests that the learning analytics methods currently used to provide feedback are not based on established pedagogical strategies for instruction and scaffolding. On the contrary, they are commonly data-driven and have limited theoretical grounding (Gašević, Dawson, & Siemens, 2015). The lack of theoretical grounding can lead to providing inappropriate support that fails the purpose of scaffolding and inhibits learning instead of enabling it: for example, providing the wrong amount of support (too much or too little), providing support at the wrong time (too late or too soon) or even providing the wrong kind of support (giving away the answer to a question when eliciting would be beneficial). The open challenge is to bridge the gap between pedagogical theories and practice when it comes to scaffolding.

My research hypothesis is that we can use learning analytics to design student models that will describe the student's knowledge and cognitive state, thus generalizing cognitive student models used in Intelligent Tutoring Systems (Corbett, Koedinger, & Anderson, 1997). The output of such student models can be used as a proxy to assess whether the student is - or, is not - in the ZPD. The core rationale is that if the student model cannot predict with acceptable accuracy whether a student will answer a question correctly, then it might be the case that the student is in the ZPD. Based on the student model's outcome - that is, whether the student is in the ZPD, above the ZPD, or below the ZPD - we can further plan the teaching strategy: what tasks to assign to the student, whether the student needs scaffolding and what kind of scaffolding is appropriate. This rationale - known as the "Grey Area" approach - has been previously studied in the context of Intelligent Tutoring Systems (Chounta, Albacete, Jordan, Katz, & McLaren, 2017; Chounta, McLaren, Albacete, Jordan, & Katz, 2017). Here, I aim to extend and generalize its use to learning activities orchestrated by Learning Management Systems and Collaborative Learning environments in Higher Education.

## Methodology

For this research, I will follow a mixed-methods approach, combining qualitative (focus groups, observations, surveys) and quantitative (machine-learning, social network analysis, sequential pattern mining, time series analysis) research methods. The research and development work will take place over four work-packages during the course of four years. The project follows an iterative methodology by adopting a design-implementation-evaluation circle (Figure 1) in order to confirm that findings from different work-packages and outcomes from various methodologies will be combined and cross-validated.

The outcome of this research will include the methodological framework for personalized scaffolding and a Learning Analytics taxonomy for informing research with respect to the significance of various learning analytics in assessing student's knowledge enriched with machine-learning cognitive models. Additionally, I will communicate the findings of the evaluation phase in the format of "lessons-learned" and use them as guidelines for future work.

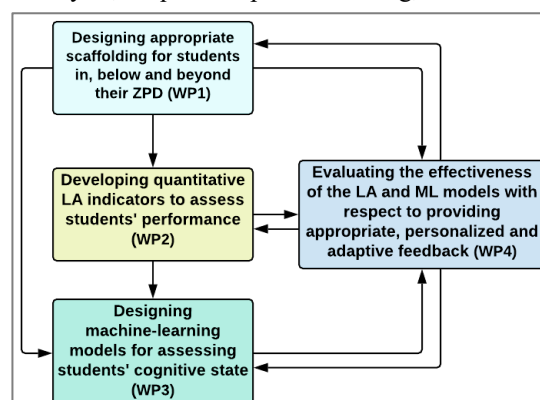


Figure 1. Method of Research

## Expected contributions

To the best of my knowledge, this is a novel approach for providing scaffolding in technology-enhanced learning environments. Existing learning analytics approaches that aim to provide scaffolding rely on rubrics and empirical rules that attempt to explain how student activity relates to student performance. The novelty of this contribution is twofold: 1. Using machine-learning cognitive models in order to dynamically assess student's knowledge state; 2. Adapting scaffolding with respect to the cognitive model's output based on the principles of pedagogical theories, namely the ZPD and Contingent Tutoring. A key broader impact of this work is that it can support complex pedagogical decision-making necessary for providing effective scaffolding. Once the proposed approach has been developed and vetted through efficacy testing it can be widely used in various contexts, such as online courses, MOOCs and collaborative learning environments. Furthermore, I envision that this approach will impact how we design learning material and learning activities, taking into account students' characteristics and needs. The project could also contribute to the ever-present assistance dilemma (Koedinger & Aleven, 2007)—that is, the challenge of providing the right amount of help to the student so that the student is challenged but not frustrated.

## Endnote

(1) <https://www.etis.ee/Portal/Projects/Display/bb291d41-e11d-4667-b374-8a801015e374?lang=ENG>

## References

- Chounta, I.-A., Albacete, P., Jordan, P., Katz, S., & McLaren, B. M. (2017). The "Grey Area": A computational approach to model the Zone of Proximal Development. In *European Conference on Technology Enhanced Learning* (pp. 3–16). Springer, Cham.
- Chounta, I.-A., McLaren, B. M., Albacete, P., Jordan, P., & Katz, S. (2017). Modeling the Zone of Proximal Development with a Computational Approach. In *International Conference on Educational Data Mining (EDM) 2017* (pp. 356–357).
- Corbett, A. T., Koedinger, K. R., & Anderson, J. R. (1997). Intelligent tutoring systems. In *Handbook of Human-Computer Interaction (Second Edition)* (pp. 849–874). Elsevier.
- Gašević, D., Dawson, S., & Siemens, G. (2015). Let's not forget: Learning analytics are about learning. *TechTrends*, 59(1), 64–71.
- Koedinger, K. R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review*, 19(3), 239–264.
- Vygotsky. (1978). Interaction between learning and development. *Readings on the Development of Children*, 23(3), 34–41.
- Wood, D. (2001). Scaffolding, contingent tutoring, and computer-supported learning. *International Journal of Artificial Intelligence in Education*, 12(3), 280–293.

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# Towards the Development of an Evidence-based Framework for Immersion in Digitally Enhanced Learning Environments

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**Abstract:** Emerging technologies, such as digital interfaces based on augmented or virtual reality, have created new educational possibilities by allowing the development of highly-immersive learning environments. Immersion, as a psychological process of cognitive and emotional involvement which can be experienced in such digitally enhanced educational settings, is argued to be among the main driving forces behind students' learning. However, empirical studies on this topic are limited and little is yet known about the theoretical grounds of immersion in relation to students' learning or about the pedagogical design of immersive learning environments. My research work aims at the development of an evidence-based theoretical framework that will contribute to the theory-building efforts of immersion in relation to students' learning and to the principled design of immersive learning environments.

## Introduction and research agenda

My primary research interests focus on the investigation of students' immersion, as a key aspect related to emerging technologies, for supporting students' learning. Immersion, which can be defined as a subjective psychological experience of cognitive and emotional involvement, is often claimed to be one of the main driving forces fostering students' learning in digital learning environments (Cheng, She, & Annetta, 2015; Dede, 2009). However, even though immersion has been previously discussed extensively in the fields of game-based research and virtual environments, it has received limited attention in the field of education. The latter motivates my research, as there are few empirical studies investigating immersion in the context of digital learning environments grounded in emerging technologies, such as for instance digital interfaces based on Augmented Reality (AR) or motion-based technologies. In this context, my research work aims at contributing (a) to the theory-building efforts about the relation of immersion to students' learning, as well as (b) to the principled design of immersive learning environments. Below, I will present my research activities per research line and my future research plans.

## Theory-building efforts for immersion in relation to learning

As part of my doctoral research, I have formulated and empirically investigated a motivational model of immersion for learning in location-based AR settings. According to this model, immersion is assumed to be positively related to conceptual understanding, while students' domain-specific motivation and cognitive motivation are potential predictors of immersion. The model was empirically investigated with 135 10<sup>th</sup> graders, who worked collaboratively (in groups of 2 or 3), employing the "Mystery at the lake" AR activity (Georgiou & Kyza, 2018a). To investigate this model, two main methodological challenges needed to be first addressed. First, an Augmented Reality Immersion (ARI) questionnaire was developed to measure students' immersion in location-based AR settings (Georgiou & Kyza, 2017a). Second, the Need for Cognition Scale–Short Form (NfC-SF) was validated in the Greek language, for measuring students' cognitive motivation (Georgiou & Kyza, 2017b). These were important milestones in my research, as they allowed the investigation of the proposed motivational model for immersion. According to my findings, immersion was positively predicted by students' motivational traits; in addition, the highest the level of immersion was, the higher was students' conceptual understanding.

As a post-doctoral researcher, I have expanded this research line by investigating immersion in embodied digital environments, which integrate bodily movement into the act of learning, via the use of motion-based technologies (Georgiou & Ioannou, In press). As part of my research, I collected positive evidence about the impact of motion-based technologies in the context of embodied digital environments, on students' immersion and conceptual understanding, due to their novel interfaces as well as due to their affordances for motion and interactivity. However, I have also found that when integrated in authentic school educational settings, a set of contextual factors (i.e., *unstructured collaboration*, *classroom noise*) in combination with various interface related factors (i.e., *gaming controls*, *technical constraints*) may affect the immersive experience negatively.

Overall, the findings derived from my research so far are supportive for the claim of Cheng, Lin, She, and Kuo (2016) that the relationship between immersion and learning is more complicated, than initially hypothesized. At the same time, these findings motivate my future plans of research, which seek to contribute to a better understanding of how personal, interface and context characteristics can facilitate immersion.

## Pedagogical design of immersive digital environments

As part of my doctoral research I have co-designed the *TraceReaders* AR platform, which allows the development

of location-based AR collaborative activities, for scaffolded, reflective inquiry learning (Kyza & Georgiou, 2018). This was a crucial part in my research work, as it provided me the opportunity to investigate the design of various AR collaborative activities in different contexts, resulting in a set of design guidelines for sustaining students' immersion. For instance, the TraceReaders AR platform allowed the iterative and evidence-informed development of the "Mystery at lake" AR collaborative activity, which had a core role in my doctoral research, for supporting 10<sup>th</sup> graders' immersion and subsequent science learning (Georgiou & Kyza, 2017c). In particular, design-based research was employed to obtain a better understanding of which were the main activity characteristics affecting students' immersion, in order to result in a more engaging AR location-based environment.

An important outcome, coming out from this design-based approach is the emergence of several characteristics that seem to mediate the immersive experience. In particular, through the design iterations of the "Mystery at the lake" app, a set of interface-related characteristics (e.g., fidelity of the digital objects and characters), content-related characteristics (e.g., narrative plot), locality-related characteristics (e.g., coupling of the activity with the location), as well as context-related characteristics (e.g., environmental distractions) have emerged as potential characteristics that may affect students' immersion and subsequent learning. These findings have created the basis for a set of forthcoming quasi-experimental studies. For instance, in my latest research work I conducted a quasi-experimental study for investigating the hypothesis that greater coupling between the physical space and the narrative of the AR location-based activity leads to enhanced immersion and learning (Georgiou & Kyza, 2018b). Likewise, my future research studies will focus on manipulating different characteristics of AR collaborative activities, such as the narrative, or the fidelity of the digital characters, for investigating their impact on students' immersion and subsequent learning gains.

## Future research plans

Overall, the long-term research goal of my work is to develop an evidence-based framework about personal, task, interface and context characteristics, that may affect students' immersion and subsequent learning, as this could contribute: (a) to the theory-building efforts about the relation of immersion to students' learning, as well as (b) to the principled design of immersive learning environments. This framework could be supportive for the efforts of multiple stakeholders (e.g., learning scientists, psychologists, educators, instructional designers, educational technologists, computer scientists and designers) aiming at the development and implementation of more effective educational environments grounded in immersive technologies for learning.

## References

- Cheng, M.-T., She, H.-C., & Annetta, L. A. (2015). Game immersion experience: Its hierarchical structure and impact on game-based science learning. *Journal of Computer Assisted Learning*, 31(3), 232-253.
- Cheng, M.-T., Lin, Y.-W., She, H.-C., & Kuo, P.-C. (2016). Is immersion of any value? whether, and to what extent, game immersion experience during serious gaming affects science learning. *British Journal of Educational Technology*.
- Dede, C. (2009). Immersive interfaces for engagement and learning. *Science* 2, 323(5910), 66-69.
- Georgiou, Y. & Ioannou, A. (In press). Embodied learning in a digital world: A systematic review of empirical research in K-12 education. To appear in P., Díaz, A., Ioannou, M. Spector, & K.-K., Bhagat (eds.), *Learning in a digital world - Perspective on interactive technologies for formal and informal education*. (Chapter 7) Springer.
- Georgiou, Y., & Kyza, E. A. (2017a). The development and validation of the ARI questionnaire: An instrument for measuring immersion in location-based augmented reality settings. *International Journal of Human Computer Studies*, 98, 24-37.
- Georgiou, Y., & Kyza, E. A. (2017b). Translation, adaptation, and validation of the Need for Cognition Scale - Short Form (NfC-SF) in the Greek language for secondary school students. *Journal of Psychoeducational Assessment*, 36(5), 523-531.
- Georgiou, Y. & Kyza, E. A. (2017c). A design-based approach to augmented reality location-based activities: Investigating immersion in relation to student learning. *Proceedings of mLearn conf., Larnaka, Cyprus*.
- Georgiou, Y., & Kyza, E. A. (2018a). Relations between student motivation, immersion and learning outcomes in location-based augmented reality settings. *Computers in Human Behavior*, 89, 173-182.
- Georgiou, Y. & Kyza, E. A. (2018b). Investigating the coupling of narrative and locality in augmented reality educational activities: Effects on students' immersion and learning gains. *Proceedings of the 13<sup>th</sup> International Conference of the Learning Sciences*. London, UK: International Society of the Learning Sciences (ISLS), 2018.
- Kyza, E. A. & Georgiou, Y. (2018). Scaffolding augmented reality learning: The design and investigation of the TraceReaders location-based, augmented reality platform. *Interactive Learning Environments*, 1-15.

# Conceptualizing and Scaling Dialogic Peer Feedback

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**Abstract:** In higher education, peer feedback is widely practiced as a one-way interaction between students, and such practices offer limited learning benefits. To address this limitation, in my project I conceptualize feedback as a dialogic process where students collaborate with their peers to negotiate meaning on the feedback received and regulate their activities to set shared goals and plan the learning strategies to enact. I propose a model of dialogic peer feedback and explore the role of learning analytics in supporting the enactment of this model when learning occurs at scale. Grounded in the theoretical model, a web-based tool (called Synergy) is developed, which will be used in several large-scale higher education contexts. This project offers significant theoretical and practical contributions.

## Background and goals

Feedback is one of the aspects with the highest potential to have a positive impact in learning and achievement. In higher education, feedback is widely practiced as a one-way communication between the receiver (students) and the provider (peers or instructors). However, feedback as ‘telling’ is problematic since students’ uptake of the feedback without further interactions with the feedback provider is not always possible for several reasons such as, feedback messages may not be clearly communicated, or students may lack skills to correctly interpret the feedback. Dialogic feedback is favoured in the last years, which involves a follow-up discussion between the students and the peers to negotiate meaning on the feedback received. However, dialogic feedback is not feasible in large scale higher-education contexts since instructors cannot possibly afford to provide feedback and continue a dialogue with students around the feedback. *Dialogic peer feedback* can be a promising solution to the feedback problem in today’s higher education environment where there is a strong trend of integrating technology into pedagogy to address the learning needs of increasing rates of students. That is, the large learning populations are readily available resources in the context to exploit for designing dialogic peer feedback, and the existing technology infrastructure can help collect fine-grained trace data that can be used to support various dialogic peer feedback processes. Although there exist many frameworks, models, suggestions, and guidelines of the deployment of feedback, there is a lack of conceptualization of dialogic peer feedback that outlines the specific learning processes that students engage in during dialogic feedback and the role of emerging trace data to support these processes. Attending to this critical gap in the literature, this research project explores (1) the learning processes involved when feedback is framed as a dialogic process involving a structured collaboration among students, and (2) the affordances of learning analytics to support dialogic peer feedback in large scale learning settings. The goals of this project are:

- To create a theoretical model that identifies the core components of dialogic peer feedback and outlines the collaborative and individual learning processes
- To identify the affordances of learning analytics to support scalable dialogic peer feedback practices as conceptualized in the model
- To support dialogic peer feedback in large scale contexts through a web-based tool (called Synergy) designed based on the theoretical model and the affordances of learning analytics

## Conceptualizing dialogic peer feedback

We present a model of peer feedback that conceptualizes feedback as dialogue whereby students receive feedback from peers and interact with them to discuss, understand, and translate the feedback into set of actions necessary to progress on the task at hand. That is, in this model, the feedback process extends to the follow-up discussions between students and peers to negotiate meaning on the feedback received and to decide on subsequent learning actions (e.g., updating goals, changing a learning strategy) (Carless, 2016). In this conceptualization, dialogic peer feedback is considered a collective task in which learners together regulate their engagement in dialogic processes to reach to shared outputs (e.g., shared understanding of the task and shared goals) (Hadwin, Järvelä, & Miller, 2017). The proposed model is targeted at learning scenarios where students interact with peers in relation to their draft work (e.g., essay or programming code) for an assignment (or task) with clear assessment criteria. The proposed model builds on social and cognitive theories of regulation of learning to conceptualize dialogic feedback and considers monitoring as a mechanism to connect dialogic interactions with regulation of learning.

