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► To cite this version:

Stéphane Safin, Françoise Detienne, Jean Marie Burkhardt, Anne-Marie Hebert, Pierre Leclercq. The interplay between quality of collaboration, design project evolution and outcome in an architectural design studio. *CoDesign*, 2021, 17 (4), pp.392-409. 10.1080/15710882.2019.1699935 . hal-02410103

HAL Id: hal-02410103

<https://telecom-paris.hal.science/hal-02410103>

Submitted on 26 May 2021

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The interplay between quality of collaboration, design project evolution and outcome in an architectural design studio

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Abstract. This paper addresses the issue of collaboration dynamics in design by examining, in a longitudinal setting, how quality of collaboration and design co-evolve during a real design studio in architecture. We observed two groups of four students working in a three-month architecture studio setting. Based on a multidimensional method for assessing the quality of collaboration, we investigated the interplay between the design project evolution, design outcomes and the quality of collaboration between the students. The two groups were compared at early, middle and final steps of the project. Results show that dimensions of collaboration evolve independently, and that ‘good’ collaboration is a cause and a consequence in the rapid progression of the design. In our conclusion, we discuss the links between design projects progression, their outcomes and quality of collaboration, which co-evolve during the sessions.

Keywords: collaborative design, quality of collaboration, design studio

1. Introduction

Understanding the collaborative processes involved in design is an important topic in the field of design research. While many approaches have been proposed (Détienne, Baker & Burkhardt, 2012), the relationship between collaboration processes and the design project progression, as well as their resulting design products, has not been fully investigated. Together with the complexity of interplays between the two processes, this can be explained by the use of observation at very small timescales in most of the previous studies. While some studies address design in longitudinal scales (e.g. Goldschmidt & Tansa, 2005), most address these issues in a relatively short temporal scale.

In this paper, we consider a long timescale of the design activity in a pedagogical studio (three months) in order to investigate the relation between quality of collaboration and evolution of the design project at hand.

The study examines two groups of four students working in a studio setting over a period of 12 weeks. The students collaborate *via* a specific digital environment for distant real-time meetings. Our goal is to capture the characteristics of, and the interplay between, the design projects evolution and outcomes, and the quality of collaboration within the students' team. For this purpose, video-recorded, weekly distant-meetings of the two groups at early, middle and final steps of their three-month project, are analysed to characterise the design advancement and to assess the quality of collaboration using a multidimensional method. Some quantitative and qualitative assessments of design outcomes are discussed to examine their links to the design and collaborative processes.

The paper is structured as follows. First, we present a state of the art on collaborative processes in design and quality of collaboration. Then, we present the study's setting and the methodological approach. This is followed by the results, which show that 'good' collaboration is related to efficient advancement of the design, but has no clear link with the project outcome quality. We discuss how different dimensions of collaboration affects design projects and vice versa. Finally, we conclude on the limits and extensions of our study.

2. Theoretical and methodological background

2.1 Collaborative processes in design

Although there is no consensus on a definition of collaboration, in particular on the distinction between collaboration and cooperation (see, for example, Jowers *et al.*, 2017), most authors would agree that it involves the sharing of goals, resources and representations relating to the joint activity of participants (Détienne, Baker and Burkhardt, 2012). In collaborative design, participants are in joint-problem-solving situations in which collaboration is referred to as the coordinated synchronous activity

resulting from the continued attempt to construct and maintain a shared understanding of a problem (Roschelle and Teasley, 1995, p70). Collaborative processes in design have been observed and described in several design domains (e.g. software design, architecture, etc., see Détienne, 2006 for a review), and several factors related to collaboration processes have been identified as important for successful design (Feast, 2012). Amongst them, one can distinguish four classes of processes involved in collaborative design.

Task-related processes. Task-related processes concern the evolution of the design problem and solution. In individual design, corresponding activities are usually referred to as problem framing, generating solutions and evaluating these solutions. They occur in iterative loops. In collective design situations, these activities are supported by argumentation and negotiation mechanisms (e.g. Détienne, Martin, Lavigne, 2005) and refer consequently to providing propositions, co-constructing knowledge about the solution(s), arguing about different viewpoints, negotiating meaning and content, and taking decisions. These processes are important for the quality of design products, and empirical studies (e.g. Stempfle & Badke-Schaub, 2002) have shown important drawbacks in the work of design teams, for example the early commitment to a single solution, lack of evaluation/verification of solutions and difficulties in considering all criteria and their inter-dependencies (constraint management).

Communication processes. Communication processes must be managed efficiently to support cross-understanding within a group through the development of a common ground - necessary for the achievement of tasks. The establishment of common ground is a collaborative process (Clark and Brennan, 1991) in which co-designers mutually share and make explicit what they know, in relation to the project, through shared representations, dialogue, and shared knowledge. Grounding supports inter-

comprehension and co-elaboration of a common (or at least compatible) reference about the design problem and design knowledge involved in problem resolution. Empirical studies of collaborative design (e.g. D'Astous et al., 2004; Olson et al., 1992; Stempfle & Badke-Schaub, 2002) found that grounding, although time-consuming, was particularly important to ensure good design; for instance, Stempfle and Badke-Schaub (2002) found that when teams bypassed grounding (referred to as “analysis”), they engaged in premature evaluation of design ideas.

