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Engineering Students' Dynamic And Fluid Group Practices In A Collaborative Design Project

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ENGINEERING STUDENTS' DYNAMIC AND FLUID GROUP PRACTICES IN A COLLABORATIVE DESIGN PROJECT

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ABSTRACT

There is a growing interest in engineering education that the curriculum should include collaborative design projects. Collaboration and collaborative learning imply a shared activity, a shared purpose, a joint problem-solving space, and mutual interdependence to achieve intended learning outcomes. The focus, in this study, is

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on engineering students' collaborative group practices. The context is a design project in the fifth semester of the problem-based Architecture and Design programme at Aalborg University. Students' collaborative work in the preparation for an upcoming status seminar was video recorded in situ. In our earlier studies video ethnography, conversation analysis and embodied interaction analysis have been used to explore what interactional work the student teams did and what kind of resources they used to collaborate and complete the design task on a moment-moment basis. In this paper we report from a one-hour period where a group of four engineering students do final designs in preparation for the status seminar. Using recorded multi-perspective videos, we have analysed students' fine-grained patterns of social interaction within this group. We found that the interaction and collaboration was very dynamic and fluid. It was observed that students seamlessly switched from working individually to working collaboratively. In collaborative work students frequently changed constellations and would not only work as a whole group, but also would break into subgroups of two or three students to do some work. Our results point to the need to investigate group practices and individual and collaborative learning in design project groups and other collaborative learning environments in more detail and the results challenge a naïve individual-collaborative-binary.

1 INTRODUCTION

1.1 Importance of design education in engineering

The ability to develop and design products, processes and systems and demonstrate the capacity for teamwork and collaboration have become essential requirements for an engineering degree in many countries. For example, the Swedish national university regulations require that to be awarded an engineering degree, students must "demonstrate the ability to develop and design products, processes and systems [and] demonstrate the capacity for teamwork and collaboration". For this reason there has been a growing interest that engineering education should include collaborative design projects and this requirement is included in the CDIO-standards (e.g. Crawley et al. 2014; Edström and Kolmos 2014)

Given that design-based learning activities have become a key component in engineering education, there is a need to better understand students' learning processes within design projects. Moreover, within design projects it is also important to better understand how students develop the "capacity for teamwork and collaboration", i.e., how they become skilled in collaborative design work.

1.2 Teamwork and collaboration

However, collaboration and cooperation are often not always clearly distinguished and the nuances are often lost in the definition of the concepts. In line with (Dillenbourg 1999), Stahl (2013, 2016), and others, we see cooperative learning as an activity there students divide up group work and then put the individual contributions together, whereas in collaborative learning students do the work

together. Collaboration and collaborative learning implies a shared activity, a shared purpose, and a mutual interdependence to achieve the intended learning outcomes (Dillenbourg 1999). Stahl (2013, 2016) argues that in studies of collaborative learning it is important to focus on small group phenomena and to use the group as a unit of analysis. According to Stahl, collaborative groups build knowledge through shared understanding, co-construction, and interaction in a joint problem space. Furthermore, he proposes that studies on teamwork and collaboration build on post-cognitive theories. Thus, a project group in a collaborative design project can be seen as a community of inquiry. Indeed, students' cognition in an engineering design project (Brereton 2004) has been seen as an example of "distributed cognition" (e.g. Goodwin 1995; Hutchins 1995), since achievements do not only arise from individuals thinking, but also through collaborative thinking distributed among the members in the design team *and* from the use of epistemic tools (Goodwin 2018).