## Scaling dialogic peer feedback

In large-scale contexts, instructors' resources are unlikely to be adequate to facilitate dialogic peer feedback. Without instructor support and facilitation, students may face difficulties undertaking the feedback tasks in different phases of the dialogic feedback, resulting in limited impact of feedback on learning and task progress. When implemented online, students' feedback activities can yield massive amount of trace data and using learning analytics techniques (Gašević, Dawson, & Siemens, 2015) these data can be exploited in a meaningful way to promote instructor facilitation and to provide direct help to learners. I will explore the use of learning analytics to scale dialogic peer feedback based on the conceptual model explained in the previous section.

## Methodology

I am currently working on several learning scenarios to illustrate the application of the proposed model in practice and outline how learning analytics is integrated to support the dialogic feedback processes. These scenarios will be evaluated by instructors of online or blended courses as well as by the expert researchers in the feedback domain. I will conduct interviews and online surveys to facilitate the evaluation, and the data collected will be analysed (using content analysis) to identify critical revisions in the scenarios, and the implications of these revisions for refining the model. After the model and the scenarios are finalized, a web-based tool for dialogic peer feedback, called *Synergy*, will be developed to use in real-world courses.

In these courses, a questionnaire with Likert scale items as well as open-ended questions will be used to inquiry about students' experiences in dialogic feedback enabled via *Synergy*. Students' responses to open-ended questions will be analysed using Grounded Theory to identify emerging themes about student dialogic engagement and their satisfaction with *Synergy*. Students' activity logs will be also analysed as they can show the actual behaviour, which will be complementarity to the subjective responses in the questionnaire. Moreover, an online questionnaire will be developed to collect data regarding students' demographic information and learning characteristics that may affect their engagement in dialogic feedback. Learning characteristics to be measured will include goal orientations, self-regulated learning skills, and perceived social support. Questionnaire will comprise items from existing instruments in the literature. I will analyse the trace data to generate indicators of student engagement in feedback (e.g., time spent reading the feedback received). I will use the correlation and regression methods to identify the influence of students' feedback activities on their performance given their background and learning characteristics.

## Expected findings

The main findings expected in this research include how students engage in dialogic feedback in online environments, the effectiveness of *Synergy* (and the learning analytics incorporated in it) in supporting dialogic feedback interactions among students, and the factors that affect students' dialogic feedback behaviour and engagement. These findings will advance the current knowledge on dialogic peer feedback when it takes place in large scale higher education contexts and how learning analytics play role in supporting student engagement in dialogic feedback. The proposed model will be further refined and enhanced based on the implications derived from these findings.

## Expected contributions

The proposed model will guide the practitioners and researchers in their efforts to design feedback in large scale contexts. The use of learning analytics in dialogic feedback will inspire future research work on connecting learning analytics with feedback design. Similarly, the findings will contribute to the literature in understanding and supporting dialogic peer feedback using learning analytics methods and techniques. Moreover, the *Synergy* tool will be released as a plug-in to various learning management systems (such as Moodle), and it will become available for free use of other researchers and practitioners. This opportunity will support other researchers to study dialogic feedback and allow instructors to implement effective feedback practices in their courses.

## References

- Carless, D. (2016). Feedback as dialogue. In M. Peters (Ed.), *Encyclopedia of Educational Philosophy and Theory* (pp. 1–6). Singapore: Springer. <https://doi.org/10.1007/978-981-287-532-7>
- Gašević, D., Dawson, S., & Siemens, G. (2015). Let's not forget: Learning analytics are about learning. *TechTrends*, 59(1), 64–71. <https://doi.org/10.1007/s11528-014-0822-x>
- Hadwin, A. F., Järvelä, S., & Miller, M. (2017). Self-regulation, co-regulation and shared regulation in collaborative learning environments. In D. H. Schunk & J. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed.). New York, NY: Routledge.



# Learner Modeling of Cognitive and Metacognitive Processes for Complex Collaborative Learning Tasks

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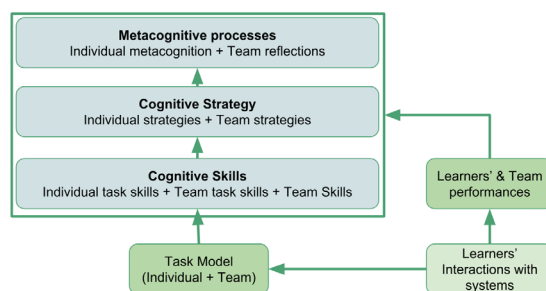
**Abstract:** Operations like dismounted battle drills, cordon and search, zone reconnaissance, and land navigation are crucial for armed forces. These operations require the trainees to learn task skills that involve thinking-skills (e.g., the skill of coming up with optimum route plan during land navigation) and the hands-on-skills (e.g., using compass and protractor to remain on correct direction during land navigation). Moreover, since these tasks are often performed as a team, it is crucial that the learners also acquire team skills in addition to the task skills. My research aim at supplementing current training of the security forces with the computer-based intelligent learning environment (ILE) to support the development of learners' cognitive skills, strategies, and metacognitive processes at individual and team levels as they collaboratively work on such complex decision-making and problem-solving tasks. The research would inquire into how the experts perform collaborative problem solving – when and how they distribute the subtasks among the team members, what are the characteristic of a “good” team problem solving, how do the novices perform the tasks. We look forward to apply quantitative and qualitative research methods to inform different components of the ILE that include: task skills expert model, team skills expert model, individual and team pedagogical models, learner models and team model, such that appropriate scaffolds can be identified and delivered to the learners at an appropriate time to help them improve their skills needed for such army tasks.

Operations such as dismounted battle drills, cordon and search, zone reconnaissance and land navigation are crucial for army and security forces. Developing proficiency in these operations, for example land navigation, does not only require individuals to understand technical knowledge of how to use tools, such as compass, maps, and protractors but also require them to learn cognitive skills such as route planning, terrain association, and situational awareness. This intertwined nature of domain knowledge and cognitive skills makes teaching-learning of such problem-solving tasks complex. The complexity is further elevated when these tasks are executed as a team. A team of individuals with fewer team skills can be counterproductive, and therefore in addition to the domain knowledge and cognitive skills, individuals also need to learn team skills. Gilbert et al., (2017) define ‘team task’ as “the task the group of individuals (team) is responsible for, which is similar to an individual task but also includes interdependency between team members.” Team task may require one or more individual skills (e.g. problem solving, computation etc.) as well as team skills (coordination, communication, etc.).

A range of intelligent Learning Environments (ILEs) exists to train learners on specific individual tasks (Capuano et al. 2000; Corbett et al. 1997). However, there is a dearth of research that deal with ILEs for team tasks. Recent research by Sottolare et al., (2017), Gilbert et al., (2017) and Fletcher & Sottolare (2017) have discussed foundations of ILEs as “team tutors”. The objective of my research is to design and implement a team tutor that can provide adaptive feedback to the learners based on their actions and performances while they practice tasks relevant to any armed forces operation in the ILE. The team tutor will use a game environment called Virtual Battle Space (VBS3) and will be implemented within the Generalized Intelligent Framework for Tutoring (GIFT) system which is a software framework made up of tools, methods, and standards that make it easier to author computer-based intelligent tutoring systems.

Contrary to the traditional ILEs, which consist of four components: i) *task skill expert model*, ii) *learner model*, iii) *pedagogical model*, team tutors require additional components of *team skills expert model*, *team pedagogical model* and *team model* (Gilbert et al., 2017). We will employ the team tutor designing steps as laid down by Gilbert et al., (2017). Which consist of 10 tasks that can be grouped into three categories: 1) *Creating domain model*, which include tasks of analyzing team task, defining team skills and task skills, defining behavioral markers of skills; 2) *Creating pedagogical model*, which include tasks of identifying common errors by team and members, creating performance metric for team and members, defining feedback approach, creating feedback, defining conditions for receiving feedback, creating conditions for GIFT (ILE); 3) *Evaluate and reiterate*, which requires the evaluations of team tutor and refinement of the domain and pedagogical models. Creation of domain model would be informed by expert studies and literature synthesis.





**Figure 1.** Proposed Three-Tier Learner model.

Novice studies and literature synthesis are expected to inform most of the tasks involved in the creation of the pedagogical model.

Learner modeling is an important component in any ILE. It helps in tracking learner achievements and performance states which is used by the pedagogical module to decide which scaffolds or feedback to be given at any given time to the learner. We propose to extend the existing learner modeling approach (Kinnebrew et al., 2017) to construct a hierarchical task model that captures the cognitive skills and strategies for complex decision making for a team tutor. As shown in Figure 1, the three-tier learner model would capture learner achievement states at three levels: a) cognitive skills level, which keeps track of individual task skills and team skills; b) cognitive strategy level, which keeps track of individual and team strategies; and c) metacognitive processes which involve individual and team reflections. Sequential mining algorithms would be employed to identify patterns of individual learner actions that can lead to desirable and undesirable learner states, and it would further help in updating feedback conditions in the domain model.

Our initial exploratory research (literature and expert interviews) in the context of land navigation tasks has thrown light into the list of specific tasks within the land navigation domain for which collaborative problem solving is beneficial. These tasks include compass reading, map reading, pace counting, dead reckoning, route planning, etc. The experts are of the view that the ideal team size for the land navigation task is two. An interesting finding from the expert interview is that while performing team tasks, team members switch between collaboration mode (when all team members perform one land navigation subtask) and cooperation mode (when different subtasks are assigned to a different team member). By cooperation, we refer to a fixed and stable division of subtasks, while by collaboration sub-task distribution is unstable and highly interwoven. After we choose an armed forces operation, in the initial phase of our research, we would apply quantitative and qualitative research methods to answer following research questions (RQ): *RQ1*) How do the experts perform the tasks in a collaborative setting? *RQ2*) What are the characteristic of a “good” team problem-solving? *RQ3*) What challenges novices face while performing the tasks? I shall continue administering expert and novice studies to answer these questions. By the end of this project, I expect to contribute with an ILE to improve learners’ task and team skills, local learning theories that explain how the collaborative problem-solving in the ILE caused the improvement in the learners’ skills, multi-modal learning analytics techniques that can help in studying collaborative learning and collaborative problem-solving.

## References

- Capuano, N., Marsella, M., & Salerno, S. (2000, June). ABITS: An agent based Intelligent Tutoring System for distance learning. In Proceedings of the International Workshop on Adaptive and Intelligent Web-Based Education Systems, ITS.
- Corbett, A. T., Koedinger, K. R., & Anderson, J. R. (1997). Intelligent tutoring systems. In Handbook of human-computer interaction, 5, 849–874.
- Gilbert, S. B., Slavina, A., Dorneich, M. C., Sinatra, A. M., Bonner, D., Johnston, J., ... & Winer, E. (2018). Creating a team tutor using GIFT. *International Journal of Artificial Intelligence in Education*, 28(2), 286-313.
- Kinnebrew, J. S., Segedy, J. R., & Biswas, G. (2017). Integrating model-driven and data-driven techniques for analyzing learning behaviors in open-ended learning environments. *IEEE Transactions on Learning Technologies*, 10(2), 140-153.
- Sottolare, R. A., Burke, C. S., Salas, E., Sinatra, A. M., Johnston, J. H., & Gilbert, S. B. (2018). Designing adaptive instruction for teams: A meta-analysis. *International Journal of Artificial Intelligence in Education*, 28(2), 225-264.

# Towards Personally-Relevant Learning: Bridging In-School and Out-of-School Learning Through Wearable Technologies

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**Abstract:** It is difficult for children to understand the relevance of science only through in-classroom instruction. Everyday experiences conversely represent rich opportunities for children to understand how science can be applicable in their everyday life. This research project proposes that wearable technologies may enable approaches that can bridge formal in-school learning with children's out-of-school experiences, especially within the domain of science. The project investigates various strands of inquiry to that effect across three studies. Results so far are promising, and appear to indicate that wearable technology, if designed properly and when combined with other types of technologies, may have potential to make science lessons more personally relevant for students.

## Goals of research

A main problem in the learning of science, especially at elementary levels, is that children do not understand how science is relevant to them. This lack of perceived usefulness often comes from the fact that science is decontextualized with respect to actual contexts of use in the science classroom (National Center for Science and Engineering Statistics, 2014). Yet, the child's experiences in the world outside the classroom is rich and full of experiences that implicitly or explicitly relate to science (Andrée, 2005; Mayoh & Knutton, 1997). These represent tremendous missed opportunities for science learning. The goal of our research is to investigate whether wearable technology can be part of an effective approach to bridge in-school formal learning of science concepts and students' science-related everyday experiences.

## Project background

Barfield and Caudell (2001) define a wearable as a “fully functional, self-powered, self-contained computer that is worn on the body ... (and) provides access to information, and interaction with information, anywhere and at anytime”. Wearables afford “interactive, communicative and functional capabilities between users, environment, information and digital data in unique ways” (Gomez, Flanagan, & Davis, 2015). Examples of modern wearable devices that have achieved a certain degree of success on the marketplace include smartwatches (e.g., Apple Watch) and wristbands (e.g., Nike Fuelband).

This project consists of two aspects: A) the use of wearables to capture and reflect on everyday experiences that are related to formal science concepts; and B) the use of the students' science-related everyday experiences in class lessons. Each of the two aspects is guided by a theoretical basis. For aspect A, we adopt the perspective of situated learning (Lave & Wenger, 1991). Situated learning states that learning happens in “authentic contexts” such as within cultural practices that are considered ordinary. The emphasis of situated learning is on the “interrelationships among learners, activity and [the] world” (Songer, Lee, & McDonald, 2003). It is particularly relevant for learning science, which entails the understanding of real-world concepts that address the physical, material and social environment around us. Situated learning has been the basis of a variety of learning technologies, including those using PDAs and more recently, virtual and augmented reality. For Aspect B, our research relates to the paradigm of culturally-relevant teaching and the idea of ‘funds of knowledge’. Funds of knowledge recognize that students come to class with prior experiences and knowledge that they have gained especially at home, in their community, from popular culture and their peer group (Hogg, 2011). Students' experiences in funds of knowledge studies are typically obtained through interviews or home visits.