Group management processes. Besides performing the task and communicating, collaboration requires group management activities such as: (a) project management and coordination activities, e.g., allocation and planning of tasks; (b) management activities, such as drawing up the meeting agenda, keeping track of decisions, handling communication turns and decision-making. These process-oriented mechanisms ensure task coordination that may be critical in design. These coordination mechanisms tend to become even more important in technology-mediated situations (e.g. Herbsleb & Mockus, 2003).

Cooperative orientation. Research on collaboration processes in design (Baker *et al.*, 2003; Barcellini *et al.*, 2008) has shown that collaborators endorse different roles in task-related, group-management and communication processes and that a good balance between roles is a part of efficient collaboration. This aspect is similar to the notion of reciprocal interaction highlighted by Spada *et al.* (2005) and symmetry in the interaction pointed out by Baker (2002) or Dillenbourg (1999) in Computer Supported Collaborative Learning research. For these authors, symmetry of interactions between members in group-learning is a factor of quality of collaboration. We consider that this is also the case in collaborative design.

2.2. Assessing the quality of the collaborative process

The term ‘quality’ refers to descriptive approaches to analysing collaboration (understanding proprieties of collaborative processes) as well as normative approaches (defining what factors could lead to ‘good’ collaboration and how to ensure efficient collaborative processes). We use both approaches as a background to assess the quality of several dimensions of collaboration.

Based on previously mentioned collaborative processes, a method has been developed to assess the quality of collaboration (Burkhardt *et al.*, 2009a, 2009b, Détienne *et al.*, 2008 and 2012). Partly based on the schema proposed by Spada *et al.* (2005), this method has been specifically adapted to design activities. The underlying model distinguishes six qualitatively defined dimensions that cover the aspects of the collaboration process identified above: communication (fluidity of collaboration, sustaining mutual understanding), task-related processes (information exchanges for problem solving, argumentation and reaching consensus), group management processes (task and time management), and cooperative orientation (symmetry of contributions)¹(see Table 1).

Dimensions	Definition	Indicators
1. Fluidity of collaboration	Assesses the management of verbal communication (verbal turns), of actions (tool use) and of attention orientation	<ul style="list-style-type: none"> - Fluidity of verbal turns - Fluidity of tools use (stylet, menu) - Coherency of attention orientation
2. Sustaining mutual understanding	Assesses the grounding processes concerning the design artefact (problem, solutions), the designers’ actions and the state of the tool (e.g. activated functions).	<ul style="list-style-type: none"> - Mutual understanding of the state of design problem/solutions - Mutual understanding of the actions in progress and next actions - Mutual understanding of the state of the system (active functions, open documents)

¹ While the model contains a seventh dimension related to motivation (individual task orientation), it is not investigated in this study.

3. Information exchanges for problem solving	Assesses design idea pooling, refinement of design ideas and coherency of ideas.	<ul style="list-style-type: none"> - Generation of design ideas (problem, solutions, past cases, constraints) - Refinement of design ideas - Coherency and follow up of ideas
4. Argumentation and reaching consensus	Assesses whether or not there is argumentation and decision taken on common consensus.	<ul style="list-style-type: none"> - Criticisms and argumentation - Checking solutions adequacy with design constraints - Common decision taking
5. Task and time management	Assesses the planning (e.g. task allocation) and time management.	<ul style="list-style-type: none"> - Work planning - Task division - Distribution and management of tasks interdependencies - Time management
6. Cooperative orientation	Assesses the balance of contribution of the actors in design, planning, and in verbal and graphical actions.	<ul style="list-style-type: none"> - Symmetry of verbal contributions - Symmetry of use of graphical tools - Symmetry in task management - Symmetry in design choices

Table 1: Quality of collaboration dimensions and indicators.

This method has been used in several contexts to compare technology-mediated situations to non-mediated processes (Burkhardt et al., 2009a) and to highlight cultural differences in collaboration practices in design (Détienne *et al.*, 2016). These studies however considered discrete collaborative episodes over short timescale periods. As Détienne *et al.* (2012) pointed out, applying methods to measure collaboration raises issues related to the evaluation timescale. Indeed, real design situations are essentially long term, and the impact of collaborative activity on design may depend on the timescale studied. For example, Bunderson and Sutcliffe’s study (2003) suggests that teams’ collaborative learning orientation is related both positively (in the long run) but negatively (in the short term) to team performance, by focusing strongly on learning instead of task related processes. Thus, it is necessary to enlarge the timespan for studying collaborative quality, to overcome limitations linked to studying particular collaborative episodes of short duration.

2.3. Assessing the design project

Taking into account a long-term perspective on collaborative processes raises the question of their articulation with the design project progression and its outputs.

Evaluating the output raises two main issues. On the one hand, design output consists essentially of reaching a (usually original) *satisfactory* solution to an over-complex problem which evolves through time (Simon, 1988, Dorst & Cross, 2001). The evaluation of such a solution on the basis of *a priori* criteria is difficult, or at least incomplete, because the ill-structured nature of design problems means that evaluation criteria are emerging from the design process itself and may highly differ depending on the designer. It is thus hard, if not impossible, to provide an objective evaluation of complex problem solutions in real situations. Nevertheless, in educational studio situations, the design product is evaluated by experts, which allows for qualitative feedback, as well as quantitative clues (grades).