1.3 Short literature review and our earlier studies

Although more than 30 years has passed since Tang and Leifer (1991) argued for the use of video recordings and interaction analysis (Jordan and Henderson 1995) to study group design activity the dominant empirical method to investigate *students'* design processes have until recently been variants of "think-aloud" exercises with verbal-protocol-analysis (Craig 2001) mostly with *individuals* in *artificial* settings (Bernhard, Edström, and Kolmos 2016) with tasks that were completed in rather *short time*, i.e. one to two hours (e.g. Atman et al. 1999; Atman et al. 2007; Cardella et al. 2008). To our knowledge, Campbell, Roth, and Jornet (2018) seem to be one of the rare cases that, beside our own studies have studied engineering students' design *process* using interaction analysis. There exist, however, studies using other forms of ethnographic methods to investigate students' design process in naturalistic educational settings. For example, using audio-recordings (e.g. Gilbuena et al. 2015), video-recordings (e.g. Goncher and Johri 2015; Campbell, Roth, and Jornet 2018), and photos and field-notes (e.g. Juhl and Lindegaard 2013).

In our own previous studies, we have made video-recordings and studied a design project in the fifth semester of the PBL-based Architecture and Design programme at Aalborg University. We found that the fifth semester students displayed epistemic fluency (Markauskaite and Goodyear 2017) by fluent use of a rich repertoire of bodily-material resources, working both "by hand and by computer", as epistemic tools to think collaboratively in design activities (Bernhard et al. 2019; Bernhard, Davidsen, and Ryberg 2020; Ryberg et al. 2021) and develop a professional dialogical space that is not only being manifested in verbal discourse but also in the previously mention resources (Davidsen, Ryberg, and Bernhard 2020). Moreover, we have analysed and discussed the different knowledge forms embedded and emerging in students' collaborative and embodied interactions (Ryberg, Davidsen, and Bernhard 2020).

In the literature regarding collaborative learning the *composition* of the studied collaborative group(s) is commonly static and does not change (e.g. Borgford-

Parnell, Deibel, and Atman 2013; Menekse et al. 2017). However, when we were analysing videos of students' interactions in our earlier studies we also noticed that students approached a particular design problem in shifting subgroups of one, two or three students or as a whole group. This implied that the collaborative group, indeed, was not static. As this, to our knowledge, was not well discussed in the literature we, in a recent study (Bernhard, Davidsen, and Ryberg 2023), investigated the dynamics of collaborative work in students' group practices in a design project. We found that the patterns of collaboration were not static, but indeed displayed a myriad of different patterns. Also the group members transition in and out of 'private conversations' and dialogue about the design.

In this study we focus the dynamics of individual and collaborative work by the four female students in the group that was carried out for an hour starting 44 minutes into the group's meeting. This part was selected as it displayed a rich and fluid repertoire of individual and collaborative work in different constellations. Our research question was *how could we describe and understand the dynamics of students' individual and collaborative work in the studied one hour of a design meeting?*

2 SETTING AND METHODOLOGY

2.1 Setting

The setting of this study is the Architecture and Design (A&D) programme given within the frame of the Aalborg problem-based learning (PBL) model which was created in response to the call that engineering programmes should include collaborative design projects of varying length and complexity. The A&D programme includes elements of architecture education, but also builds on knowledge, skills, and competencies from engineering. In the Danish context this was a novel approach when the programme started in the 1990s, as traditionally the fields of architecture and engineering are separated. The creation of the A&D programme was an attempt to combine the "technical theoretical" knowledge of engineering with the "aesthetic and artistic" artisanship of architecture, to create a new interdisciplinary education.

The data analysed in this paper is from a period 14 days into a project work where fifth semester A&D students are tasked with designing an office building for an external partner. The particular session studied is where a student group (group 3: four females, two males) is preparing to take part in a formal review session the next day. After the review session the groups have approximately four weeks left to complete their design of the building. The preparation for the review session was selected for analysis as it is what Jordan and Henderson (1995) refer to as a natural unit of analysis – limited in time and with a particular purpose.

The main workspace for the group was encircled by a fixed wall with windows, and two "walls" consisting of whiteboards, pinboards and blackboards. One of the "board walls" is used for various design ideas and sketches with each board having a particular type or category (e.g., printed computer designs or drawings). The other board wall is used as a calendar and overview of tasks (with different colour-

codings). In the midst of the group space is the “working table”, which is littered with paper, sketches, laptops, models, iPads, bottles etc.