## Methodology and findings

We have conducted three main studies thus far in this project. Study I was a lab-based study whereby 18 children aged 8 to 10 were invited to a lab and given a smartwatch to take home. Study II was conducted in collaboration with an elementary school. Twenty-two students from a fourth-grade class were assigned to capture stories related to the science concept that they were learning at school on a smartwatch. The teacher was tasked to subsequently integrate the students' stories into his science lessons. And Study III consisted of an analysis of video data of typical science classrooms covering a range of elementary grade levels and a diversity of science teachers. Notably, the studies have investigated the following strands of inquiry. We described here very briefly the results with respect to the different strands.

i) **Strand I:** The kind of motivational structures (storytelling VS gamification) that is most effective at

supporting children's motivation to capture science-related stories during their daily life using the smartwatch. We compared three different versions of the smartwatch app (a narrative-based, gamified, and hybrid version) and found a significant effect of app version for the construct of *effort*. The gamified version revealed the best compromise in terms of number of science stories and quality of stories (Garcia, Chu, Nam, & Banigan, 2018).

- ii) **Strand II:** The effects of capturing science-related everyday stories on students' feelings of self-efficacy in science, as opposed to only traditional classroom instruction. Students' self-efficacy increased after having used the smartwatch app as opposed to regular classroom instruction (Garcia et al., 2018).
- iii) **Strand III:** The types of stories related to given science concepts that children capture from their everyday experiences. We found two types of responses from the science recordings: i) short-answer and ii) long-answer. Short-answer responses had three subgroups: i) concept completion; ii) feature specification; iii) irrelevant. Long answer responses had five subgroups: i) definition; ii) example; iii) interpretation; iv) judgment; and v) irrelevant (Chu & Garcia, 2017).
- iv) **Strand IV:** Characteristics of the contexts in which children capture stories related to given science concepts. We found that there were three spikes of time where recordings were most frequent: i) 7am to 8am; ii) 4pm; iii) 8pm. We also found different triggers that caused students to initiate recordings: purposeful action, purposeful thinking and serendipitous connection.
- v) **Strand V:** Strategies that teachers currently use to make science lessons relevant for students. We found that teachers incorporate content that can be considered relevant into their lessons at different levels: using the context of the students, using the students' direct experiences, using their (teachers') own life experiences to create a vicarious connection with students, and at a general societal level.

## Expected contributions

This research project contributes to the literature at several levels: in terms of human-computer interaction, it contributes to our understanding of how to design wearable technology to support everyday science reflection; in terms of science learning, it help to understand how children make sense of their everyday experiences through the lens of science concepts; and in terms of education, it provides insights on a new pedagogical paradigm from which new approaches can be developed to bridge in-school and out-of-school science learning.

## References

- Andrée, M. (2005). Ways of using 'Everyday Life' in the science classroom *Research and the quality of science education* (pp. 107-116): Springer.
- Barfield, W., & Caudell, T. (2001). Basic concepts in wearable computers and augmented reality. *Fundamentals of wearable computers and augmented reality*, 3-26.
- Chu, S. L., & Garcia, B. (2017). *Toward Wearable App Design for Children's In-the-World Science Inquiry*. Paper presented at the International Conference on Tangible, Embodied and Embedded Computing (TEI), Yokohama,, Japan.
- Dibia, V. (2014). *An Affective, Normative and Functional Approach to Designing User Experiences for Wearables*. Paper presented at the International Conference on Information Systems SIGHCI 2014 Proceedings, Auckland, New Zealand.
- Garcia, B., Chu, S. L., Nam, B., & Banigan, C. (2018). *Wearables for Learning: Examining the Smartwatch as a Tool for Situated Science Reflection*. Paper presented at the Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems.
- Gomez, R. E., Flanagan, T., & Davis, R. M. (2015). *Designing experiences with wearables: A case study exploring the blurring boundaries of art, design, technology, culture and distance*. Paper presented at the Proceedings of the 6th IASDR (The Intl Association of Societies of Design Research Congress).
- Hogg, L. (2011). Funds of knowledge: An investigation of coherence within the literature. *Teaching and teacher education*, 27(3), 666-677.
- Lave, J., & Wenger, E. (1991). *Situated Learning : Legitimate Peripheral Participation* (1st ed.). Cambridge: Cambridge University Press.
- Mayoh, K., & Knutton, S. (1997). Using out-of-school experience in science lessons: reality or rhetoric? *International Journal of Science Education*, 19(7), 849-867.
- National Center for Science and Engineering Statistics. (2014). *Elementary and Secondary Mathematics and Science Education*. Retrieved from
- Songer, N. B., Lee, H. S., & McDonald, S. (2003). Research towards an expanded understanding of inquiry science beyond one idealized standard. *Science Education*, 87(4), 490-516.

# Flexible Scripting and Orchestration for Synchronous Learning

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**Abstract:** By bringing together carefully designed learning tools that support synchronous collaboration and generate rich data, with the idea of a graphical editor for flexible collaboration scripts that supports a workflow of algorithmically-driven group formation, artefact distribution and transformation, and a run-time environment that supports teachers during in-class orchestration, I hope to both further develop our understanding of how collaboration scripts and interfaces for collaborative learning can support student learning, but also enable teachers to implement CSCL approaches more widely in their classrooms.

## Introduction

My work focuses on the design, scripting and orchestration of collaborative learning scenarios. As a post-doc researcher at École Polytechnique Fédérale de Lausanne, I am currently leading the development of FROG, a modular system for synchronous collaborative learning workflows. FROG enables rapid experimentation with different CSCL scripts, innovative interfaces for student collaboration and knowledge co-construction, and learning analytics algorithms to support both teacher orchestration and agent-supported adaptivity. This platform not only supports a rich research program around technology-enhanced learning, but also aims at bridging the gap between research and prototypes, and real-world access and usage.

To ensure that rich interactive collaborative learning gains a foothold in universities and schools, and actually leads to better learning outcomes, we need to conduct research across a number of different grain sizes, and make connections between traditionally separate disciplines and research approaches. In this short paper, I will discuss my work at the micro and meso levels (from individual activities to collaboration scripts), but I am also interested in continuing work from my PhD on the macro level (integrating scripts into a curriculum design) and even at the mega level (integrating and tracking learning across an academic program).

## Design and analysis of synchronous activities/tools (micro)

We can define individual activities – such as collaborative writing, interacting with a simulation, or participating in a debate – as the micro-level. These activities are realized through tools and interfaces that need to support synchronous collaboration, and be optimized for learning in groups. By abstracting the complexity of synchronizing data, generating live-dashboards, managing student social groups, etc., FROG aims to provide an ideal test-bench for new designs, whether they be adding threading to chat, or social indicators to a concept mapping tool.

While interacting with these tools, learners generate a high density of “behavioural dust”, small data points that by themselves have no semantic meaning, but combined and analyzed can reveal patterns related to understanding, mental state, and the group collaboration process. A promising example of ongoing work is synchronous collaborative editing. We are currently working on a pipeline for analyzing the collaborative editing data, which aggregates atomic operations into meaningful Operations like inserting a whole sentence, and then annotates these Operations with contextual metadata about the history of the paragraph, the user’s previous actions, other users concurrent actions, the semantic relationships between text (spatially and longitudinally), and then using these rich sequences to infer writing strategies, role-taking, and progress.

## From activities to scripts (meso)

Going beyond individual activities, the Learning Science community has long been interested in scripts that foster certain cognitive and social processes. Asking students to first predict the outcome of a given simulation has been shown to provide much higher learning gains than simple unguided play, and our community has also provided elaborate scripts to support learning in groups, such as the jigsaw script mentioned above, think-pair-share, argue graph, pair-instruction, etc. These scripts typically require the use of multiple kinds of tools/activities, at multiple social planes (individually, in a small group, with the whole class), and a flow of artefacts between different activities and groups, and this complexity has not been well supported with existing software tools.

Orchestration Graphs (Dillenbourg, 2015), is a proposed formal language for expressing the dependencies of collaborative learning sequences. Based on this language, I designed FROG to provide this functionality in an extensible and user-friendly way. Teachers configure and place activities on a timeline consisting of three parallel social planes (individual, team, whole class), and then connect them together with connections. It gives researchers the ability to rapidly iterate multiple script designs, and quickly prototype new

collaborative interfaces, and teachers the ability to design or reuse complex scripts with no knowledge of programming.

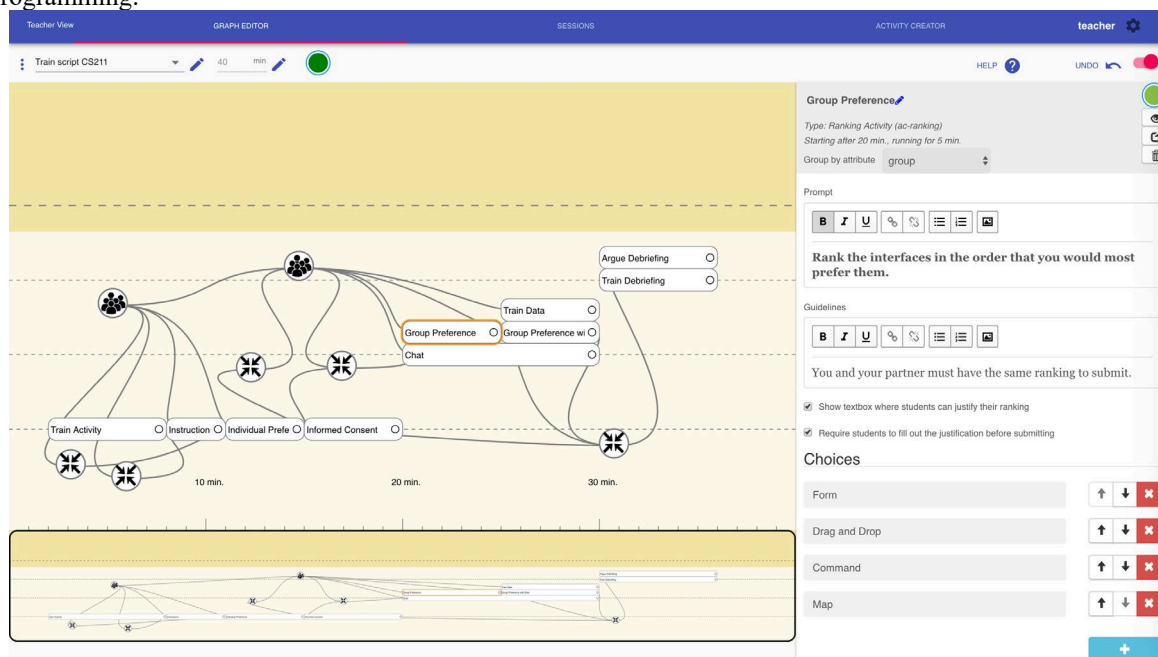


Figure 1. FROG script that was run in a lecture with 140 students, and also contained an experimental condition.

An important aspect of running complex scripts in actual classrooms is the teacher’s ability to orchestrate – using dashboards to understand what and how students and groups are doing, being able to modify or repair the script depending on changed circumstances. The learning analytics research done around individual activity types, such as the collaborative writing analyses mentioned above, directly feeds into the script design and orchestration support. At the primo-scripting phase, inferences about students’ collaboration or the semantic growth of the text can be connected to adaptive learning or automatic prompts, however at runtime they support teacher orchestration through contextual dashboards and alerts. In addition to these traditional content- and process-based dashboards, FROG also automatically predicts when students will complete multi-step tasks. I am currently investigating how these orchestration interfaces are being used in practice by teachers in large lectures at the University of Lausanne.

### Connecting learning design with learning analytics (meso)

Because of its formalization of the learning design and pedagogical scripts, as well as the detailed data captured, FROG opens new opportunities for script research. I am currently planning a series of experiments with CSCL scripts in MOOCs, where I will attempt to quantify the conditions under which scripts such as argue graph and jigsaw lead to the desired results. I will work with teachers who design MOOCs to add optional interactive sessions, where I can test multiple conditions (interfaces, algorithms for student grouping, specific prompts, script variations, etc.) at once. This will both give us a deeper and more rigorous understanding of how to implement these scripts in learning situations, but also serve as a proof of concept for more interactive MOOCs.

My longer-term goal is to enable teacher inquiry into student learning, by allowing teachers who design or reuse pedagogical scenarios to embed micro-hypotheses about student knowledge, the effect of different materials or questions, and rapidly test these hypotheses with their own students. I also wish to better understand what kind of scripts teachers and instructional designers develop.

### References

Pierre Dillenbourg. 2015. *Orchestration Graphs: Modeling scalable education*. EPFL Press.



# **Doctoral Consortium**





## 2019 CSCL Doctoral Consortium

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The CSCL 2019 Doctoral Consortium, designed to support the growth of young talented individuals working in the area of computer-supported collaborative learning (CSCL), provides an opportunity for Ph.D. students to share their dissertation research with their peers and a panel of faculty serving as mentors. Participants engage in collaborative inquiry and scholarly discourse to improve their dissertation work and to advance their understanding of the field. Participants are advanced graduate students at a stage in their dissertation research where the other participants and mentors may be of help in shaping and framing their research and analysis activities. Specifically, the Doctoral Consortium aims to:

- Provide an opportunity for participants to reflect on their dissertation research and to identify problems/issues for discussion and inquiry;
- Provide a setting for participants to contribute ideas and receive feedback and guidance on their current research;
- Provide a forum for discussing theoretical and methodological issues of central importance to CSCL and the learning sciences;
- Develop a network of supportive scholars in CSCL and the learning sciences across countries and continents;
- Collaborate and draw upon literature across countries and institutions;
- Contribute to the conference experience of participating students through interaction with other participants, mentors, and organizers; and
- Support young researchers in their effort to enter the CSCL and learning sciences research communities.

Doctoral Consortium activities, which begin online prior to the conference and run for two days before the full conference, are organized in diverse participation modes. Participants have opportunities to familiarize each other with their dissertation project and highlight specific aspects they would like to have further discussion on. Based on the common issues and themes identified (theoretical models, research design and questions, pedagogy and technology, data collection, methods of analysis, etc.) participants receive support from expert mentors to engage in further inquiry and discussion. Participants work on the various problems and issues identified making reference to their own dissertation project and the broader field of CSCL.

This year, a total of 11 doctoral consortium participants were selected out of a very competitive application pool. The attendees are currently engaged in their doctoral studies in Canada, Finland, Germany, Hong Kong, Israel, and the USA.

# Learning in the City: Joint Pursuits in Relational Pivot Points

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**Abstract:** This paper is about an undergraduate course in education. This preliminary analysis identifies how the agents and actants of city spaces elicited transformational learning experiences for students' regarding their own expertise and positionalities; during which they formed emergent relationships within their university community.

## Goals of the research

This work seeks to understand how undergraduate students in an education program at an urban university developed relationships with each other and their community through transformational learning experiences. I worked with a research team to co-design an instructional model for a course, *Learning Across and Within Settings* (LAWS), that focuses on the socio-cultural, -historical, and -political nature of learning environments. Within contextual exchanges, students developed relationships with their peers, community members, and local places through *joint pursuits* for collective sense-making and problem-solving.

## Conceptual framing

This project begins with the idea that individuals always develop in relation to their social world (Bang & Vossoughi, 2016). It is in their interactions with the social world that people develop cultural (Gutiérrez, 2002), embodied (Lindgren & Johnson-Glenberg, 2013), and narrative frames (Kirshner, 2015) for knowing and being; and these are always political and powered (Esmonde & Booker, 2017). Furthermore, the cultural tools employed in social practices make *material* the historical and political nature of the community (Cole, 1998), and they hold in relation bodies and histories-in-place (e.g., Taylor, 2018). We asked students to take up course objectives by observing and analyzing local practices through sociocultural frames of teaching and learning. In discussing these theories, our instructional design foregrounded the idea that students should endeavor for their experiences in LAWS to be transformational (e.g., Taylor, 2007) and to identify the relational nature of their own learning. At sites of local practices students encountered “pivot points” (Ellsworth, 2005) with environmental actants (e.g., people, tools, animals, plants) that introduced their own sociohistorical selves to ‘new’ places where personal pivots were made during emergent relationships with local stakeholders, peers, and the materiality of activities (Sannino, et al., 2016;).