Moreover, evaluating the final solution is insufficient to fully understand the processes that lead to that solution in its temporal dimension (Goldschmidt, 1992). Assessing the design project progression requires a structure to analyse the current state of progress and to situate it along a path from the initial state to the final state of the design (in particular the final solution as achieved by the team at the end of the project). Several models have been used to describe either generic design or domain-dependent architectural design process. These models are structured either as a sequence of stages, or as a set of cognitive processes involved in the design (Visser, 2006). However, both approaches can be combined since stages can be defined on the basis of the involved processes. A simple model can be derived from the three stages widely found in models of design (e.g. Pahl & Beitz, 1984): definition, refinement, and production. As designing involves the construction of representations, and because the nature of representations evolves throughout the project (Lebahar, 1983, Safin, 2011), the progression of design can be assessed *via* the types of external representations created

and used by design teams in the design studio. The three stages have been operationalised as follows:

- The **definition** stage consists of elaborating the general principles and concepts of solutions. Representations at this stage in architecture may include global volumes, conceptual sketches, functional charts about high-level properties of the building, and global implantation plans.
- The **refinement** stage is oriented towards taking most of the decisions related to building (planning sub-areas, envisaged technologies, materials that respond to structural problems, etc.). Here, representations are a mixture of plans with different levels of detail, including approximate 3D models and several detailed sketches.
- The **production** stage, during which the group, based on the core decisions taken earlier, produces all the necessary elements for its communication and its verification: maps, precise calculations, 3D views, etc.

This model is relatively simplistic since, in reality, these stages are intermingled, with some decisions being taken whilst concrete plans are being produced, for example. It nevertheless provides a clear framework for assessing advancement of design projects.

3. Research questions

At a general level, our questions address the links between the project progress and the quality of the collaborative process. More specifically, we aim to address the two following questions: How do the dimensions of the quality of collaboration evolve over time, and how are they linked to the project progression? Does a “good” collaborative process ensure an efficient project progress?

To address these questions, we studied groups of students assigned to a collaborative studio in architecture curriculum over a 12-week period, and specifically examined the following elements:

- (1) *Design state of progress* using the three-stages (definition, refinement, and production) model of design progression previously presented;
- (2) *Design project's outcome* assessed through grades obtained by students, as well as from interviews of the teachers;
- (3) *Collaborative processes among students* using six dimensions of the QC method (fluidity of collaboration; mutual understanding; information exchanges; argumentation and consensus; task and time management; cooperative orientation (balance of contributions)).

We adopted a longitudinal approach by assessing the design and collaborative process at three moments during the design project, i.e. in meetings at the beginning, middle and end of the project. This allows us to reveal how the design project and the quality of collaboration evolve. Also, in order to observe the broadest range of collaborative processes, we compare two groups, with contrasted quality of collaboration at the beginning of the studio.

4. Method

In order to address our research questions, we used a mixed-method approach, combining 'external' (third party) analysis (researchers' observations), which are completed by 'internal' (first-person) points of view (judgements and comments by the participants involved) to support the understanding of the activities and interpretations of the results.

4.1. Context: the studio

A distant collaborative design studio was developed between the University of Liège in Belgium and the National School Architecture of Nancy in France. Sixteen Master students (5th-year architecture and 4th-year engineering-architecture students) were collaboratively involved during one term (three months) in the design of a large and realistic, yet ambitious, architecture program. The students were organised into groups of four (two in Belgium and two in France). They had to collaboratively and remotely design a polyvalent concert hall from a completely defined program on a real site in Liège. For this purpose, the groups had different tools at their disposal: asynchronous classical collaborative tools (email, file exchange servers, etc.), synchronous classical collaborative tools (chat, videoconferencing, etc.) and a multimodal collaborative environment, the “Distant Collaborative Digital Studio” (DCDS) (see, Safin, Delfosse & Leclercq, 2010; Safin & Leclercq, 2009; Kubicki et al. 2008; Elsen & Leclercq 2008).

Besides asynchronous collaboration and informal contacts, the groups had 12 weekly formal synchronous meetings (M1 to M12). The first meeting (M1) lasted an entire day and aimed at creating the groups, explaining the program, visiting the project site and defining the first concepts of the project for each group. The 10 next meetings took place remotely on the DCDS and lasted about one hour for each group. Twice during the experiment, at M5 and M8, the groups had a meeting with the client, simulated by one of the teachers. The last meeting (M12), organised in co-presence, was dedicated to presentations of the results and the jury. The studio took place under the supervision of four pedagogical staff members (two in Belgium and two in France).

4.2. Participants / group selection

For the analysis, we selected two groups amongst the four that participated in the studio. The selection was made after three weeks of the studio work, and was based on the subjective evaluation of teachers (following their own experience with and observations of groups), bearing on the most and least successful groups with respect to task completion at that point in time. The objective was to maximise the contrast between the two chosen groups. The first group (named Group 1) was judged as being quickest to progress on the task, whereas the second sampled group (Group 2) was evaluated as being late with respect to this. The selection was made with a consensus between the four teachers.