2.2 Data collection and method for analysis

To achieve a rich picture of students’ individual and collaborative work and enabling studies to increase our understanding of engineering students’ learning processes in collaborative design projects we have recorded the interactions within the group using five digital camcorders (including one body-mounted GoPro camera) during the complete session (Jordan and Henderson 1995; Heath 2016; Goodwin 2018; Tang and Leifer 1991; “Big Video”, e.g. Mcilvenny and Davidsen 2017). In this case the session lasted almost six hours. In this study we have focused on the work, and interactions, by the four female students in the group that was carried out for an hour starting 44 minutes into the group’s meeting. This part was selected as it displayed a rich and fluid repertoire of individual and collaborative work in different constellations.

Fig. 1. Still pictures from videos displaying first individual work (pictures a and b)and a transition to a dyad between Ina and Mette (c and d).

For the purpose of this study recorded videos were viewed and analyzed by coding in which constellations students worked (e.g., individually, in subgroups, or in whole group). Furthermore, students’ membership in subgroups were noted, and it was noted the time constellations changed. To count as a member of a constellation a student had to actively display participation either verbally or bodily. Fig. 1 display a transition from individual work by all female students to a dyad between Ina and Mette and continued individual work by Sine and Heidi (corresponding to episodes 19 and 20 in Fig. 2). It should be noted that the students speak Danish and students’ expressions have been translated to English. The first author is a native Swedish speaker, but understands Danish quite well and the second and third authors are native Danish speakers.

Although parts of the videorecorded interactions have been transcribed, the transcripts have not been used in this part of our analysis. The reason is that standard transcripts primarily display the verbal part of interactions and to identify collaboration patterns we found it to be essential focus on embodied interaction.

The study was conducted under the ethical guidelines in place at Aalborg University and at Linköping University in accordance with Danish and Swedish laws. Informed consent forms were signed by each research participant. In this paper, participants have been given pseudonyms to protect their anonymity.

3 RESULTS

3.1 General findings

Before the analysed session the students had eaten breakfast together and as whole group (including two male students Anders and Sven). As one of the female students, Heidi, has just returned from being away there is a lot informal talk in the beginning. At the beginning of the work session the two male students leave the main room to work with their tasks at another place while the four female students remain at the groups main working space. For an hour (actually an alarm clock is set to mark timings) they work together in shifting constellations. An overview of the coding of the constellations is displayed in Fig. 2, with each student colour coded. Contrary to our previous study, in this study we have also included students' individual work in our coding as represented in Fig. 2. After the hour the group splits up and Sine and Heidi leaves the room at 1:44 while Ina and Mette remain in the room and work together until lunch-time. At 3:20 the whole group reconvene first to eat lunch together and after finishing lunch to coordinate and finalise designs and plan the presentation during the upcoming review seminar. An overview of the whole meeting can be found in Bernhard, Davidsen, and Ryberg (2023).

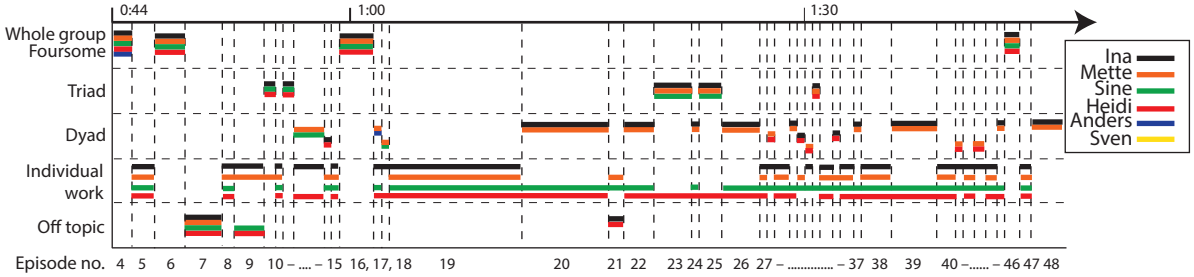

Fig. 2. Timeline for students' collaboration in the project meeting displaying their different forms of collaborations during the meeting as seen in the main group room. Each student is colour coded making their participation in different constellations visible. The scale on the time axis is hour and minutes from the beginning of the session. Episodes are numbered in line with numbering in Bernhard, Davidsen, and Ryberg (2023).