## Project background

The goals of this project take place within an undergraduate education program: Education, Communities, and Organizations (ECO). LAWS was developed as a required course for the major, and it enrolls students who have a variety of interests and goals related to classroom teaching, social work, and psychology, to name a few. Of the students enrolled in the 2017-2018 ECO program, slightly more than half were first generation, four-year degree students. Demographics of this cohort include 6% of students self-identifying as African American, 20% self-identifying as Asian American, 32% self-identifying as white, about 23% self-identifying as Hispanic, 5% self-identifying as two or more races, about 13% self-identifying as international; some students identified as unknown.

## Methods

This is a design-based research project (Brown, 1992) that draws on principals of “social design experimentation” (Gutiérrez & Vossoughi, 2010) to instigate social inquiry for students about their relationships with each other and with the places and agents they pass by and through every day. Our course design required students to be out beyond the classroom, on the move (Taylor, 2017), and work together in *site visit groups* (SVGs) during their class time with 7 to 9 other undergraduates (UGs), alongside a graduate student mentor (GSM). GSMs utilized mobile wearable cameras to record learning activities. After each site visit, students developed page-length reflections about their experiences connected to the course readings, along with culminating course projects. Video analysis leveraged techniques from interaction analysis (Jordan & Henderson, 1995) and discourse analysis (Gee, 2004) to identify moments when students encountered relational pivot points in their interactions with local agents. These pivot points were signaled by changes in talk (Erickson, 2004) and body movement (Kendon, 1990) within the moment and over the duration of the 10-week LAWS course. After content logging a variety of relational pivot points across SVG experiences, I turned to student reflections of the corresponding visits to triangulate students' narrative accounts (Merriam, 2009) within these specific moments of relational exchange.

## Preliminary findings

I have identified key interactions in which UGs and GSMs engaged in *joint pursuit*, or a transitional space in which students and local actants engaged in relational exchanges for collective sense-making about the self and/or the sociocultural nature of the environment. In one example, a student encountered an ancient rhinoceros tomb in a local museum that challenged her religious beliefs. The triad of two UGs and one GSM (me), embarked on a joint pursuit to understand how both the student's inner reality and the outer social reality could be reconciled. The student later wrote in her reflection that her "perspective of the world is rooted in [her] family's traditions and values, and when [she] observe[s] or learn[s] about other cultures, [she] naturally compares them to" her own. In another example, an SVG traveled to an Indigenous cultural center of a local tribe, which is not federally recognized, where students noticed a lack of transit to the center, as well as having to cross a dangerous road to get to the building. This pivot point set students on a path toward potential future engagement with the local tribe by developing new relationships with each other and with presenced Indigenous knowledge systems that few had previously encountered.

## Expected contributions

Contributions of this work are three-fold. First, students who participate in relational pivot points with local stakeholders learn how to observe, analyze, and reflect on the political and powered nature of teaching and learning. Second, students' conceptions of self and community are transformed through collaborative problem-solving driven by joint pursuit. Third, the design principles of the LAWS course are adaptable for multiple contexts that focus on students' emergent relationships with their peers and community members. In so doing, we work together to foster potential future engagements with each other and with local stakeholders to define and work toward goals formed during collective sense-making.

## References

- Bang, M. & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and Instruction*, 34(3), 173-193.
- Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of Learning Sciences*, 2(2), 141-178.
- Cole, M. (1998). *Cultural psychology: A once and future discipline*. Harvard University Press.
- Ellsworth, E. (2005). *Places of learning: Media, architecture, pedagogy*. Routledge.
- Erickson, F. (2004). *Talk and social theory: Ecologies of speaking and listening in everyday life*. Blackwell Publishing.
- Esmonde, I., & Booker, A. N. (Eds.). (2017). *Power and privilege in the learning sciences: Critical and sociocultural theories of learning*. New York: Routledge.
- Gee, J. P. (2004). *An introduction to discourse analysis: Theory and method*. Routledge.
- Gutiérrez, K. D. (2002). Studying cultural practices in urban learning communities. *Human Development*, 45(4), 312-321.
- Gutiérrez, K. D., & Vossoughi, S. (2010). Lifting off the ground to return anew: Mediated praxis, transformative learning, and social design experiments. *Journal of Teacher Education*, 61(1-2), 100-117.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences* 4(1), 39-103.
- Kendon, A. (1990). Spatial organization in social encounters: The F-formation system. *Conducting interaction: Patterns of behavior in focused encounters*.
- Kirshner, B. (2015). *Youth activism in an era of education inequality*. New York: New York University Press.
- Lindgren, R. & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher*, 42(8), 445-452.
- Merriam, S. B. (2009). *Qualitative Research: A Guide to Design and Implementation*. Jossey-Bass.
- Sannino, A., Engeström, Y., & Lemos, M. (2016). Formative interventions for expansive learning and transformative agency. *Journal of the Learning Sciences*, 25(4), 599-633.
- Taylor, E. W. (2007). An update of transformative learning theory: A critical review of the empirical research (1999-2005). *International Journal of Lifelong Education*, 26(2), 173-191.
- Taylor, K. H. (2017). Learning along lines: Locative literacies for reading and writing the city. *Journal of the Learning Sciences*, 26(4), 533-574.
- Taylor, K. H. (2018). The role of public education in place-remaking: From a retrospective walk through my hometown to a call to action. *Cognition and Instruction*, 36(3) 188-198.

# Teacher Identity and the Co-Design of CSCL That Creates Change

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**Abstract:** My dissertation explores how one teacher's professional vision (PV) was constructed across the co-design of a human-centered robotics curriculum. I consider the affordances of joint video analysis for supporting the development of nuanced PV—shaping the ways that one instructor reflected, adjusted facilitation, and designed CSCL experiences. In examining PV, I work to better understand how teacher identity (as designer and facilitator) is constructed and supported in co-design.

## Background and goals

My dissertation begins after a nearly four-year trajectory of implementations conducted with an instructor and our research team (see Gomoll et al. 2016; 2018). I focus on our recent work to iteratively co-design and implement a robotics unit focused on school safety for students (ages 13–14) in a rural U.S. community. The unit was co-designed to promote engagement with local issues—asking student groups to design and build robot prototypes that addressed problems in their school. School stakeholders (e.g., administrators, office staff) provided feedback to student groups as they identified safety concerns and designed robots to address them (e.g., providing a live hallway video feed during active shooter scenarios).

My dissertation explores how my teacher partner refined her identities as designer and facilitator during the work of co-design. Prior research has highlighted that for teachers to develop robust practices, they need to develop rich professional vision (PV)—the ability to see nuanced issues of teaching and learning in their environment (Borko, 2004; van Merriënboer et al., 2003). Carefully organized viewing of classroom video can highlight PV and thus make identity visible. Though video has been powerfully incorporated into teacher professional development in prior research (e.g., Maher et al., 2014; Sherin & van Es, 2005), further research is needed to understand how reflective video viewing of an instructor's own teaching in collaboration with a research partner can inspire shifts in PV and in the design of curricula. Across my dissertation, video is considered as a boundary object—a shared space for meaning making (Akkerman & Bakker, 2011).

Co-design sessions were structured to include goal setting, video analysis of prior and current curriculum implementations, and activity design. Sessions held prior to the unit mapped out the curriculum trajectory while those held throughout the implementation supported real time changes to facilitation and activity design. Video clips used in co-design highlighted instructor problem framing, scaffolded support, and varied examples of student engagement. Ongoing conjecture mapping (Sandoval, 2014) helped us to consider how our instructional design could support student outcomes.

The goal of my dissertation is to investigate how the use of video as a reflective tool can support the development of PV and the co-design of CSCL experiences. I ask: 1) How is professional vision discursively constructed in reflective co-design? 2) How can teacher professional vision construction in co-design inform the development of culturally situated and empowering PBL curricula?

## Methodological framework

Discourse analysis (DA) considers talk as a social action, and it can be used to identify discursive patterns and norms that both shape and are shaped by participants. DA begins with unmotivated looking and moves on to the identification of discursive actions (e.g., pointing, laughter) and the functions of these actions for creating meaning in the interaction (e.g., to establish joint attention, Potter & Wetherell, 1987). DA throughout my dissertation work will be informed by tenets of discursive psychology (DP) and conversation analysis (CA). DP is an interdisciplinary set of principles used to explore how psychological constructs (like identity) are made visible in interaction by participants (Edwards & Potter, 1992). CA focuses on the systemic organization of talk (membership categories, turn-taking, gesture) and identifies patterns related to how a discursive action is accomplished. DP as a methodology uses CA to understand how psychological objects are constructed (Potter, 2012). I use both approaches to understand how identity, and professional vision in particular, is enacted in the work of co-design.

## Data collection and analysis

The corpus of video data collected for this dissertation includes 29 co-design sessions conducted throughout an afterschool implementation of the robotics curriculum in Spring 2018 and an implementation of the curriculum in Fall 2018. 13 impromptu afterschool planning sessions during the Fall 2018 implementation were also collected. This corpus provides a longitudinal sense of shifts in co-design. The Spring 2018 afterschool

implementation of this curriculum included 10 students (3 female, ages 12 - 14) and took place weekly over the course of four months at a rural Midwest Junior High School. The Fall 2018 classroom implementation included 20 students (10 female, ages 13 - 14) engaged daily in an elective science class over the course of six weeks at the same school. Co-design video data was logged in 3-5 minute increments and emergently coded. Early code categories included professional vision (e.g., noticing, reasoning, and designing), identity (e.g., positioning or assessing expertise or roles), and cultural context (e.g., rules and norms). After preliminary coding, I have narrowed my analysis to center on the Fall 2018 implementation and codes surrounding PV—offering a thick description of our Spring 2018 work as context for what unfolded in the fall.

## Preliminary findings

Early analysis highlights discursive patterns including the instructor's attention to establishing and maintaining group norms (e.g., ensuring that all voices are heard), emphasizing the iterative nature of design (e.g., modeling how to talk about work as "a prototype"), and helping students build on each other's design ideas. Instructor-researcher reflection on video of the teacher's classroom during the implementation allowed the instructor to view group work that she had not witnessed during the class period—informing interventions made during future class periods. Across co-design experiences, instructor and researcher used video to communicate and collaborate as well as to design rich CSCL experiences for students. The instructor was motivated to integrate video analysis into students' design work—highlighting how the work of video analysis made her a better instructor and could also help students to become better communicators and collaborators. These early findings suggest that video analysis experiences conducted throughout the CSCL unit hold promise for real-time refinements of curricula that support both the development of instructors' facilitation practices, teacher identity, and student learning.

## Contributions

Rather than designing "innovative" curricula and handing them over to instructors who may not see the relevance of those innovations to their lives or those of their students, we must consider how shifting context, culture, and climate make different ideas relevant to teachers and learners at different points in time. This requires understanding teachers' identities and the ways that these identities develop and change. We need to work to understand and provide learning experiences where students and teachers are agents—working to create change in their local, national, and global communities. To do this well, we might consider the dynamic nature of teacher identity, how it emerges in co-design, and the promise of video analysis for informing instructional decisions and innovations. My proposed research serves as a starting point for this endeavor.

## References

- Akkerman, S. F., & Bakker, A. (2011). Learning at the boundary: An introduction. *International Journal of Educational Research*, 50(1), 1-5.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15.
- Edwards, D., & Potter, J. (1992). *Discursive psychology* (Vol. 8). London: Sage Publications.
- Gomoll, A., Hmelo-Silver, C. E., Šabanović, S., & Francisco, M. (2016). Dragons, Ladybugs, and Softballs: Girls' STEM Engagement with Human-Centered Robotics. *Journal of Science Education and Technology*, 25(6), 899-914.
- Gomoll, A. S., Tolar, E., Hmelo-Silver, C. E., Šabanović, S. (2018). Helping students fail: Constructive failure in middle school human-centered robotics design. *Thinking Skills and Creativity*, (in press).
- Maher, C. A., Palius, M. F., Maher, J. A., Hmelo-Silver, C. E., & Sigley, R. (2014). Teachers can learn to attend to students' reasoning using videos as a tool. *Issues in Teacher Education*, 23(1), 31-47.
- Potter, J. (2012). Discourse analysis and discursive psychology. In H. Cooper H. (Ed.), *APA handbook of research methods in psychology* (pp. 111-130). Washington: American Psychological Association Press.
- Potter, J., & Wetherell, M. (1987). *Discourse and social psychology: Beyond attitudes and behaviour*. London, UK: Sage.
- Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning?. *Educational researcher*, 29(1), 4-15.
- Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences*, 23(1), 18-36.
- Sherin, M., & van Es, E. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of technology and teacher education*, 13(3), 475-491.
- van Merriënboer, J. J., Kirschner, P. A., & Kester, L. (2003). Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist*, 38(1), 5-13.

# Modeling and Modes: Broadening Participation in Science Practices for Emerging Bilingual Students

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**Abstract:** Science practices integrate multiple modes for expression and sensemaking. Yet, verbal and written representations using academic English are often privileged over other modes in science education. In a design study, I explore how multimodal modeling shapes opportunities for reasoning and expression for emerging bilingual students. I use multimodal content analysis to identify how available resources interact to create meaning, and I use evolutionary and interactional mechanisms to understand students' appropriation of disciplinary practices over time.

Science practices rely on several modes, including visual, actional, and linguistic systems (Kress, 2000). These modes are not simply interchangeable or additive; rather, their differing affordances shape scientists' *professional vision* – their socially organized ways of seeing and understanding phenomena (Goodwin, 2017). Specifically, scientific modeling involves the creation, use, and revision of multimodal representations (Lehrer & Schauble, 2015). With sketches, structures, and computational representations, scientists laminate multiple modes to reason about and express ideas (e.g., Nersessian, 2017). Science classrooms similarly rely on multiple modes (Lemke, 2000), although formal verbal and written representations are often privileged over other modes (Grapin, 2018). Science education with bilingual learners has historically emphasized English learning as a pre-requisite for engagement in disciplinary practices. However, academic English is neither necessary nor sufficient for learning (Lee, Miller, & Januszyk, 2014). Instead, contemporary research promotes engaging students in language-intensive science practices to simultaneously support language and science learning, finding that students can leverage and laminate hybrid resources, including language, drawing, and gesture, to engage in complex and rigorous disciplinary thinking (e.g., Moschkovich, 2015).

In a classroom design study, I aim to understand the opportunities afforded by multimodal modeling contexts for emerging bilingual students to appropriate and transform science practices. A central feature of the design is engaging students in modeling activities that privilege unique modes for sensemaking and expression, including diagrammatic, physical, and computational modeling. These activities are paired with discursive practices and task structures that facilitate reflection and choice among modes to promote student ownership of ideas. This study is focused and motivated by the following questions: (1) What resources for sensemaking and expression are afforded by multimodal modeling, and how do these resources shape emerging bilinguals' opportunities for appropriating science practices? (2) How do design decisions support or constrain emerging bilinguals' opportunities for engaging in multimodal modeling practices?

## Methods

I address these questions with data from a five-cycle design study (Cobb et al. 2003), operationalizing learning as students' use and productive transformation of modeling practices (Goodwin, 2017). Within a 9-week NGSS-aligned ecology unit, the design aims to provide students with opportunities to reason about science and express their ideas across multimodal representations. Data sources include whole class video, student artifacts, and data from 3 to 5 focal students per cycle, including Camtasia computer screen recordings and interviews. Focal students are selected with input from the 6<sup>th</sup> grade teaching team to represent a variety in terms of background, academic performance, experience, and engagement. To understand resources and affordances for emerging bilingual students in this design, half of the selected focal students are classified as English Learners.