4.3. Collected data

The following data was systematically collected:

- Design representations. During each weekly DCDS meeting, all shared and annotated graphic productions were recorded and analysed to assess the project progression.
- Video recording of synchronous meetings. Sampled DCDS sessions (see next section) were videotaped in synchronised channels (front view of both sides and shared workspace view). These videos were used for assessing the quality of collaboration.

Furthermore, a researcher followed the entire design studio by observing all the meetings and engaging in frequent exchanges with the teachers in order to achieve a global understanding of the undergoing design processes and projects. At the end of the final presentations of the projects, grades were collected and the main supervisor was

formally interviewed to collect her observations and personal comments on the projects' outcomes. Extracts from this interview are provided below to illustrate the analyses.

4.4. Selected meetings

Three selected meetings per group were videotaped and analysed to assess the quality of collaboration. These meetings were sampled to illustrate each of the project stages (see Figure 1): one at the beginning (M3, which is the second distant meeting), one in the middle (M6, between the two presentations to the client) and one at the end (M10, the second last distant meeting).

[INSERT FIGURE 1]

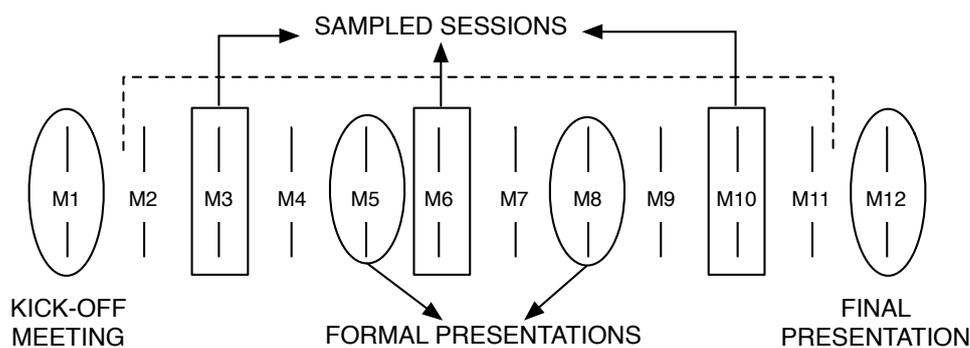


Figure 1: observed sessions in the studio.

4.5. Data analysis

The data collected for the two groups was analysed with the methods described in the following sections.

4.5.1. Design progression

Based on direct observations, collected design representations and interviews, we described each group's design project. As detailed in section 2.3, we characterised the stage of design on the basis of the types of representations constructed and/or shared

during the meeting, which corresponds also to specific requirements of the studio: high-abstraction level representations in the *definition* stage; sketches, basic CAD plans, rough 3D models, etc. in the *refinement* stage; and detailed CAD plans, detailed 3D models in the *production* stage.

4.5.2 *Design outcomes*

The design outcome was assessed by collecting the final grades obtained by the groups for the studio. These grades were given by a jury composed of the four architecture teachers, from both institutions, who had to agree on a project rating based on final presentations and the usual criteria of the design studio. The grades constitute a relevant indicator, though obviously not ideal, of projects quality (Goldschmidt & Tatsu, 2005). Those numerical assessments were completed with a retrospective interview with the main teacher (also part of the jury), to address the projects' qualitative features. These two lines of data obviously do not constitute an objective assessment of the project quality; they are mainly used as a focus for discussion.

4.5.3. *Quality of collaboration*

The assessment of collaboration quality is based on the QC method (Burkhardt *et al.*, 2009a, 2009b; Détienne *et al.*, 2008). The method consists, for an external judge observing a videotaped design meeting, of answering 46 questions with positive or negative valencies, distributed along six dimensions: F = fluidity of collaboration; MU = mutual understanding; IE = information exchanges; AC = argumentation and consensus; TM = task and time management; CO = cooperative orientation (balance of contributions) (see section 2.2. for details on the dimensions).

By way of illustration, consider the following two examples. For the indicator “mutual understanding of the state of design problem/solutions” of *Dimension 2*

(Sustaining mutual understanding) the judge is requested to answer two questions (by Yes, Yes/No, or No): the question with positive valence is “Do the designers ask questions, give clarifications or complementary information, using verbal or behavioural backchannels, on the state of the design artefact?” The question with negative valence is “Are there misunderstandings on the state of the design artefact during relatively long periods of time?” As another example, the indicator “common decision taking” of *Dimension 4 (Argumentation and reaching consensus)* is split up into two questions; the question with positive valence is “Are the individual contributions equal concerning the design choices?” and the question with negative valence is “Is there one contributor who imposes the design choices?”

A score for each dimension (from 0 to 5) is then calculated on the basis of the answers given by the judge to the questions, via a scoring algorithm based on the number of positive and negative answers to questions. Scores of 4 or 5 can be classified as high, and a score of 3 or less as low. This method has proven to have a strong reliability based on inter-rater correlations in previous studies (Kappa=.92, see Burkhardt et al., 2009a, 2009b).

