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A qualitative study on how to scaffold for collaborative learning in an innovative learning area, a student perspective

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Abstract
Discussions and hands-on activities represent essential elements for student active learning, where students are engaged through group work and collaboration. This qualitative study gives insight into students' experiences of activities designed for learning collaboratively and sheds light on how teachers can scaffold these activities. The constant comparative method has been applied to analyse focus-group interviews with students on a physics course for prospective engineering students. Different aspects that improve the collaboration in the learning process are found and discussed. Further, this research provides knowledge about how an innovative learning area designed for student active learning with technology such as an interactive screen can be used as part of the collaborative learning process, and how teachers can create an arena for cognitive apprenticeship in physics.

Keywords:
group work, collaborative learning, innovative learning areas, scaffolding, qualitative, physics

Introduction

Group work is an established way to implement active learning (Prince, 2014), which Freeman et al. (2014) have found to improve student performance. The Norwegian Ministry of Education and Research recommends increased use of such learning methods in higher education. They issued a white paper in 2017, "Quality Culture in Higher Education" (Meld. St. 16 (2016-2017)) where they state that: 'Active learning methods are not used to a sufficient degree, and plenary lectures and traditional forms of examination continue to dominate' (p. 20). We interpret active learning as described by Freeman et al. (2014): 'Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work' (p. 8413). On this basis, we designed collaborative learning sessions for an introductory physics course. The term 'collaborative' indicates that students are working together on the same task, where the intention is to construct common knowledge (Mercer & Littleton, 2007) and thereby learn together. It is the teachers' responsibility to find a way to scaffold this type of group work. We use an extended understanding of 'scaffolding' that refers to any measure which 'helps a learner to accomplish a task they would not have been able to do on their own' (Mercer & Littleton, 2007, p. 15), including the teacher's supportive approach and the facilities surrounding the students' group work.

The aim of this article is to explore how teachers can effectively implement active learning strategies based on the students' experiences with collaborative learning. More specifically we will answer the research question:

What kinds of scaffolding are reported by students to promote their collaborative learning?

This article presents a qualitative study of students' experiences with collaborative learning activities based on a recent analysis of focus-group interviews from May 2017. In the academic year 2016/17, we collaborated closely in planning, implementing, and finally teaching a physics course.

We have more than ten years of experience in using innovative learning areas as part of our teaching. These learning areas include technology such as interactive screens which can create a joint focus in a group work setting. During these ten years, we have developed and documented our teaching systematically, to explore the potential of technology-enhanced collaborative learning activities. Results from this development have previously been published in Andersen et al. (2018), and Andersen et al. (2020).

Theoretical framework and related research

This study is based on a sociocultural view of science learning (Leach & Scott, 2003), originating from the work by Vygotsky (1978, 1986), which at its core states that students actively learn together through interactions and compromises using language (Vygotsky, 1986). Group work is an example of how to organize social learning activities, in which students are using language to discuss both with their peers and the teachers to reach their individual zone of proximal development. The zone of proximal development was defined by Vygotsky (1978) as the distance between what a person can perform independently (the actual development level) and the maximum that a person can achieve under guidance (the potential development level). Language is a tool to approach the zone of proximal development and thereby create a third space. The third space is understood as the space where students, based on their everyday life experiences, meet the scientific discourse using verbal language as well as representational forms characteristic for science in a way that the students find meaningful (Knain et al., 2017). Students' typical way of thinking and talking about everyday life experiences and observations differ from how these experiences are described scientifically. To support meaning making in science, teachers need to shift between a dialogic approach in which the teacher is open to students' ideas, and an authoritative approach where the teacher focuses on the scientific view (Scott et al., 2006). Using this framework in group work settings, the teacher utilizes the third space for a dialogic approach and shifts to authoritative interventions to introduce the scientific discourse. Thereby, group work settings can allow cognitive apprenticeship to occur. Brown et al. (1989) created a list of salient features to be present for achieving a cognitive apprenticeship in group work. These are: Collective problem solving, displaying multiple roles, confronting ineffective strategies and misconceptions, and providing collaborative work skills (p. 40).

A meta-analysis has shown that learning in small groups is effective in promoting greater academic achievement, more favourable attitudes towards learning, and increased persistence in undergraduate courses in mathematics, engineering, and technology (Springer et al., 1999). To promote collaborative learning, the group tasks should be designed in such a way that the students need to work together. The tasks should therefore be challenging and open-ended (Cohen, 1994).

A study on group work in a learning area like the one used in this study has indicated that the interactive screen may facilitate three processes that are conducive to collaborative learning in physics (Mellingsæter & Bungum, 2014): First, an exploratory process where the students engage in a collaborative brainstorming, sketching, and writing on the screen; second, an explanatory process where one of the students acts as a teacher, explaining to the rest of the group with reference to the interactive screen; third, a clarifying process where the students inquire or ask clarifying questions about what has been written on the screen. The same study also indicated a fourth work process which did not facilitate collaborative learning, which is insertion, characterised by one student writing a solution on the screen already sketched on paper with the rest of the group not participating. To prevent this latter process, we showed how the design of the tasks created a common focus and made the students work *as* a group and not just *in* a group (Andersen et al., 2018).