My analysis draws on methods from several fields. I use multimodal content analysis (Bezemer & Jewitt, 2010) to identify available modal resources and to describe how these resources interact to create meaning. To understand how students engage with modal resources, I use evolutionary and interactional mechanisms that explain the incremental development of practices over time (e.g., Goodwin, 2017). With this lens, I explore how available resources shape students' opportunities for participating in modeling practices. To analyze how activities and resources shape power and agency within the classroom, I use *interactive footing* (Goodwin 2007) to describe shifting dynamics between participants, and I use *ownership of ideas* (Cornelius & Herrenkohl, 2004) to operationalize power and agency. These methods allow me to put into conversation the fine-grained modal resources available to students, the ways that students leverage these resources, and the shifting practices and dynamics within the classroom over time.

## Preliminary findings

I have begun to analyze data from the first cycle of the project, focusing on how computational models shift students' participation in science as they engage in collaborative modeling. I find that computational models offer dynamic representations that can serve as projections of students' agency and identity, shaping lines of inquiry and facilitating student ownership of models. My data suggest that the computational model's *visual dynamic* mode supports disciplinary engagement, and the customizable visual mode for representing agents allows students to become increasingly *identified with* and *inhabiting of* the agents (Nemirovsky et al., 1998). The testable aspect of the computational model allows students to act on their interests by testing conjectures and immediately receiving feedback. In this way, the computational model creates unique opportunities for collaborative reasoning and expression and facilitates engagement in disciplinary lines of inquiry.

## Expected contribution

This study contributes an understanding of how emerging bilingual students participate collaboratively in modeling in a learning environment with rich multimodal resources, addressing the pressing need to broaden participation in computational thinking and science to communities of learners underrepresented in STEM. Currently, multimodality research is framed differently across fields. In English Learner (EL) education, multimodal resources are often framed as scaffolds to support academic English (Grapin, 2018). In linguistics and STEM education, modes and representations are framed as having unique affordances for reasoning and expression (e.g. Lehrer & Schauble, 2015). These fields also approach multimodality with different timescales and units of analysis. In linguistics, analysis is often limited to brief interactions, limiting opportunities to consider how modal resources shape the development of practices over time (Lemke, 2000). Science education research considers longer timescales; however, analysis often frames representations as self-contained artifacts, limiting opportunities to explore unique modal resources embedded within representations (Tang, Delgado, & Moje, 2014). In this study, I bridge research across these fields to explore how available modal resources shape students' opportunities for powerful and agentic reuse and transformation of collaborative modeling practices.

## References

- Bezemer, J., & Jewitt, C. (2010). Multimodal analysis: Key issues. In L. Litosseliti (Ed.) *Research methods in linguistics* (pp. 180-197). New York, NY: Continuum International Publishing Group.
- Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design Experiments in Educational Research. *Educational Researcher*, 32(1), 9–13.
- Cornelius, L., & Herrenkohl, L. R. (2004). Power in the classroom: How the classroom environment shapes students' relationships with each other and with concepts. *Taylor & Francis*, 22(4), 467–498.
- Goodwin, C. (2007). Interactive Footing. In E. Holt & R. Clift (Eds.), *Reporting Talk: Reported Speech in Interaction* (pp. 16–64). Cambridge, UK: Cambridge University Press.
- Goodwin, C. (2017). *Co-operative Action* (Learning in Doing: Social, Cognitive, and Computational Perspectives). Cambridge, UK: Cambridge University Press.
- Grapin, S. (2018). Multimodality in the new content standards era: Implications for English learners. *Tesol Quarterly*. doi: 10.1002/tesq.443
- Kress, G. (2000). Multimodality: Challenges to thinking about language. *Tesol Quarterly*, 34(2), 337–340.
- Lee, O., Miller, E., & Januszyk, R. (2014). Next Generation Science Standards: All standards, all students. *Journal of Science Teacher Education*, 25(2), 223-233.
- Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. In R. M. Lerner (Ed.), *Handbook of child psychology and developmental science* (pp. 1–44). Hoboken, NJ: Wiley.
- Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity*, 7(4), 273–290.
- Nersessian, N. J. (2017). Hybrid Devices: Embodiments of Culture in Biomedical Engineering. In K. Chemla & E. F. Keller (Eds.), *Cultures without Culturalism: The Making of Scientific Knowledge*. Durham, NC: Duke University Press.
- Moschkovich, J. N. (2015). Academic literacy in mathematics for English learners. *The Journal of Mathematical Behavior*, 40, 43-62.
- Nemirovsky, R., Tierney, C., & Wright, T. (1998). Body motion and graphing. *Cognition and instruction*, 16(2), 119-172.
- Tang, K.S., Delgado, C., & Moje, E.B. (2014). An integrative framework for the analysis of multiple and multimodal representations for meaning-making in science education. *Science Education*, 98(2), 305-326.

# Sustaining Knowledge Building Across Communities With Boundary Objects

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**Abstract:** Knowledge Building across boundaries benefits from community members' idea contribution and diverse social interaction. This study aims to explore designs of Knowledge Building across communities to sustain students' inquiries over time. This study used a design-based research approach with the support of two online platforms over two school years. As students conducted focused inquiry with their own discourse in their own community, they reviewed productive threads of ideas and created idea thread syntheses for cross-community sharing and interaction. Qualitative and quantitative methods were used to investigate the generation process and the quality of their idea thread syntheses and how cross-community interaction advances students' inquiry.

## Goals of the research

New advances in CSCL are needed to support emergent interactions at higher social levels (Stahl, 2013). This research contributes to addressing this need by exploring cross-community interaction for sustained knowledge building. Specifically, this study will attempt to bridge different knowledge building communities through idea thread syntheses in a design-based research approach (Collins, 1990). The goals and questions that this research intends to investigate are: (a) What characterizes the quality and nature of the idea thread syntheses generated by the students? (b) What kind of cross-community interaction occurs mediated by the synthetic boundary objects and how do students perceive the idea thread syntheses learning process? (c) How does cross-community collaboration affect the inquiry work in each classroom community? (d) What role do the teachers play in facilitating cross-community interaction?

## Background of the project

CSCL research has produced deep insights into how students pursue joint inquiry and collaborative discourse to build deep disciplinary knowledge (Bielaczyc & Collins, 1999; Hod, Bielaczyc, & Ben-Zvi, 2018; Scardamalia & Bereiter, 2006). Various social technology platforms have been developed to support students' collaborative inquiry, knowledge building, and discourse (Slota, Suthers, & Roschelle, 2014). Existing designs of collaborative learning and knowledge building focus on supporting students' interaction in individual classroom communities, and the inquiry activities tend to be short, lasting a few weeks (Lai & Law, 2006; Laferriere, 2012). In order to produce deep and sustainable changes in education, CSCL research needs to explore innovative designs to extend students' collaboration and inquiry to longer terms and higher social levels (Engle, 2006; Stahl, 2013). The current research explores improved strategies to connect the knowledge spaces of different communities by using "boundary objects" in a multi-level emergent interaction design (Star & Griesemer, 1989). The boundary objects are artifacts that can be used to bridge boundaries with an interpretative flexibility and a clear structure that is common to make them recognizable across social worlds. In this research, the idea thread syntheses were used as "boundary objects" in Knowledge Building communities.

## Methodology

This two-year research tested cross-community interaction among four grade 5 classrooms each year from a public elementary school located in the Northeast U.S. The students study human body systems for 6 and 8 months each year respectively. Their inquiry was designed in line with the principles of knowledge building and supported using Knowledge Forum Software (Scardamalia & Bereiter, 2006).

Adopting a multi-level emergence approach to knowledge building interactions, this study investigated the processes and impacts of cross-community knowledge building mediated through synthetic idea threads with three major phases: Phase 1-Study 1; Phase 2- Study 2. In *Study 1*, the participants expanded to four grade 5 classrooms. First, students in each classroom generated various interests and questions and formulate focal wondering areas, which informed students' subsequent inquiry. Students in each classroom contributed to and built on one another's ideas by writing notes in their home classroom's Knowledge Forum views. Second, as students deepened their inquiry, they were introduced to the cross-classroom "Super View." The Super View space included a section for each of the four classrooms together with a collection of all idea thread syntheses



created by previous classrooms that studied the human body. To support students' reflective review and structuring of distributed online discourse, this study used a new technology tool Idea Thread Mapper (ITM) to sort out the valuable notes (Zhang et al., 2018). Third, members of each classroom posted the idea thread syntheses in the Super View and had conversations to discuss what they learn from the other classrooms, identify connections, and build on the information gained for deeper research. *Study2*, this study tested a number of improvements to the cross-classroom interaction design. A new design of "Super Talk" which enables students across four classes working together to solve the challenging research question collaboratively were added and investigated.

## Preliminary findings

The preliminary analyses have shown promising results. The Study 1 findings show that students created high quality of reflection on substantive inquiry progress and complex scientific ideas for cross-classroom sharing, and generated more research questions that focus on specific issues seeking elaboration of reasons. Students built rich social connections with the peers from the other classrooms as well as deeper connections with peers from their own classroom. The insights gained from the cross-community space were further cycled back to each classroom to develop deeper understandings and inspire deeper collaboration and inquiry. The results of Study 2 show that students generated solid reflections and built on knowledge building interactions through the cross-classroom collaboration to extend and enrich the discourse in their home class. The "Super talk" enabled students further to expend their social connections while addressing challenging research questions.

## Expected contributions

This research will make contributions in several aspects. First, this study will provide an elaborated account of how young students create idea thread syntheses and work across the boundaries of the different classrooms to engage in collaborative knowledge building focusing on complex scientific issues. Second, the results of the study will extend the current literature of boundary crossing in the Knowledge Building field, and extend the design of collective knowledge space to include a multi-layer cross-community approach. Last, it will provide practical insights for other researchers and teachers to facilitate cross-classroom knowledge building activities to deepen students' inquiry with the support of idea thread syntheses.

## References

- Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C.M. Reigeluth (Ed.), *Instructional design theories and models Vol. II* (pp. 269-292). Mahwah NJ: Lawrence Erlbaum Associates.
- Collins, A. (1990). Toward a design science of education: Technical report no. 1 (Descriptive No. 1-135562167-A1). New York, NY: Center for Technology in Education.
- Engle, R. A. (2006). Framing interactions to foster generative learning: A situative explanation of transfer in a community of learners classroom. *Journal of the Learning Sciences, 15*(4), 451-498.
- Hod, Y., Bielaczyc, K., & Ben-Zvi, D. (2018). Revisiting learning communities: innovations in theory and practice. *Instructional Science, 46*(4), 489-506.
- Laferriere, T., Law, N., & Montané, M. (2012). An international knowledge building network for sustainable curriculum and pedagogical innovation. *International Education Studies, 5*, 148-160.
- Lai, M., & Law, N. (2006). Peer scaffolding of knowledge building through collaborative groups with differential learning experiences. *Journal of Educational Computing Research, 35* (2), 123-144.
- Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97-115). Cambridge University Press.
- Slotta, J., Suthers, D., & Roschelle, J. (2014). *CIRCL primer: Collective inquiry and knowledge building. CIRCL primer series*.
- Stahl, G. (2013). Learning across levels. *International Journal of Computer-Supported Collaborative Learning*.
- Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science, 19*, 387-420.
- Zhang, J., Tao, D., Chen, M. Sun, Y., Judson, D., & Naqvi, S. (2018). Co-Organizing the Collective Journey of Inquiry with Idea Thread Mapper. *Journal of the Learning Sciences, 27*:3, 390-430.

# Emergent Leadership in Student-led Collaborative Activity in a School-based Makerspace

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**Abstract:** The aim of this dissertation study is to analyze how leadership emerges in a school-based makerspace, and analyze the ways in which emergent leadership mediates student-led making activities. The study also aims to investigate how teachers can support productive leadership during student-led collaboration. In the study, leadership is defined as a reciprocal social process that develops in students' interactions. I argue that school-based makerspaces provide an important platform for the development of students' emergent leadership.

## Goals of the research

As a response to the ongoing changes in society and their learning requirements, there is an increased interest in education in the development and uptake of digitally enhanced, collaborative learning environments based on student-interest and initiation (Griffin, Care & McGaw, 2012; Kumpulainen, Kajamaa, & Rajala, 2018). These new environments change the traditional roles of teachers and students, engendering different possibilities for social activity than more traditional school settings. These changes are evidenced in students being able to take more leadership over their learning activities (Martin, 2015). However, the understanding of students' emergent leadership remains poor (Li et al., 2007; Sun et al., 2017; Yamauchi, 2001). It is hence important to increase research knowledge on students' leadership in contemporary learning environments. Recent research on student leadership primarily focuses on traditional classroom settings in which the problem to be solved and the group composition are defined from the outset. The proposed study aims to contribute to the understanding of students' emergent leadership in a school-based makerspace in which students have a substantial say in how they choose to engage in group activities, and thus take leadership over their learning activity.

In my doctoral study, I aim to depict emergent leadership from three angles: (a) student-student interactions, (b) student-teacher interactions, and (c) students' tool mediated interactions. The research questions are as follows: (a) What types of leadership moves can be detected in students' collaborative work? How do the identified leadership moves mediate collaborative design and making activities? (b) How do the teachers orient towards students' leadership in their reflections on the uptake of a school-based makerspace? How do the interactions between students and teachers enhance students' emergent leadership in the FUSE Studio learning environment? (c) In what ways do the tools and materials used in the FUSE Studio, create a context for diverse students' opportunities to emerge as leaders of joint learning activities?

## Background of the project

Previous research has shown that leadership is a pivotal, yet inadequately understood component of collaborative learning (Li et al., 2007; Sun et al., 2017, Yamaguchi, 2001). Emergent leaders can mediate interaction between group members, which in turn, shapes students' collaborative learning experiences (Li et al., 2007; Sun et al., 2017). Moreover, little is known about how leadership emerges in contemporary, digitally enhanced, open learning environments. The overall theoretical framing of my study draw on sociocultural and post-humanistic approaches, enriched by research on collaborative learning embedded in the learning sciences tradition (e.g. Barron, 2003; Li et al., 2007; Sun et al., 2017). According to this theoretical framing, I define emergent leadership as a social process that develops in students' interaction (Li et al., 2007; Sun et al., 2017; Yamaguchi, 2001).

## Methodology

The data comprise of video-recordings (142h), and semi-structured teacher interviews (22). The data were collected in a Finnish city-run comprehensive school, which had introduced a new school-based makerspace called the FUSE Studio (Stevens et al., 2016), in the fall 2016. The FUSE Studio is a student-centered, digitally enhanced design and making environment, which provides students with open-ended STEAM (*Science, Technology, Engineering, Arts, & Mathematics*) challenges.

I will use the techniques of interaction analysis (Jordan & Henderson, 1995) and multimodal interaction analysis (Norris, 2004) in the analysis of the video recordings, and qualitative content analysis (Kvale & Brinkmann, 2009) in the analysis of the interviews. The analytic approach is inductive (Derry et al., 2010) and involves repeated iterations between theory and data. I will use a multi-dimensional approach in the analysis of the data; I aim to depict the emergence of leadership from three different angles to address the research questions of each sub-study. These include: (a) Analysis of the verbal and nonverbal interactions of the students (b) Analysis

of the reflections of the teachers, and the verbal and nonverbal interactions between teachers and students (c)  
Analysis of students' tool-mediated interactions

### **Preliminary findings**

The results of the first sub-study of my dissertation showed that students emerged as leaders of the collaborative activities through the use various content-related and relational leadership moves, some of them unique to the makerspace environment. The study also showed that the use of leadership moves contributed to students' roles in collaborative work and these roles seemed to affect the outcome of the students' collaboration. The findings call for promotion of relation building and flexible shifts in role taking during student-led collaborative work

### **Expected contribution**

The study will produce important information for educational practice by unpacking how students' leadership emerges in a school-based makerspace, how leadership shapes student-led collaboration, and how teachers can support students' leadership as an important component of their transversal 21st century skills. The information and findings will also be significant for the developers of school-based makerspaces in Finnish schools.