In this study, we applied the QC method to assess three extracts per group corresponding to one for each sampled session. Each extract was about 20 minutes in length, at the middle of the meeting, to rate the main collaborative activity, not the beginning and the closure of the meetings, which may not be representative of the process (see Détienne et al., 2008 for full details of the method). Four coders (co-authors of the paper) evaluated the first extracts. They shared their results in order to ensure the coordination and consistency of their coding. Following a large consensus between these coders, other extracts were coded by only one coder.

5. Results

The following sections describe the results of each considered dimension (design project evolution, design outcomes and quality of collaboration). The final section discusses their inter-relations and co-evolution.

5.1. Design project evolution

Figure 2 shows the timelines of the design project evolution for the two groups based on the nature of collected design representations. The progression was divided into the three aforementioned stages: (1) a *definition* stage of the building's main components, (2) a *refinement* stage about the entire set of building components and (3) a *production* stage of representations (plans, 3D).

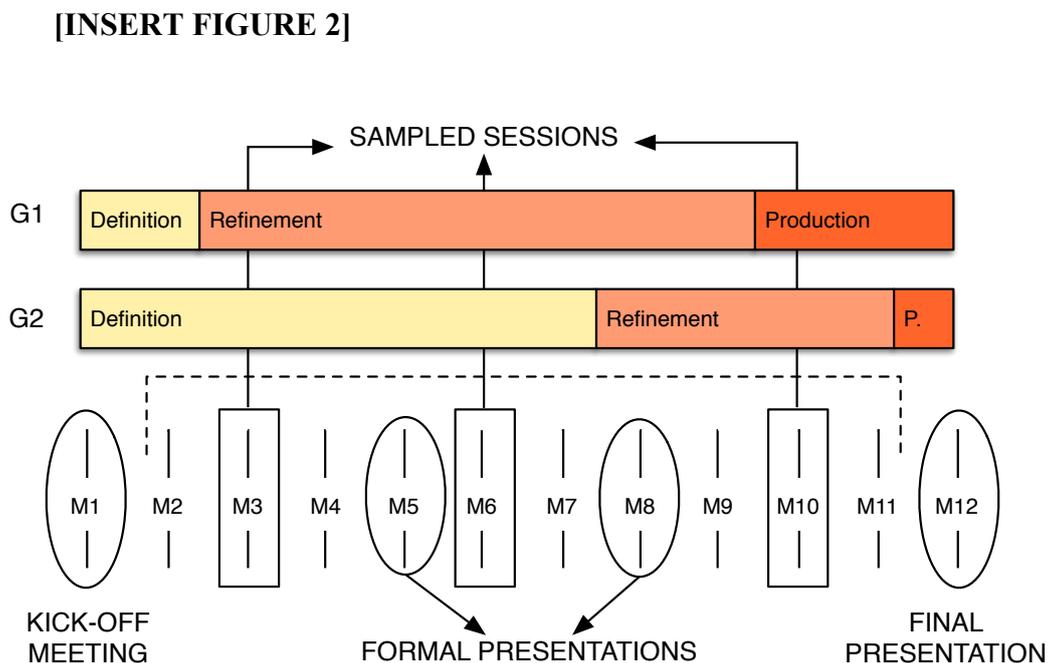


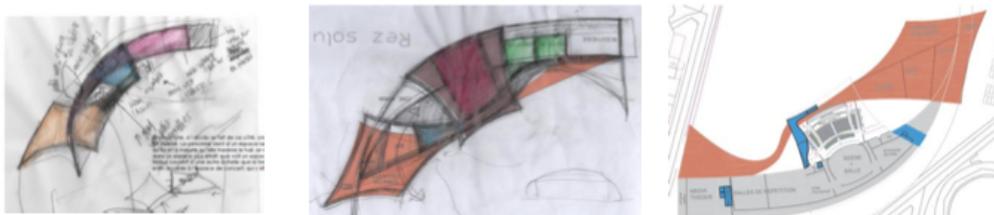
Figure 2: Project timeline for the two groups.

In parallel with these timelines, the following narratives of the groups' design activities enable a qualitative account for the observed design stages and some of their underlying aspects. This narrative is based on direct observations, as well as comments from the

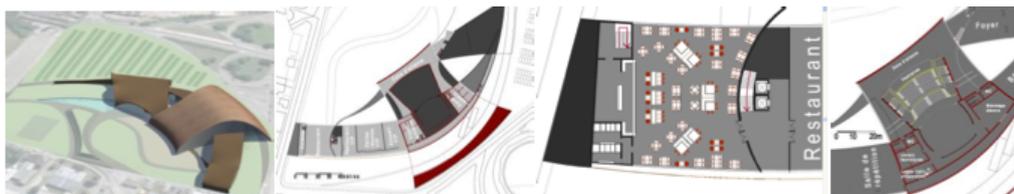
teacher.