The analysis presented in Fig. 2 clearly display that the students for a considerable extent work individually. However this individual work is interspersed with several longer and shorter collaborations in dyads and triads in shifting constellations. Some "whole group" discussions in this group of four can also be seen. Furthermore, a 10 s pause was observed between the dyad in episode 22 and the triad in episode 23. In

a similar vein we usually observed pauses of 5 – 10 seconds in the interactions when students shifted from participating in one constellation to another as for example in episodes 30 – 33. Episode 11 also represent a very short, but distinct episode of individual work, between triads in episodes 10 and 12. In these short pauses the students would typically have a quick look in their computer, on a note, or to a drawing. To not clutter Fig. 2 to much we have usually not represented these, very short, pauses in the Fig.. Nevertheless, we think that these pauses are important in the interactions and for the collaborative work as they allow the students to check their drawings and notes.

3.2 Examples of different individual and collaborative constellations

In the first example we can in Fig. 1a above see the female students Ina, Heidi, Mette, and Sine working individually (episode 19) around the group's main table. Ina is trying to resolve an issue with conflicting design requirements by making drawings and trying things out with a Styrofoam model (Fig. 1b). After a while, in Fig. 1c she calls for Mette's attention. Mette, still sitting on her chair, "rolls" over to Ina's place. Here we can clearly see the initiation of a dyad between Ina and Mette both by their verbal exchange and by the embodied action in form of a physical movement of Mette to Ina's place. It can also be seen that Heidi and Sine continue to work individually.

a. 

b. 

Fig. 3. Episodes 22 and 23 – Ina and Mette (a dyad) continue their discussion from episode 20 turn to Sine (a triad) to be allowed to make adjustments.

In Fig. 3a continuation of the discussion between Ina and Mette in Fig. 1c – 1d is displayed. However, Mette have now "rolled" back to her place and Ina has walked over to Mette's place at the table. They make use of CAD, photos, and different gestures to discuss the issue at hand. In Fig. 3a it is displayed how they make use of photos of different buildings as a resource in their discussion. However, as a change might affect what Sine is working with, she is addressed by Ina in Fig. 3b. The dyad Ina-Mette (episodes 20 and 22) is changing into a triad Ina-Mette-Sine (episode 23). Heidi is still working individually. It should be noted that Ina and Mette are silent for 10 s before addressing Sine.

As is shown in Fig. 1c – 1d Mette oves over to Ina's place around the table to move back to her place in Fig. 3a. Instead Ina have in Fig. 3a moved over to Mette's place and is standing behind her. In our analysis of the video-recordings we have seen other, similar, movements among the students in their interactions. Even during the

phase that followed the one hour period analyzed in this study we observed that the collaborative patterns were not “static”, but the students made “guest visits” for co-ordination purposes. Thus, we not only observed different constellations of individual and collaborative work but also observed fluidity in “spatial” constellations. In Fig. 4 we have made a “spatial” representations of the collaborations presented in Fig. 1c – 1d and 3a – 3b.