### **References**

- Barron, B. (2003). When Smart Groups Fail. *Journal of the Learning Sciences*, 12(3), 307–359.
- Griffin, P., Care, E., & McGaw, B. (2012). The changing role of education and schools. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills*. New York, NY: Springer. 1–15.
- Jordan, B. & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences*, 4(1), 39 –103
- Kumpulainen, K., Kajamaa, A. M. & Rajala, A. (2018, in press). Motive-demand dynamics creating a social context for students' learning experiences in a making and design environment. In A. Edwards, M. Fler & L. Bottcher (Eds.) *Cultural-historical approaches to studying learning and development: societal, institutional and personal perspectives*. London: SAGE Publications Ltd
- Kvale, S. & Brinkmann, S. (2009) *InterViews: learning the craft of qualitative research interviewing*, 2<sup>nd</sup> ed. Los Angeles: SAGE
- Li, Y., Anderson, R., Nguyen, K., Dong, T., Archodidou, A., Kim, I. -H., Kuo, L. - J., Clark, A., Wu, X., Jadallah, M., & Miller, B. (2007). Emergent leadership in children's discussion groups. *Cognition and Instruction*, 25(1), 75 –111
- Martin, L. (2015). The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research*, 5(1), 30-39.
- Norris, S. (2004). *Analyzing multimodal interaction – A methodological framework*. New York: Routledge
- Stevens, R., Jona, K., Penney, L., Champion, D., Ramey, K.E., Hilppö, J., Echevarria, R., Penuel, W. (2016). FUSE: An alternative infrastructure for empowering learners in schools. *Proceedings of International Conference of the Learning Sciences, ICLS*, 2(2016), 1025–1032.
- Sun, J., Anderson, R.C, Perry, M., Lin, T-J. (2017) Emergent Leadership in Children's Cooperative Problem Solving Groups. *Cognition and Instruction*, 35(3), 212–235.
- Yamaguchi, R. (2001). Children's learning groups: A study of emergent leadership, dominance, and group effectiveness. *Small Group Research*, 32(6), 671–697.

# Temporal Patterns and Visualizations of Peer Talk: Toward Understanding the Process and Performance of Dialogic Collaborative Problem-Solving

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**Abstract:** Dialogic collaborative problem solving (CPS) describes how students collaboratively solve a problem mainly through talk. Existing studies intensively explored cumulative features of productive peer talk based on a coding-and-counting approach. Nevertheless, it has not been fully understood how utterances historically and dynamically unfold overtime and gradually shape the group solution quality. This dissertation aims to identify temporal patterns of peer talk that can distinguish high-performing groups from low-performing groups in the dialogic CPS and examine the degree to which these temporal patterns help better predict group solution quality.

## Introduction

Benefits of collaborative problem solving (CPS) have been intensively explored and well-established (e.g., Johnson & Johnson, 2016; Slavin, Lake, Hanley, & Thurston, 2014). CPS competence, as a relatively new construct, has been increasingly emphasized nowadays (e.g., Cukurova, Luckin, Millán, & Mavrikis, 2018; Griffin & Care, 2015; OECD, 2017).

Language is a powerful tool supporting human intra- and inter-thinking in CPS (Voygotsky, 1978). Discourse manifests cognition (Resnick et al., 1997, p.2). Certain forms of peer talk could induce higher-order thinking and larger amount of academic learning (Chi et al., 2018; Gillies, 2017; Sullivan & Barbosa, 2017).

Talk is historical and dynamic (Bakhtin, 1981; Mercer, 2008). Temporal analysis of interaction has been increasingly emphasized fairly recent in both Learning Analytics and Computer-supported Collaborative Learning communities (Chen, Wise, Knight, & Cheng, 2016; Chen, Resendes, Chai, & Hong, 2017; Csanadi, Eagan, Kollar, Shaffer, & Fischer, 2018; Knight, Wise, & Chen, 2017; Knight, Wise, Chen, & Cheng, 2015; Kapur, 2011; Mercer, 2008; Reimann, 2009; Swiecki, Ruis, Farrell, & Shaffer, 2019). Interaction patterns affect learning outcomes in collaborative learning (Cen, Ruta, Powell, Hirsch, & Ng, 2016). There are interdependencies of peer talk at multiple time scales (Wise & Chiu, 2011). It is necessary to know the temporal development of the dialogue in order to make educational sense of peer talk (Mercer, 2008) and further scaffold promotive interdependencies in collaboration.

The emerging temporal learning analytics face theoretical and technical challenges in analyzing time-series data and making educational sense of the results (Chen et al., 2016; Knight et al., 2017, 2015). Visual learning analytics as an emergent trend in making sense of learning data and supporting decision making of stakeholders has attracted lots of attention (Vieira, Parsons, & Byrd, 2018). It aims at leveraging computer and human power through integrating data mining as well as information visualization techniques. There are a lot of temporal visual learning analytic techniques that have been used to decompose the temporality of peer talk including the chronologically-oriented representation for discourse and tool-related activity (CORDTRA diagrams) (Hmelo-silver et al., 2009), Epistemic Network Analysis (ENA) (Gašević, Joksimović, Eagan, & Shaffer, 2018; Shaffer et al., 2009), Lag Sequential Analysis (LsA) (Chang et al., 2017; Chen et al., 2017; Kapur, 2011), Knowledge Building Discourse Explorer (KBDeX) (Oshima, Oshima & Matsuzawa, 2012; Oshima et al., 2019) and Markove Models (Reimann, 2009; Thompson et al., 2013).

## Goal of research

This dissertation aims at identifying core temporal patterns of peer talk in dialogic CPS in terms of turn-taking, joint knowledge construction and move-taking three aspects. These temporal patterns are expected to distinguish high-performing and low-performing groups and thus help better predict group performance.

## Methodology

This research will contain two phases. Phase 1 aims at identifying turn-taking, joint knowledge construction and move-taking patterns that can distinguish high-performing and low-performing groups. Quantitative and qualitative methods will be integrated to extract and interpret the patterns. Visualization techniques will be

adopted not only to illustrate temporal patterns but also conduct exploratory data analysis to visually evaluate hypotheses and generate new assumptions.

It is hypothesized that there are more leadership rotations, progressive knowledge construction and co-constructive move-taking sequences in high-performing than the low-performing groups. To test these hypotheses, phase 1 will involve around 400 fourth-grade students from around 10 classes in mainland China. Each group will include 3 or 4 students and solve two process-open challenging mathematics problems. Before the test, students need to independently finish questionnaires on their demographic information, personality type, self-efficacy in CPS, and the degree to which they like to collaborate with their partners. After solving the two problems, students will be asked to evaluate their own performance, group performance, peer performance and the degree that they would like to collaborate with their partners again. Group discussion will be videotaped and transcribed. Their written discourse will be collected as well to facilitate the interpretation of peer talk. Leadership rotation in turn-taking will be analyzed by the change of betweenness centrality in social network through the KBDex. Progressiveness of joint knowledge construction will be analyzed through lag sequential analysis and frequent sequence mining. Co-constructive move-taking sequence will be examined through the epistemic network analysis.

Phase 2 will use the same dataset with phase 1. Group performance will be represented by raw solution scores. Linear regression analysis will be adopted to model group collaboration and identify significant predictors of group performance. To automatically predict group performance in the early-stage, non-verbal features (e.g. individual prior knowledge, self-efficacy, personality, friendship etc.) and turn-taking features (e.g. number of turns/words and leadership rotation etc.) will be considered as potential predictors. To compare the impact of temporal features and cumulative features, all relevant cumulative verbal and non-verbal features and temporal patterns identified in phase 1 will be included as potential predictors.

## Expected contributions

This dissertation is expected to extend research on talk temporality and usage of visualizations in analyzing talk. It will extract temporal patterns of face-to-face peer talk and link it to group performance in the dialogic CPS context. It will help us better make sense of how peer talk shapes group performance from three aspects: turn-taking, joint knowledge construction and move-taking. Though it has been a core interest to predict group performance in the CSCL context, few efforts have been put to include temporal features of face-to-face peer talk. This dissertation will develop a regression model including core temporal features of peer talk to explain and predict group performance.

## Selected references

- Chen, B., Resendes, M., Chai, C. S., & Hong, H. Y. (2017). Two tales of time: uncovering the significance of sequential patterns among contribution types in knowledge-building discourse. *Interactive Learning Environments*, 25(2), 162–175. <http://doi.org/10.1080/10494820.2016.1276081>
- Chi, M. T. H., Adams, J., Bogusch, E. B., Bruchok, C., Kang, S., Lancaster, M., ... Yaghmourian, D. L. (2018). Translating the ICAP Theory of Cognitive Engagement Into Practice. *Cognitive Science*, 42(6), 1777–1832. <http://doi.org/10.1111/cogs.12626>
- Csanadi, A., Eagan, B., Kollar, I., Shaffer, D. W., & Fischer, F. (2018). When coding-and-counting is not enough: using epistemic network analysis (ENA) to analyze verbal data in CSCL research. *International Journal of Computer-Supported Collaborative Learning*, 13(4), 419–438. <http://doi.org/10.1007/s11412-018-9292-z>
- Gillies, R. M. (2017). Promoting academically productive student dialogue during collaborative learning. *International Journal of Educational Research*, (July), 0–1. <http://doi.org/10.1016/j.ijer.2017.07.014>
- Hmelo-silver, C. E., Liu, L. E. I., & Jordan, R. (2009). Visual representation of a multidimensional coding scheme for understanding technology-mediated learning about complex natural systems. *Computers & Education*, 4(3), 253–280.
- King, A. (2008). Structuring peer interaction to promote higher-order thinking and complex learning in cooperating groups. In *The teacher's role in implementing cooperative learning in the classroom* (pp. 73-91). Springer, Boston, MA.
- Shaffer, D. W., Hatfield, D., Svarovsky, G. N., Nash, P., Nulty, A., Bagley, E., ... Mislavy, R. (2009). Epistemic Network Analysis: A Prototype for 21st-Century Assessment of Learning. *International Journal of Learning and Media*, 1(2), 33–53. <http://doi.org/10.1162/ijlm.2009.0013>
- Vieira, C., Parsons, P., & Byrd, V. (2018). Visual learning analytics of educational data: A systematic literature review and research agenda. *Computers and Education*, 122, 119–135. <http://doi.org/10.1016/j.compedu.2018.03.018>

# Interplay of Different Group Awareness Information for Improving Collaborative Learning in Social Media

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**Abstract:** In computer-supported collaborative learning, group awareness tools have shown to be helpful regarding learning processes and outcomes. Previous research has focused on the support via cognitive and behavioral group awareness information, largely ignoring emotional problems and often investigating these aspects separately. To support large social media groups, integrating different awareness information may yield benefits, since these communities deal with several challenges. Therefore, my Ph.D. project aims at exploring interaction effects between different group awareness information.

## Background and goals

Wikis are web-based social media platforms that enable collaboration and therefore social interaction at virtually any point in time and between anyone (Chen, Jang, & Chen, 2015). They offer a tremendous potential for computer-supported collaborative learning (CSCL). Wiki environments can facilitate cognitive processes as the mutual exchange in wiki talk pages can lead to socio-cognitive conflicts that allow the beneficial reorganization of individuals' cognitions (Bell, Grossen, & Perret-Clermont, 1985). However, as part of a series of undergraduate studies, we have already shown that learners only participate in joint discussions when instructed to do so. Otherwise, collaborators tend to show cooperative behaviors instead of engaging in valuable social interactions (Heimbuch, Ollesch, & Bodemer, 2018). Based on the current state of the art, three main reasons for this can be identified: 1) Participatory challenges: Within CSCL environments, participants often lack the motivation to engage in collaboration or the sharing of knowledge (Kimmerle & Cress, 2008); 2) Cognitive challenges: Meaningful contributions are often not salient enough in wiki talk pages (Heimbuch & Bodemer, 2017); 3) Emotional challenges: Socio-emotional issues like relational conflicts can strongly influence task performance (Avry & Molinari, 2018). Although group awareness tools (GA tools) are expected to be beneficial in all these areas to stimulate productive interaction activities (Miller & Hadwin, 2015), it is postulated that the three challenges mentioned above are not addressed by one GA component alone. Figure 1 provides an overview of the challenges and how they can be overcome by different types of GA information. Cognitive GA tools have shown to mainly address cognitive challenges by facilitating the navigation and selection of meaningful content. Moreover, the visualization of partner knowledge facilitates grounding and partner modeling in the content space of social interactions (Janssen & Bodemer, 2013). Behavioral GA tools address participatory challenges by the visualization of collaborators' activities and thus serve as a source of motivation for (equal) participation in the social interaction space (Kimmerle & Cress, 2008). Emotional GA tools are helpful to facilitate joint emotion regulation in the relational space, to enhance mutual transactivity and to create a positive group climate (Avry & Molinari, 2018). A special feature of the visualized model is the distinction between the information presented by the GA tool and the actual person's GA, which depends on the individual's interaction with the GA information. Moreover, the model differentiates between behavioral and emotional GA information which is often summarized as social GA aspects (e.g., Janssen & Bodemer, 2013).

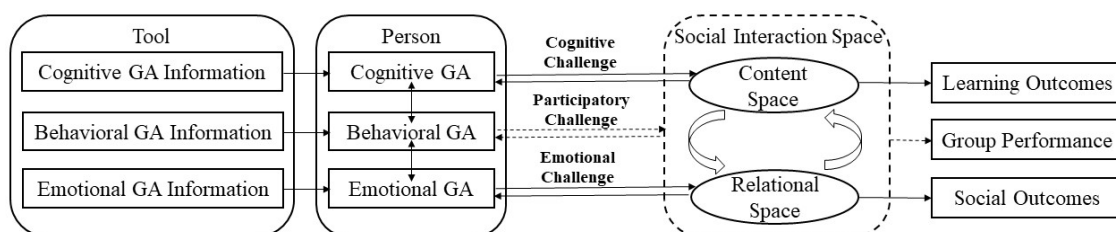


Figure 1. Framework which serves as basis for the upcoming studies.

It is obvious that for an effective group performance (see Figure 1, e.g., wiki article quality), cognitive, behavioral and emotional GA is required, thus necessitating GA tools that provide different types of GA information. Therefore, the aim of my Ph.D. project is to investigate 1) how wiki collaboration can be optimized by the interplay of different GA information, 2) what kind of processes and outcomes are triggered by the single and combined visualization of GA information, 3) how learners perceive and interact with the tool information

and 4) which role influencing personality variables play, such as the need for cognition, the mental effort and the tendency towards social comparisons. Two empirical studies are planned for this year, which will help to improve the support of wiki learning processes and outcomes.

### **Methodology, expected findings and further issues**

In one experimental study individual learners will collaborate in a bogus one-to-many wiki collaboration on the controversial topic of energy sources. A 2x2 between-subjects design with the factors cognitive and behavioral GA information is planned. GA information will be displayed in the form of two vertical bar charts (average expertise and participation rate). These will be presented on an accumulative level and next to each of twelve talk page threads. Subjects will be asked to learn with the talk page contributions and may write their own contributions. In the end, every subject is going to receive a knowledge test as well as a questionnaire about social outcomes and personal GA. Eye-tracking will be used to examine the learning process and to identify if more and specific tool fixations are related to specific interactions and outcomes. Moreover, it will be examined how pupil and attention metrics differ when a high mental effort is reported. Among the expected results is that behavioral GA primarily activates participation, whereas cognitive GA guides the direction of participation. A high tendency towards social comparisons should especially strengthen the behavioral GA effects, whereas need for cognition should influence the willingness to engage in discussions of high qualitative content. Emotional GA (friendliness bar chart) and group performance will not be considered in this study but will be regarded in the follow-up studies, having regard to real collaborations. Depending on the outcomes, the future studies will consider more concrete strengths and weaknesses of the GA information, as well as qualitative methods.