Group 1 started quite quickly and easily with a single common idea: at M3, the group defined and agreed upon the entire concept, which was a curved building with special attention paid to the fluidity of transitions. The refinement stage lasted for seven weeks, and the group took three weeks at the end of the design project to produce the required models and plans for the final presentation. Figure 3 provides a sample of representations of the building showing evolutions of the project. It shows the core concept, which structured the whole design. While images from M12 (the final presentation day) are clearly more detailed than those from M3, they share the same common patterns.

[INSERT FIGURE 3]



Representations of G1 solution at meetings M3 (left), M6 (center) and M10 (right)



Representations of G1 solution at the final presentation (M12)

Figure 3: Design project from Group 1.

By contrast, Group 2 took a great deal of time to define a single concept (cf. Figure 2). The refinement stage was much shorter and the production stage lasted only one week. The long duration of the definition stage was due to an “impasse” until meeting M7: Group members disagreed on the design direction, and two competing projects were developed in parallel (representations from M3 and M6 in Figure 4 clearly show these

two distinct projects). The teachers identified this problem during the meetings as well as from informal input from the students. Consequently, the group organised a “crisis meeting” just before M7 with all the studio teachers (two full professors and two assistant professors) in order to overcome this hurdle before the second formal presentation occurred. The teachers forced the group to take an agreed-upon decision between the two projects. Ultimately, the group selected only one option and saw it through to the end of the project.

[INSERT FIGURE 4]



Representations of concurrent solutions from M3

Representations of concurrent solutions at M6



Representation from M8



Representations from the final presentation (M12)

Figure 4: Design project from Group 2.

5.2 Design outcome

Both groups obtained the same grade for their project (15 out of 20). The collaboration quality seems to have no impact on quality of the product. Nevertheless,

qualitative comments of the interviewed teacher show that the two projects are quite different.

In the teacher's own words, the G1 final project is "*a curved building, which relies on the form of the field. It is a sensual building, almost feminine, in a continuous motion for both internal and external walls*" (extract from teacher interview). However, according to the teacher, the result was somehow disappointing with respect to such a promising design process. "*This conceptually exciting choice did not translate well on technical level. It was only conceptual*". The result was not complete and many issues were not tackled. "*From a technical point of view (structure, implementation of materials), the quality is below what one would expect.*"

For Group 2, the final result was "*much more rational, very masculine, very rigorous, with clearly identified volumes. It is quite easy to design, but on the other hand, it is done with a high degree of architecture mastery.*" The design produced by G2 was even judged to be better than the one produced by G1 by the interviewed teacher, although the jury agreed on a similar final grade for both groups.

5.3. Quality of collaboration

The scores on the collaboration quality grid for the two groups and the three observed meetings are presented in Figure 5. Scores of 4 or 5 can be classified as high, and score of 3 or less as low.

[INSERT FIGURE 5]

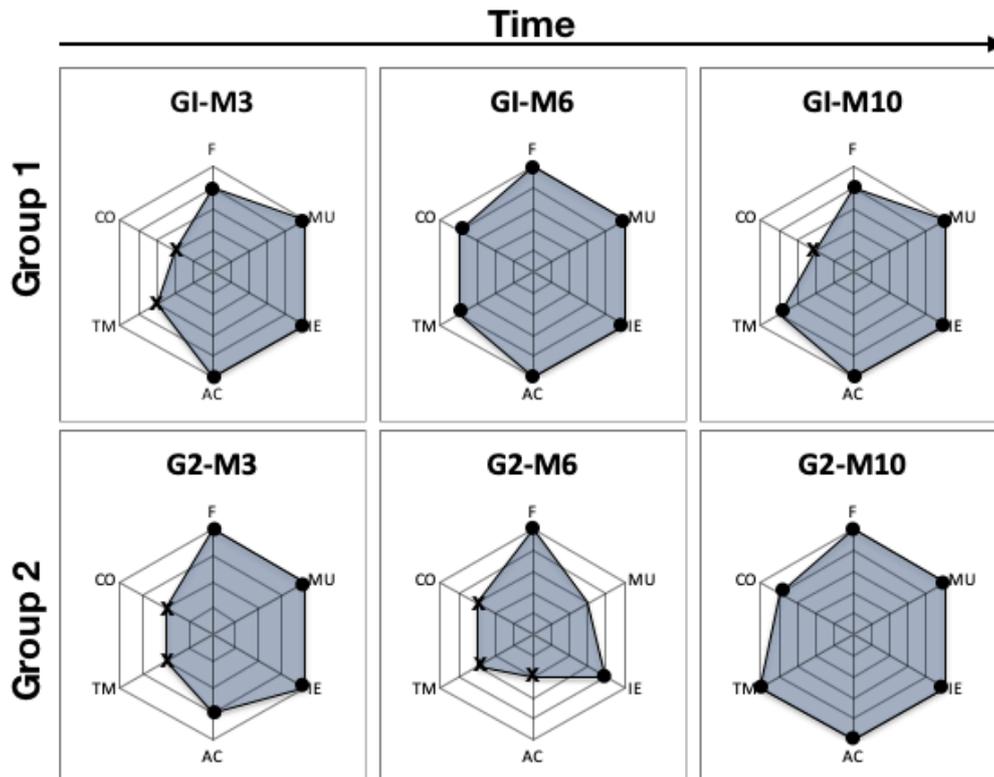


Figure 5: Scores on the Collaboration Quality Scale. F = Fluidity of collaboration; MU = Mutual Understanding; IE = Information exchanges; AC = Argumentation and Consensus; TM = Task and time management; CO = Cooperative orientation (balance of contributions) High scores (>3) are represented with a dot and low scores (≤ 3 are represented with an X).