Although collaborative learning is student-centred, the teacher plays a crucial role in the success of the students' learning process and their learning outcome (Blatchford et al., 2003). The teacher needs to consider how to scaffold the students' learning process by providing support and guidance during group work. Regarding the latter point, the success depends on the teacher's ability to adapt the feedback to the students (Chiu, 2004), which again depends on the teacher's insight into the students' needs (Webb, 2009).

The context of this study

The Pre-course for prospective engineering students at the Norwegian University of Science and Technology (NTNU, 2021) is mainly for students with a vocational background who intend to apply for engineering studies. To implement active learning strategies, while at the same time using the available time and resources effectively, we decided to merge two classes into one. Instead of giving separate lectures to two classes of approximately 45 students each, 90 students received joint lectures given by one of the teachers. Each lecture was followed by two group work sessions, one for each class where both teachers were present. All students had lectures and group work two days a week, a total of eight hours (8 × 45 min) of teaching activities in physics per week. The first group work session of the week for all students took place in an innovative learning area, while the second one took place in a conventional classroom. The group work sessions had practical exercises which focused on conceptual understanding, for example establishing the connection between force and motion. In the conventional classroom, the students performed analogue experiments and worked with exercises from a textbook. For the group work sessions in the innovative learning area, the students discussed concepts and used dataloggers to track their measurements which would then be displayed on the interactive screen in real-time. The design of these activities was inspired by the real-time physics laboratory exercises by Sokoloff et al. (1999) and problem-solving strategies like Van Heuvelen's strategies of learning to think like physicists (1991). Throughout the year the group formations were set by the teachers. This was often done simply by dividing the students into groups of four when they entered the rooms. Participation was voluntary.

During the academic year, we continuously reflected on our practice and improved the design of the exercises. This was based on discussions about: What and how much information should be given in the lectures, how to form the actual groups, how to formulate the questions to enhance discussion, and how to engage with the students.

The innovative learning area: a modern teaching facility

The innovative learning area consists of separate group stations where each group station is equipped with an interactive screen connected to a computer (figure 1). Dataloggers are used to do measurements relevant for learning basic physics. Sound reducing curtains not only reduce noise but also visual distractions and form separate cubicles for each group of up to four students.

Figure 1. Photos of the innovative learning area a) without students (Photo by T.H. Andersen), b) with curtains where students are working in each cubicle (Photo by T.H. Andersen), and c) a view inside a cubicle with students working (Photo by B. Voaidas).

Designing the exercises for the interactive screen

We deliberately designed the exercises to facilitate for the students to work collaboratively using the screen as a joint focus. This was done by using the screen actively in all steps of the group work. The group downloaded the relevant file, which contained all information and exercises for the session, with space for the students to fill in their answer by hand. Handwriting is quite essential in physics and the interactive screen supports this. The exercises were written in short sentences, not following a recipe of what to do in detail. The text could be as brief as 'Measure the force when you pull the box', having a photo showing how to do it. Then follows: 'What do you observe?', 'Discuss how to interpret the graph', and 'Use your measurements to calculate the coefficient of friction', something which had been the subject of the lecture earlier the same day. The file also contained calculus-based exercises on the same topic. Typically, we modified standard exercises from the textbook by adding questions for discussion, and coordinate systems for graphs if needed. Hence in this way, it was easier and quicker to work directly in the file as compared to writing on paper. This should help the students to work collaboratively, focusing on the same task on the screen. The size of the screen also made it easy for the teacher to get a quick overview of the progression within the group and support the learning process. At the end of the session, the file was handed in and shared among the group members. This file was not assessed since all parts had been discussed with the teachers during the session. However, during the next lecture the teacher could choose to share results, comments, or figures made by the students, to clarify important aspects for the whole class.

Methodology

The goal of this study is to establish what kinds of scaffolding promotes collaborative learning among students. To obtain a deeper understanding of the students' experiences and perspectives, a qualitative research design was chosen, using focus-group interviews. For this article, the transcriptions of the interviews were analysed by the constant comparative method, which is useful for extracting clear information (Corbin & Strauss, 2015; Postholm, 2019) about the students' experience of the teaching and learning activities and to get an understanding of the students' perspective.