A further Ph.D. study will examine three types of GA information (average expertise, participation and friendliness) at once by means of decision-making tasks. Every task will include three visualizations of wiki group constellations, each containing three bar charts with different levels of the aforementioned GA aspects. The subjects will be provided with a scenario and will be asked which wiki group out of the visualized groups they would like to join for collaboration. Here, choice-based conjoint analysis is going to be applied. This will help to determine how people value different types of GA information and their interactions based on several collected personality characteristics. This quantitative approach will be supplemented by qualitative interviews to identify the motives behind the decision-making.

### **Contribution to the doctoral consortium workshop**

Although there are already some promising separate findings on various GA tools, the special contribution of my work is that I combine findings from recent cognitive, behavioral and emotional GA tool research and examine GA effects and their interplay already at the stage of visual perception. Moreover, my research does not only focus on the objective information given by a GA tool but also the mediating effect of personal GA, which is currently rarely considered. Especially when several aspects of GA are combined, it may be that some types of information are used more heavily than others. Thereby, I contribute to the conceptual development of the CSCL research field and connect different research communities.

### **References**

- Avry, S., & Molinari, G. (2018). Sharing emotions impacts computer-supported collaborative processes: Effect of an emotion awareness tool. *Revue Tranel*, 68, 85–96.
- Bell, N., Grossen, M., & Perret-Clermont, A.-N. (1985). Socio-cognitive conflict and intellectual growth. In M. Berkowitz (Ed.), *Peer conflict and psychological growth*. San Francisco: Jossey-Bass.
- Chen, Y.-H., Jang, S.-J., & Chen, P.-J. (2015). Using wikis and collaborative learning for science teachers' professional development. *Journal of Computer Assisted Learning*, 31(4), 330–344.
- Heimbuch, S., & Bodemer, D. (2017). Controversy awareness on evidence-led discussions as guidance for students in wiki-based learning. *The Internet and Higher Education*, 33, 1–14.
- Heimbuch, S., Ollesch, L., & Bodemer, D. (2018). Comparing effects of two collaboration scripts on learning activities for wiki-based environments. *International Journal of Computer-Supported Collaborative Learning*, 13(3), 331–357.
- Janssen, J., & Bodemer, D. (2013). Coordinated computer-supported collaborative learning: Awareness and awareness tools. *Educational Psychologist*, 48(1), 40–55.
- Kimmerle, J., & Cress, U. (2008). Group awareness and self-presentation in computer-supported information exchange. *International Journal of Computer-Supported Collaborative Learning*, 3(1), 85–97.
- Miller, M., & Hadwin, A. (2015). Scripting and awareness tools for regulating collaborative learning: Changing the landscape of support in CSCL. *Computers in Human Behavior*, 52, 573–588.

# Weaving Together: Exploring How Pluralistic Mathematical Practices Emerge Through Weaving

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**Abstract:** Inequities in math achievement and participation still exist, particularly for women and people of color. I argue that there is promise in weaving, a craft with deep roots in mathematics, to encourage diverse mathematical practices. This dissertation explores these intersections through interviews with experienced weavers and a 10-day weaving workshop with children.

## Goals of the research

Despite recent efforts to support learners from traditionally minoritized backgrounds in mathematics, inequities in math achievement and participation still exist, particularly for women and people of color (e.g., Boaler & Sengupta-Irving, 2012). Multiple issues, including the undervaluing of learners' diverse skills and abilities (e.g., Moses & Cobb, 2001) may impact who is invited and allowed to be successful in STEM spaces. To address these issues, educators need to more carefully consider how diverse mathematical practices can be recognized and valued. In this dissertation, I argue that there is unique promise in traditional yarn crafts for encouraging this diversity in STEM education, particularly through weaving. While the craft has been shown to be highly mathematical in certain contexts (e.g., Greenfield & Childs, 1977; Saxe & Gearhart, 1990), work has not explored the mathematical nature of weaving in modern educational contexts. I will conduct the project in two phases of qualitative inquiry. First, I will conduct semi-structured interviews with adult weavers, seeking to honor the experiences and knowledges of expert crafters to further inform future classroom interventions. Second, I will design and conduct a two-week weaving unit to better understand how to leverage weaving toward epistemological pluralism in STEM classrooms.

## Background of the project

In this work, I adhere to the constructionist lens of epistemological pluralism, a commitment to valuing multiple ways of knowing (Turkle & Papert, 1990). This lens allows us to see that there are multiple forms that can demonstrate learning and pushes us to think more broadly to recognize those forms as valid. Research on disciplinary content embedded in weaving practices is relatively rare. One study focused on the pattern representation abilities of children in Mexico (Greenfield & Childs, 1977). Other work explored the topological representation abilities of young straw weavers in northeastern Brazil (Saxe & Gearhart, 1990). These researchers concluded that weaving experience influenced children's abilities to notice and reconstruct topological features, although they were more skilled at physically representing their understanding than verbalizing (Saxe & Gearhart, 1990). This study is promising, as topological representation is an advanced area of mathematics not often explicitly discussed in elementary or middle school math. The study also honors the ways the learners do math, recognizing the value in the physical representations.

## Methodology

Phase A of the dissertation asks the question: #1: How do experienced weavers characterize the intersections, overlaps, and departures between weaving and mathematics, such as algebraic reasoning or working with patterns? I work to answer this by building on ethnographic methods and perspectives. I am conducting semi-structured interviews with at least 20 weavers with 5 years or more of experience who are being recruited from online craft communities. Hearing directly from experienced weavers will illuminate the lived experiences of crafters as well as authentic similarities and differences in the ways weavers talk about math in relation to their weaving practice. Building on these responses, phase B asks two questions: #2: In an intervention designed to expose youth to the mathematical practices inherent in weaving and from a critical and feminist perspective, how and what are youth learning about mathematics as they learn to weave? Particularly, how do student-created artifacts showcase learning and epistemological pluralism? #3: When and how do learners employ pluralistic mathematical ways of doing as they learn to weave? I am conducting a two-week workshop designed to help youth learn to weave and explore mathematics with 15-20 learners. This intervention will allow me to track changes in youth participation as they learn to weave and to use expansive definitions to understand the mathematical engagement taking place.



Table 1: Research methods and plan

	Research Question	Data Source	Data Analysis
Phase A	#1: How do experienced weavers characterize the intersections, overlaps, and departures between weaving and mathematics?	Semi-structured, in-depth interviews	Bottom-up coding -> traditional mathematics and new/unexpected forms of doing math
Phase B	#2: How and what are youth learning about mathematics as they learn to weave?	Pre-post design task artifacts and video Planning grid sheets	Artifactual analysis with attention to change over time and evidence of diverse mathematical thinking
	#3: When and how do learners employ pluralistic mathematical ways of doing while weaving?	Video of weaving intervention	Mediated Discourse Analysis with attention to expected and unexpected mathematical practices

## Preliminary findings

I conducted a pilot workshop that informs the design of the weaving implementation in this dissertation. Results began to illuminate that using tools such as grid paper to design weaving patterns prompts learners to invent their own notations for elements of the woven product such as “over,” “under,” and changing colors. These learner-generated notations resemble mathematical formalisms, similar to symbols standing in for ideas and numbers in traditional forms of mathematics. Learners were also seen employing problem-solving strategies such as wrapping yarn around several threads and using negative space as an aesthetic element. One participant began to invent a recursive pattern sequence, in a way that went above and beyond definitions of “math proficiency” by Common Core standards. He spoke his sequence as follows: (3, 2, 4, 3, 5, 4, 6, 5, 7, 6, 8, 7, 9, 8, 10, 9). This “minus one, plus two” pattern (see figure 1) showcases a robust way of thinking about patterns that was prompted by the weaving activity. Such practices may not be recognized or valued as mathematical in traditional math contexts, but the innovations of these learners can be seen through this work.

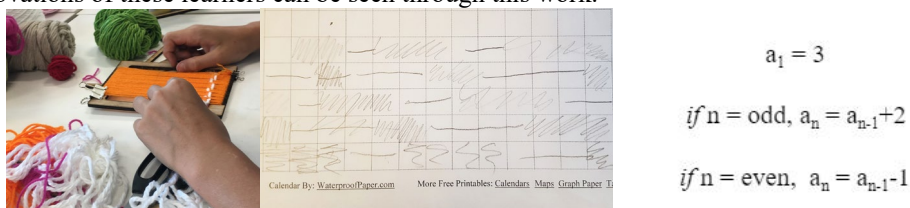


Figure 1. Kade weaving (left), Kade's project plan (center), Recursive function for Kade's pattern (right).

## Expected contribution

Rethinking and improving STEM education has long been a fruitful and necessary area of research. In the short term, the outcomes of this research will provide a framework for recognizing mathematical practices that emerge through weaving. This represents a crucial commitment in educational research to epistemological pluralism and lays groundwork for future work around epistemological pluralism in crafting and STEM classrooms. Future work should continue to examine what else is learned while learning to weave (e.g., computation, material science, color theory). Additionally, rethinking what counts as math and what math can look like could not only lead to new theorizing about mathematics, but could also potentially lead to new generations of researchers, mathematicians, and artists with radically different conceptions about the role of mathematics in education and everyday life.

## References

- Boaler, J. & Sengupta-Irving, T. (2012). Gender equity and mathematics education. In J.A. Banks (Ed.) *Encyclopedia of diversity in education* (pp. 973-976). Thousand Oaks: SAGE Publications.
- Greenfield, P. M., & Childs, C. P. (1977). Weaving, color terms and pattern representation: Cultural influences and cognitive development among the Zinacantecos of Southern Mexico. *Interamerican Journal of Psychology*, 11, 23-48.
- Moses, R. P., & Cobb, C. E. (2001). *Radical equations: Math literacy and civil rights*. Beacon Press (MA).
- Saxe, G. B., & Gearhart, M. (1990). A developmental analysis of everyday topology in unschooled straw weavers. *British Journal of Developmental Psychology*, 8, 251-258.
- Turkle, S., & Papert, S. (1990). Epistemological pluralism: Styles and voices within the computer culture. *Signs: Journal of women in culture and society*, 16(1), 128-157.

# Implicit Guidance, Explicit Guidance, or Both? Examining the Differential Effects of Collaboration Prompts and Group Awareness Tools on Students' Regulation of Online Collaboration

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**Abstract:** During collaborative learning in computer-mediated settings, students face challenges such as unequal participation or delayed feedback on contributions. These challenges decrease the effectiveness of the collaboration and potentially lead to frustration. Regulation in terms of these challenges can be facilitated by providing students with support. In an experimental field study, I investigate if students benefit more from explicit guidance (i.e., adaptive prompts), implicit guidance (i.e., a group awareness tool), or from the combination of both.

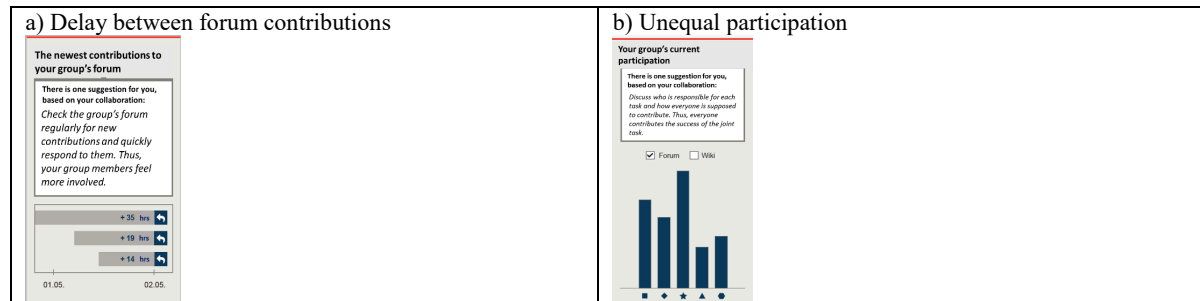
## Goals of the research and background of the project

During asynchronous online collaboration, groups face typical challenges such as unequal participation or long delays between contributions. These challenges not only can lead to process losses but also to frustration with the collaboration (Strauß et al., 2018). To facilitate regulation in terms of these typical challenges, a group can be provided with explicit or implicit guidance. Prompts (GE & Land, 2004) are an example of explicit guidance. Prompts suggest actions that learners can use to regulate their collaboration. Group awareness tools (GATs) are an example for implicit guidance (“tacit guidance”, Bodemer, 2011). GATs aggregate information about the current state of the collaboration and visualize it for the group. Combining these types of support has been suggested by several authors (e.g., Dehler et al., 2009, Janssen et al., 2011). However, research on the effects of combining GATs with explicit guidance has been scarce. Recently, Hadwin et al. (2018) combined a collaboration script with a (meta)cognitive GAT to examine the effect of different visualizations of students' task perceptions during collaborative planning of the collaboration. However, the aim was to augment an existing collaboration script with a GAT, hence, a control condition without any additional collaboration support was not included. Consequently, their study allows limited insights into the differential effects of implicit or explicit guidance. My current study addresses this gap by focusing GATs and collaboration prompts on the same “target” (c.f. Rummel 2018), that is, students' regulation during online collaboration. The study addresses the following research questions: (1) Do students benefit from a combination of a GAT and adaptive prompts in terms of their regulation of long delays between forum contributions and unequal participation? (2) Is there a correlation between satisfaction with the collaboration and a) delays between contributions in the groups' forums and b) unequal participation? Additionally, this study explores how students use and perceive these types of collaboration support.

## Methodology

Currently, a field experiment is being conducted in a 14-week online course for university students. The online course is offered for course credit via the university's LMS Moodle. Each course topic spans over two weeks and contains a video lecture, literature for basic reading and a group task. Each group task is solved collaboratively within the two weeks of each topic and requires the group to formulate a joint answer for a problem. For example, groups are asked to write the text underlying a short presentation, which presents the cognitive mechanisms behind collaborative brainstorming, presents a method how brainstorming processes can be facilitated and provide reasons for their choice. Students work on the task in Moodle using a private group forum and wiki. To answer the research questions outlined above, a 2×2 design is implemented using the following two factors derived from the dimensions of collaboration support presented in Rummel (2018): (1) information basis (cf. “foundation” in Rummel, 2018): Providing the group with aggregated information on the current state of their collaboration (GAT vs. no GAT), and (2) “directivity”: Suggesting the group explicit actions in order to regulate the collaboration (prompt vs. no prompt). The GAT and prompt target the groups' regulation in terms of two typical challenges during online collaboration (long delays between forum contributions and unequal participation). The GAT and the prompts are presented within Moodle using custom block-plugins for each typical challenge. The GAT visualizes a) the amount of time which had elapsed since the creation of the last three forum posts, and b) the amount of words each group member has contributed to the group's forum and wiki. The prompts suggest actions for the group to regulate but do not contain information on the current state of the collaboration (see [Figure 1](#)). The GAT and prompt are updated each time a student

contributes to the group's wiki or forum. The adaptive prompts are realized using threshold values. The prompt for each typical challenge is automatically presented if the delay between two forum contributions exceeds 24 hours, or if the distribution of participation in a group yields a gini-coefficient (c.f. Janssen et al., 2011) equal to 0.5 or higher, respectively.



**Figure 1.** Moodle plugins for the support provided to groups in the GAT | prompt condition. a) GAT and prompt for delay between forum contributions, b) GAT and prompt for unequal participation.

Data is collected during three topics (six weeks). For each student, the number of words contributed to the groups' discussion forum and wiki as well as the respective content (timestamped) are collected. In addition, online questionnaires are administered to measure group awareness, perceived participation of group members, satisfaction with the collaboration and perceived usefulness of collaboration support.

## Expected findings

Data collection is currently under way. It is hypothesized that students who receive both, a group awareness tool and a collaboration prompt, can regulate their collaboration more effectively in terms of the delay between forum contributions and unequal participation. As students reported these two challenges as frustrating, it is further hypothesized that groups which show a) shorter delays, or b) a more equal distribution of participation are more satisfied with their collaboration than groups which exhibit longer delays or more unequal participation.