Group 1 is globally characterised by high-quality collaboration.

- At M3, the balance of contributions, or equilibrium between the participants, (CO) and the time management (TM) are weak. This may be explained by the fact that the students were only beginning the project; they were able to agree on the content, but failed in managing their time and processes due to the novelty of the setting (a new group in a new collaborative environment).
- In M6, Group 1 efficiently collaborated along all dimensions. The group was engaged at the core design stage, where all decisions had to be taken (the refinement stage).

- Finally, during M10, the group was still quite efficient in terms of collaboration quality except in the balance of contributions (CO). This decrease of the CO score is due to the fact that the group has entered the production stage (see Figure 2). The discussion themes are focussed on specific issues relative to the work previously done by two team members, which explains why the contributions are out of balance. In fact, at the end of the project, the quality of the design outcome decreased. According to the teacher, *“I think it [the imbalance of contributions] reflects the fact that they do not bring more information into the design, so they arrived at a fairly low production although they were well organized and on time. But since they would not bring forth additional ideas, the result is still of average quality.”*

Therefore, Group 1 excelled in all task-related dimensions (information exchanges (IE) and argumentation (AC)), and showed optimal communication (regarding fluidity (F) and mutual understanding (MU) dimensions). The dimensions relative to the organisation of the group (Balance of contributions (CO) and time management (TM)) depended on the stage in which the group is engaged.

Group 2 globally exhibits low scores at the beginning and middle of the project. Then, the quality of their collaboration increased toward the end of the project.

- At M3, scores are quite low (3 and below) in management (TM) and balance of contributions dimensions (CO) (like Group 1 at the same stage - the beginning of the project), but also on argumentation and consensus (AC). This is clearly linked to the fact that they do not choose between the two competing proposals, as explained in the previous section.

- M6 shows a real crisis in the group, which is evident through the weak score on almost all dimensions, and particularly the decrease in scores on the consensus (AC) and mutual understanding (MU) dimensions.
- In the last observed meeting, M10, however, the collaboration seems to achieve a high level. It shows that the conflict has been resolved and that the group succeeds in managing efficient collaboration at that time.

These results are interesting with regard to the design stage progression. The difficulties in collaborating and their incapacity for making the core decisions in M6 could be related to the fact that the group was still in the definition stage of the project. On the other hand, the definition stage is longer than expected because the group experiences collaboration difficulties at that moment. Even though they exchanged a great deal of information (IE dimension), they failed to reach a consensus. It seems that the difficulty of decision-making involves weak collaboration, and this hinders the advancement of the design. The key to overcoming the obstacle and moving on is the role assumed by the teacher, and the ‘crisis meeting’ organised by the entire pedagogical staff. Once the crisis is overcome and the group has reached the design stage, Group 2 exhibits a collaborative pattern (G2-M10) similar to Group 1 at the same stage (G1-M6). One can even make the hypothesis that this conflict has been constructive (Baker, 1999): thanks to the time it took to decide on one of the two the concepts, the analysis and grounding processes have been deepened, and fostered high quality collaboration by the end of the project.

Therefore, it seems that there is an interplay between the quality of collaboration and the design project evolution: *optimal collaboration allows the design project to progress, and the progression of the design project provides the conditions for optimal collaboration.*

In addition, it is interesting to notice the link between the quality of collaborative processes and the quality of the outcome. Although global grades of the two projects are equivalent, which may mean that there is no clear link between collaboration and outcome, qualitative comments of the teachers suggest that different collaboration patterns may have a different impact on the project evolution. Group 1 succeeded in defining a strong concept, which was the main strength of the project, but as the collaboration quality decreased at the end of the studio, the production stage was less successful, and the concrete execution was somehow disappointing. On the other hand, Group 2 struggled at defining a common concept, which was deemed too simple. But the quality of their collaboration excelled at the end of the project and the group succeeded at producing a noteworthy project, with a “*a high degree of mastery of architecture*”.

Our results show that analysing collaboration in its different dimensions can highlight several features of collaborative design processes:

- Our observations show that two dimensions are high (with a score of 4 or 5) for both groups and on all sessions: fluidity of communication (F) and information exchanges (IE). Both groups communicated effectively during meetings. We thus make the hypothesis that the setting (formal meetings with a dedicated platform of real-time document annotation) affords effective information exchange (through the upload of representations), and speech turn management.
- The “cooperative orientation (balance of contributions) (CO) dimension is the one with the lowest scores. These weak scores can be explained by a conflict or difficulty in focussing on a single project for Group 2, whereas for Group 1, the diminished score at the end of the studio is linked to the fact that students

perform tasks at hand quite independently and share only information relative to specific problems to be solved.