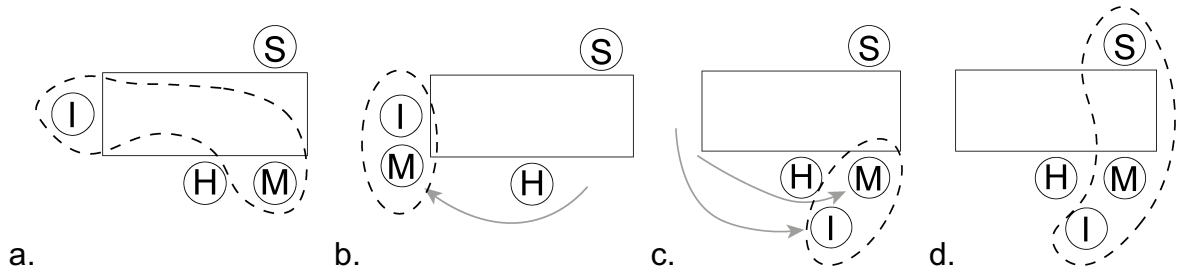

Fig. 4. Spatial representation of collaborations: a) represent the collaboration in Fig. 1c, b) represent the collaboration in Fig. 1d, c) represent the collaboration in Fig. 3a, and d) represent the collaboration in Fig. 3b. Dashed encirclements show collaborations and arrows show movements. I = Ina, S = Sine, H = Heidi, and M = Mette.

For space reasons we are not able to present more example although we have analyzed the whole, one hour, session as can be seen in Fig. 2.

4 CONCLUSION AND DISCUSSION

This study set out to answer the research question *how could we describe and understand the dynamics of students’ individual and collaborative work in the studied one hour of a design meeting?*

A limitation of this study is that we hitherto only have had time to do an in-depth study of the group practices in one collaborative design group. This somewhat limits the conclusion that can be drawn. Nevertheless, we argue that anyway several conclusions can be drawn from our findings. In the literature (e.g. Borgford-Parnell, Deibel, and Atman 2013; Menekse et al. 2017) intra group practices in static groups are reported. On the contrary we found, by analysing video-recordings, that the fine-grained patterns of students’ social interaction within the observed collaborative design group to be complex and dynamic and it display fluidity as well as structure (cf. Sørensen 2022) as the students during the day worked in many different constellations. It was observed that students often changed constellations and break into subgroups of one, two or three students to do some work and to congregate later as a whole group. Thus, we found that the patterns of collaboration in groups practical day-to-day work were not static but displayed a myriad of different patterns. To our knowledge, this study and our previous study (Bernhard, Davidsen, and Ryberg 2023) is one of the first studies to report this fluidity of constellations and to report complex collaborative patterns in students collaborative group work.

Furthermore, in line with the observation by Ryberg, Davidsen, and Hodgson (2018, 240), we also noted that the distinction between cooperative and collaborative work

seem to blur when we studied students' interactions in detail as they, in their activities, alternated dynamically between individual, cooperative, and collaborative patterns of work. Thus, our results challenge a naïve individual-collaborative-binary and a naïve cooperative-collaborative distinction. Rather, the observations made in this study might imply that individual work might be an important element in constructive and skilled collaborative work.

Thus, our results points to the need to investigate group practices and individual and collaborative learning in design project groups and other collaborative learning environments in more detail. It would be important to better understand which features (e.g., collaborative patterns, skills needed by students, etc.) are important for successful learning and good collaborative work in students' collaborative design projects and how these can be fostered and developed in engineering education. We have collected a large corpus of video data from A&D-students at Aalborg University in their first, fourth and fifth semesters. Thus, we have an excellent empirical material to continue study the questions raised by this study.

For engineering education researchers to be able to make more realistic and sound pedagogical recommendations, and for engineering educators to make sound decisions, they need to have a good understanding of how students' design processes play out in reality. As already mentioned, a limitation of this study is that we hitherto only have had time to study the group practices in one collaborative design group and it limits the pedagogical recommendations we can make based on our empirical material. Still, one conclusion is that localities where collaborative work is taking place need to be designed, or adapted, for flexible group work and another tentative conclusion might be that instructors should encourage fluid collaboration patterns in students' collaborative work.

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