## Expected contributions

With this study, I want to contribute first results on how two forms of collaboration support – implicit guidance and explicit guidance – support students during online collaboration in a university context. A second contribution concerns the perceived usefulness of GATs and collaboration prompts, as well as their combination.

## References

- Bodemer, D. (2011). Tacit guidance for collaborative multimedia learning. *Computers in Human Behavior*, 27(3), 1079–1086.
- Dehler, J., Bodemer, D., Buder, J., & Hesse, F. W. (2009). Providing group knowledge awareness in computer-supported-collaborative learning: Insights into learning mechanisms. *Research and Practice in Technology Enhanced Learning*, 04(02), 111–132.
- GE, X., & Land, S. M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development*, 52(2), 5–22.
- Hadwin, A. F., Bakhtiar, A., & Miller, M. (2018). Challenges in online collaboration: Effects of scripting shared task perceptions. *International Journal of Computer-Supported Collaborative Learning*, 13(3), 301–329.
- Janssen, J., Erkens, G., & Kirschner, P. A. (2011). Group awareness tools: It's what you do with it that matters. *Computers in Human Behavior*, 27(3), 1046–1058.
- Rummel, N. (2018). One framework to rule them all?: Carrying forward the conversation started by Wise and Schwarz. *International Journal of Computer-Supported Collaborative Learning*, 13, 123–129.
- Strauß, S., Rummel, N., Stoyanova, F., & Krämer, N. (2018). Developing a library of typical problems for collaborative learning in online courses. In J. Kay & R. Luckin (Eds.), *Rethinking Learning in the Digital Age: Making the Learning Sciences Count, 13th International Conference of the Learning Sciences (ICLS) 2018* (pp. 1045–1048). London, UK: International Society of the Learning Sciences.

# Towards Equitable Learning Futures: Sociopolitical Discourses, Practices, and Joint Work in an LGBTQ+ Youth Group

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**Abstract:** This dissertation deploys newer political approaches to the learning sciences to study the political and ethical dimensions of learning in an LGBTQ+ youth group in the United States. Using discourse analysis (specifically, discursive psychology and conversation analysis) alongside educational ethnography, I study (a) what kinds of knowledge these youth generate, (b) what the valued conceptual practices of the youth are and why they are valued, and (c) how youth work collaboratively to accomplish these practices.

## Introduction and background

Lesbian, gay, bisexual, transgender, queer, and other sexual and gender non-conforming (LGBTQ+) youth experience particular forms of discrimination in educative contexts. This learning sciences dissertation represents work *alongside* youth to offer a more nuanced, rather than damage-centered (Tuck, 2009), account of LGBTQ+ youth's intellectual lives. It draws on newer sociopolitical approaches to the study of learning (Politics of Learning Writing Collective, 2017; Philip, Bang, & Jackson, 2018) to examine the ethical and political dimensions of learning processes and practices. I work with Chroma, a community-based group for LGBTQ+ and allied youth ages 12-20. I engage in critical qualitative analysis – specifically, discourse analysis and educational ethnography – to address three research questions (each of which is the basis for an article of the dissertation) about learning in Chroma's teaching committee (TC), the subgroup of Chroma youth who give presentations to educators and other youth-serving professionals about issues affecting LGBTQ+ youth:

- RQ1. What sociopolitical knowledges are negotiated in Chroma's TC? In particular, what kinds of discourses have emerged around their collective minoritized experiences? How have these discourses shifted over time?
- RQ2. What are the valued collaborative conceptual practices of Chroma's TC? What are the ends of these practices?
- RQ3. At the level of interaction, how do youth go about accomplishing these conceptual practices?

Using theories from the learning sciences, I argue that Chroma's conceptual and discursive practices reflect political forms of learning that create opportunities to support collective dignity. In the dissertation, I show what these conceptual practices are, why youth value them, and how youth work collaboratively to accomplish them. In doing so, I seek to contribute to emergent political theories of learning that in turn support the study of the political dimensions of learning processes.

## Methodology

I draw on data collected over a three-year period culminating in academic year 2018-2019 (the "study year"). For RQ1, I examine PowerPoint presentations created by the TC over a three-year period from the lens of *discursive psychology* (DP; Edwards & Potter, 1992), an approach to the study of discourse that focuses on what versions of reality are constructed by discourse and how the discourse functions to create that reality. For example, in an early slide presenting to their teachers, TC youth wrote that teachers "will deny they're at fault for their words/actions when confronted." From a DP lens, this statement both constructs a reality in which this statement is true of TC youth's teachers and may threaten the face of these audience members (these teachers) by positioning them as bad listeners. I examine how this language has shifted over time (for example, TC youth no longer use this sentence in their slide decks) and treat this language as representative of TC youth's knowledge about both youth advocacy and gender and sexuality. For RQ2, I use audio recordings of biweekly TC meetings collected over the study year, individual interviews, and a focus group to discover what kinds of collaborative practices are valued by TC youth and why (e.g., youth strongly value presenting themselves rather than having adults do it for them). Using techniques of educational ethnography (e.g. Erickson, 1984), I examine when and how these conceptual practices become consequential for the group (Hall & Jurow, 2015). In the final research question, I analyze how youth go about accomplishing these valued practices at the level of interaction. I aim to understand the collaborative and coordinative processes (e.g., joint problem solving) that support political forms of learning. I draw again on DP as well as conversation analysis to understand how youth come to work together to accomplish their goals. Analytic techniques primarily follow discourse analytic and qualitative approaches to analysis (Wiggins, 2017),

specifically transcribing data, engaging in open memoing of transcripts, returning to the transcripts with emergent patterns, and finally member-checking the findings with participants.

## Preliminary findings

My data includes slide decks the youth have produced since the TC was formed. Preliminary findings reveal discursive shifts in the TC's slide decks that are representative of changes in both their knowledge about sexuality and gender and their knowledge of how to present this information to a potentially-resistant audience. For example, a slide presented in Fall 2015 entitled "Take Initiative to Learn on Your Own" directly addresses the audience (e.g., "make it clear that you've at least tried to learn on your own"), which may be face threatening (Goffman, 1955) and qualifies expectations placed on teachers by implying that it is sufficient to "at least try" and to "take initiative" without respect to final outcomes. In contrast, an analogous later slide presented in Summer 2018 instead is titled "Learn on Your Own." It more directly appeals to value claims around learning and to outcomes (e.g., "learning is a lifelong opportunity"; "leads to a more comprehensive understanding"), constructions of reality that are difficult to argue with. In this way, the discourse in the second slide may better resist accusations of bias or incorrectness from the audience. Discursive psychologists use the term *stake inoculation* (Potter, 1996) to refer to people's practice of minimizing the possibility that they will be dismissed as overly invested. Using these two slides as a representative example, the discourse has shifted in significant ways to provide both more nuanced perspectives on LGBTQ+ issues and to deliver that information more effectively to a wide variety of audiences.

## Goals and impact

This project's outcome will be a dissertation that details the intellectual, sociopolitical lives of LGBTQ+ youth, offering insight into how these youth learn, share, and use their political knowledge. Extensive attention is paid to discursive analyses of digital artifacts (i.e., the PowerPoint slides), which helps bridge political approaches to the learning sciences with the strengths of the CSCL community. Further, the dissertation contributes to newer political theories of learning. Given the large role political concerns have in everyday lives, attention to politics is a necessary part of equitable learning sciences research. My analyses extend sociocultural learning theories into openly and overtly political contexts in the service of developing new analytic tools and supporting learners' educational dignity, an area of increasing interest in the learning sciences. I see this dissertation as the start of a long-term program of community-based learning research that I hope to engage in throughout my career.

## References

- Edwards, D. & Potter, J. (1992). *Discursive psychology*. Sage Publications.
- Erickson, F. (1984). What makes school ethnography 'ethnographic'?. *Anthropology & Education Quarterly*, 15(1), 51-66.
- Goffman, E. (1955). On face-work: An analysis of ritual elements in social interaction. *Psychiatry*, 18(3), 213-231.
- Hall, R., & Jurow, A. S. (2015). Changing concepts in activity: Descriptive and design studies of consequential learning in conceptual practices. *Educational Psychologist*, 50(3), 173-189.
- Philip, T. M., Bang, M., & Jackson, K. (2018). Articulating the "how," the "for what," the "for whom," and the "with whom" in concert: A call to broaden the benchmarks of our scholarship. *Cognition and Instruction*, 36(2), 83-88.
- Politics of Learning Writing Collective (2017). The Learning Sciences in a new era of US nationalism. *Cognition & Instruction* 35(2), 91-102.
- Potter, J. (1996). Attitudes, social representations and discursive psychology. *Identities, groups and social issues*, 119-173.
- Tuck, E. (2009). Suspending damage: A letter to communities. *Harvard Educational Review*, 79(3), 409-428.
- Wiggins, S. (2017). *Discursive Psychology: Theory, Method and Applications*. London, England: Sage.

# Modeling the Contributions of Individuals to Collaborative Problem Solving Using Epistemic Network Analysis

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**Abstract:** Using data from team training simulations, I will use Epistemic Network Analysis to model collaborative problem solving while accounting for time-dependent relationships between the contributions of an individual and the contributions of their team. I will conduct a qualitative analysis of the data, comparisons between models that either ignore or account for team contributions, and a simulation study that investigates the conditions under which team contributions significantly impact the individual level of analysis. This work will test a measurement approach that is potentially more valid than extant approaches and provide tools for determining whether the interaction between team and individual will meaningfully impact models.

## Project background and goals

Collaborative problem solving (CPS) is widely recognized as critical 21<sup>st</sup> Century Skill. When individuals on teams solve problems, their processes include actions toward accomplishing a task and actions toward managing the processes of collaboration. Team processes are not simply the sum of individual actions; rather, individual actions *interact* with one another, creating a context independent of any single individual. As interactions unfold, they contribute to the *common ground*—the shared knowledge and experience that exists between people when they interact (Clark, 1996); as a result, the discourse of the team is *interdependent*: the actions of one individual impact the actions of others on the team. Importantly, this impact is *temporally* bounded; as Suthers and Desiato (2012) argue, interactions are interpreted with respect to immediately preceding events. These features suggest that valid measurements of CPS should account for the relationships between the contributions of an individual and the recent contributions of the team.

Despite these features of CPS, extant measurement approaches treat individuals as isolated, independent, and atemporal actors. For example, *coding and counting* aggregates discourse codes attributed to individuals over the course of collaboration while ignoring contributions from the team. Other approaches script CPS interactions. For example, the PISA CPS assessment (OECD, 2017) has students interact only with computer agents using a small set of choices. Still other approaches, such as sequential pattern mining (SPM) and social network analysis (SNA), model the complexity of CPS. However, SPM only models individuals irrespective of the team, and SNA only models the structure of team processes (who talks to whom), not the discourse.

An alternative approach is Epistemic Network Analysis (Shaffer, 2017) (ENA). ENA builds network models that describe interactive, interdependent, and temporal phenomena that (unlike SNA) describe interactions among the discourse of an individual and the discourse of others within the context of recent contributions (Siebert-Evenstone et al., 2017). It thus accounts for the interactivity, interdependence, and temporality of CPS at the individual level.

In my dissertation project, I will examine ENA for modeling individual CPS processes. I ask: (1) How do individual contributions relate to team contributions? (2) How does a quantitative model that accounts for the relationships between individual and team contributions compare to models that ignore these relationships? (3) Under what conditions should we account for the relationships between individual and team contributions?

## Methods

My data comes from the Tactical Decision Making Under Stress project. Sixteen teams participated in simulated training scenarios to test the impact of a new decision-support system (DSS) on team performance in the context of air defense warfare (Cannon-Bowers & Salas, 1998). During the scenarios, teams needed to detect and identify ships and aircraft, assess whether they were threats, and decide how to respond. Teams in the control condition use standard technology; teams in the experimental condition used the DSS. The dataset consists of transcripts of team communications.

To address my first research question, I will conduct a grounded qualitative analysis informed by existing literature, and code the data with topics relevant to this CPS context.

To address my second research question, I will create three models of individual contributions. Models I and II will *ignore* the contributions of other team members, while Model III will *account for* their contributions.

For Model I, I will calculate the code frequencies for each code for each individual and use Principal Components Analysis (PCA) to create explanatory variables. For Models II and III, I will use ENA. The ENA algorithm uses a sliding window to construct a network model for each turn of talk in the data, showing how codes in the current turn of talk are connected to codes within the recent temporal context. Individual networks are created by aggregating turns of talk for each person. In this way, ENA can model the connections that each individual makes between concepts and actions while accounting for the actions of others. ENA uses a technique similar to PCA to create ENA scores for each individual which summarize their network of connections; I will use these ENA scores as explanatory variables for Models II & III. In Model II, I will create an ENA model that only identifies connections between codes within an individual's own talk. In Model III, I will create an ENA model that identifies connections between an individual's own talk and the talk of other team members. For each model, I will construct a subsequent regression model of individual performance using explanatory variables from ENA or PCA. I will compare these models based on their fidelity to the qualitative analysis, variance explained, and model efficiency measured by the Akaike information criterion (AIC).

To address my third research question, I will generate simulated datasets that vary individual contributions to the common ground by varying the code frequency distribution of the team, and create ENA models for each dataset. At one extreme, the distribution of code frequencies will be completely asymmetric, simulating situations where team members have specific expertise and the team must be interdependent to function. At the other extreme, the distribution of code frequencies will be completely symmetric, simulating situations where team members have identical expertise. I will vary the distribution of code frequencies between these extremes to identify the *threshold* at which contributions of other team members have a significant impact on individual contributions by testing for significant differences between ENA scores at each step.

## Expected findings and contributions

My preliminary work has focused on processes used by commanders in the two conditions. I produced a reliable automated coding scheme and conducted a qualitative analysis of the data. I developed two quantitative models of commander contributions, one using a coding and counting approach and one using an ENA approach accounting for team interactions. Only the ENA approach corroborated findings from the qualitative analysis, and the ENA approach found significant differences that coding and counting did not, suggesting that it could be a more valid approach for measuring individual CPS. I will extend these findings by examining all roles on the team, making more sophisticated quantitative comparisons between models, and using simulation studies. These studies will determine whether team contributions are more relevant in datasets with asymmetric code frequency distributions, suggesting that accounting for the interaction between individual and team is critical when assessing CPS for individuals, particularly those in heterogeneous groups.

The implications of this work are primarily methodological: This work will empirically test an approach to measuring individual contributions to CPS that is potentially more valid than extant approaches. Similarly, the proposed simulation study could provide a tool that allows researchers to determine if the interaction between team and individual will meaningfully impact their models. Furthermore, this approach will be replicable across contexts, and in many cases, automatable, meaning that it could be integrated with real-time or after-action assessment systems. As such, this work also has the potential to impact pedagogy and learning in a variety of collaborative contexts.

## References

- Cannon-Bowers, J.A., Salas, E. (1998). *Making decisions under stress: Implications for individual and team training* (pp. 39–59). Washington, D.C.: American Psychological Association.
- Clark, H. H. (1996). *Using language*. Cambridge university press.
- OECD. (2017). PISA 2015 collaborative problem-solving framework. In *PISA* (pp. 131–188). Organisation for Economic Co-operation and Development.
- Shaffer, D. W. (2017). *Quantitative ethnography*. Madison, WI: Cathcart Press.
- Siebert-Evenstone, A., Arastoopour Irgens, G., Collier, W., Swiecki, Z., Ruis, A. R., & Williamson Shaffer, D. (2017). In Search of Conversational Grain Size: Modelling Semantic Structure Using Moving Stanza Windows. *Journal of Learning Analytics*, 4(3), 123–139.
- Suthers, D. D., & Desiato, C. (2012). Exposing chat features through analysis of uptake between contributions. In *System Science (HICSS), 2012 45th Hawaii International Conference on* (pp. 3368–3377). IEEE.





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