- The “task and time management” dimension scores are relatively weak at the beginning of the studio and can be explained by the novelty of the setting; students are not used to managing large-scale collaborative processes. Learning to effectively manage time and tasks can take time.
- Finally, the “mutual understanding” (MU) and “argumentation and consensus” (AC) dimensions are strongly related to the conflict and the difficulty to agree on a core concept. This means that difficulties in the decision process (AC) are accompanied by communication difficulties (MU), illustrating co-dependencies between task-related and communication processes in design.

6. Discussion

In this paper, we report on a case study of the evolution of collaborative process quality, which is linked to the design project progression addressed in a longitudinal way. Two groups were monitored and the developments of their collaboration were analysed.

Limitations

Our study contains a number of limitations. Firstly, the setting is quite specific, and other settings (different studio types, technologies, or design brief) may lead to other conclusions. Secondly, the sample is not representative; other students may behave differently. Thirdly, our methods do not support the identification of any causal link between variables, but only co-evolution and co-occurrences, which may limit the interpretations. Nevertheless, the work described here is based on a corpus of genuine, on-site activities, which are closer to the reality of collaborative design than what would be achieved in laboratory experiments.

Another limitation is that the collaboration samples only represent a part of the collaborative process. Long-term collaboration is characterised as many stages of asynchronous collective work which could be studied too, in order to address the entire collective process; articulation between individual and collective production may also be informative. Synchronous collaboration is also a moment in which individual previous productions are gathered together, but it only represents mere “slices” of collaboration.

With respect to our methodological approach, we can point to several weaknesses of the QC method. Besides its main advantages, allowing comparisons between groups and within groups at different times, the method does not address the issues of socio-emotional aspects of collaboration (affinities, roles, mood, etc.). These reflections will be taken into account in future work.

Insights

Our results inform us of several critical characteristics of the articulation between design and collaboration in a design educational setting. Firstly, there is no determinism in the collaboration. Collaboration quality is constantly evolving along with the design progression, and several factors, internal and external, contribute to the collaboration quality at different moments of the project. For example, Group 2 initially experienced difficulties, but finally achieve high-quality collaboration. The different dimensions of collaboration appear to evolve in relation with different factors. Task Management and Cooperative Orientation are weak at the beginning of the project for both groups, presumably associated with collaboration learning. Argumentation and Mutual understanding are associated to conflict issue. Cooperative orientation is also linked to task separation at the end of the project.

Secondly, amongst these factors, the evolution of the design process seems closely related to the dynamics of the collaboration and its quality. It seems that a rapid progression of the design supports quality collaboration, which, in turn, fosters the decision processes needed for the project to advance. Nevertheless, this link between design and collaboration is more complex, and has unexpected consequences. In group 1, perhaps a premature commitment to a single idea led to strong collaboration and rapid process progression, but had implications for the quality of the outcome.

Thirdly, this study also raises a series of questions concerning the relationship between the quality of collaborative processes and the quality of the collaboration outcome, i.e., the group performance. Whilst collaboration in Group 1 was quite satisfying along many dimensions, the product of their collective design project was not better than Group 2, which was plagued by strong difficulties in collaborating, especially at the beginning. It should not be excluded that difficulties of Group 2 enabled a "constructive conflict" (Baker, 1999; Badke-Schaub et al., 2010), leading to a more thoughtful, deeper, more strongly argued and potentially more creative product. On the other hand, Group 1 may have been locked in a "groupal illusion", avoiding any conflicts and promoting decision processes aiming at preserving the positive interpersonal ambience of the group, rather than action on the project, resulting in poorer outcome quality. At the end of the project, this group seemed to be trapped in a single solution, and the quality of the outcome does not increase significantly during the final tasks (production phase). The two outcomes are similar in quantitative evaluation (grades) but differ in their qualitative features: Group 1 has a powerful concept, which is not fully exploited, and Group 2 has a simpler, yet successfully implemented, concept. Our hypothesis is that Group 2's "constructive conflict" and the long definition phase may have led to the selection of a agreed-upon, yet less innovative concept, but

involved a significantly deep analysis of the problem, supporting rapid refinement and production stages, as well as a high degree of achievement of the solution. Our observations are close to those of Stepmfle and Badke-Schaub (2002), which highlighted that a rapid *definition* stage can lead to errors and a potentially less efficient process.

Perspectives

To conclude, the QC method, although not used here for this purpose, could also be used to quickly evaluate the quality of the collaborative process of a group in order to provide feedback to its members. Allowing to understand collaborative process in (almost) real-time could genuinely support the type of reflection-on-action processes suggested by Schön (1983). This educational orientation remains to be explored. Future work will be adapted and use the QC method not only to analyse spontaneous behaviours, but also to help students and teachers to engage in reflective activities during collaboration; by helping them to highlight strong and weak points in their collaborative processes, they may be able to perform better, and to learn more efficiently. For such purposes, a simplified version of the method could be provided to students and staff.

7. Acknowledgments

This research was carried out in the framework of the ECODIM Tournesol Wallonia-France collaboration funding. It has also been supported by the Research Council of the University of Liège and the ARC-COMMON project. We'd like to express special thanks to the students, the teachers, Aurelie Verschuere, Bethany Cagnol and Michael Baker.

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