Data collection

This is a case study bounded in time and space (Creswell, 2013), where 10 students from the physics classes of 2016/17 volunteered for interviews. To benefit from interactions and discussions between the students, semi-structured focus group interviews were chosen (Robson & McCartan, 2016). In the interviews, the students were asked about their activities during the lectures, how the group work sessions went, the difference between working in a conventional classroom as compared to the innovative learning area, the group compositions, how the screens were used, the reasons why they participated, the practical experiments, how they perceived the teachers' expectations, and how they perceived the teachers, their weaknesses and strengths. In total, three focus-group interviews were conducted with students that had taken part in the group work sessions in both the conventional classroom and the innovative learning area. In order not to bring the female students into minority, two groups with 3 and 4 male students, respectively, and one group of 3 female students were formed. The interviews lasted between 70 and 100 minutes and took place within one of the cubicles at the innovative learning area in May 2017, after finishing all teaching activities and before the exam. All qualitative data material was digitally recorded, subsequently transcribed verbatim in Norwegian, deleting the parts where it was possible to identify individuals, and the students were given pseudonyms to protect their identity.

Ethics

For ethical reasons, as some of the questions were concerning the students' perception of the teachers' role, the interviews were performed by a researcher who did not have a relation to the students. She designed the interview guide in collaboration with us and was responsible for the transcription, where all names were removed before we received the data material. She informed the students prior to the interviews that their participation was entirely voluntary, and they could withdraw at any time, or if they wished, later have their data withdrawn from the study.

Method of analysis

The constant comparative method of analysis was applied to obtain a systematic overview of the data (Creswell, 2013). The basic procedure for the constant comparative method is to compare data to form codes; codes are compared to form categories, which then again are compared to form a core category (Corbin & Strauss, 2015; Postholm, 2019). As some years have passed since this data material was collected, it was necessary to reconnect with the material before starting the coding process. This was done by reading the transcribed interviews. The first author was responsible for the analysis, while the second author was a discussion partner. In the first phase of the coding, the open coding phase, sentence by sentence was coded in the process of breaking down the information and exploring the students' statements, categorising the data in preliminary categories. In the second phase, axial coding, the categories from the first phase from all three interviews were connected through a thorough comparison of the preliminary categories. To extract and form the categories in the second phase, questions such as 'What does it mean, why are the students expressing this?' guided the analysis. The data material from the three interviews give rise to aspects within the categories; the material is therefore considered sufficiently saturated for the purpose of this study (Corbin & Strauss, 2015). In the third phase of the analysis, the selective coding phase, the core category 'collaborative learning' was extracted, comprising the following three main categories:

1. How group work differs depending on the room.
2. Factors that promote collaborative learning:
   - The screen as a joint focus
   - Practical experiments as a help in understanding theory
   - The design of the tasks
   - The teacher providing suitable support and the engagement of the teacher
   - Curtains give rise to less disturbance
3. Students' roles and behaviour in group work.

Results

In the following, we provide a rich description of the three main categories, listed above. The section is organized according to the three main categories and students' quotes are used to illustrate and support the results.

How group work differs depending on the room

Even though the students were expected to work in groups both in the conventional classroom and in the innovative learning area, different work routines evolved. For the group work sessions in the conventional classroom, the students used analogue equipment to do practical exercises and they had calculus exercises as well. Instructions were handed out on paper. Even though the tables in the conventional classroom were arranged groupwise, the students tended to work individually on the calculus exercises, and they occasionally discussed with the student next to them. One aspect which hampered the process of collaborative learning was that the students were not working at the same pace, hence they were not working on the same task simultaneously. Some students even used a headset with music to block out noise. It was only on the practical exercises in the conventional classroom that the students worked together: *'You might be sitting in a group but you can do the tasks individually and when there is a practical task the group will do it together'*. The work routine in the conventional classroom differed from how the students worked in the innovative learning area, as expressed by one of the students when asked about the purpose of working in the innovative learning area: *'because students should actually do something instead of just be in the (conventional) classroom'*.

The work routine introduced in the innovative learning area was well known by the students: *'We enter, find the group table assigned by the teacher, the seats get occupied, we find the file online, we start with exercise one, and find the necessary equipment'*. The next student followed *'It's group work every time'*, *'the task is answered using the screen, and then handed in'*. *'It's a very important point that we write on the screen not on paper'*, and *'everybody takes turns in writing'*. The benefits from this working method were recognised by the students: *'You learn so much by explaining to others what you have understood, and to get input on what you have not understood yourself. So, you get a complete picture, as long as everyone participates'*. Working in groups was helpful since *'everyone explains things differently'* and it '*can be easier to understand when someone at your level talks about it rather than the teacher. Also, if you sit there and do not understand something, there are three "teachers" who can teach you in three different ways'*.

The students acknowledged the experience of collaboration in the innovative learning area, while in the conventional classroom they worked individually rather than collaborative. They reported several factors which are associated with collaboration from the innovative learning area, these are described in the next category.

Factors that promote collaborative learning

The innovative learning area is a modern teaching facility for group work. As shown in the photos in figure 1, there is a large screen at each group station. The students recognised the screen as creating a joint focus in their group work. *'Everything takes place on the screen; the screen is crucial. It is somehow the whole point of being there'*, and *'You look at the same thing, you are working together. Remove it, and you have an ordinary group room with students working on their own'*. *'It makes people work together.'* The students perceived the screen as a joint focus, which contributed to the process of learning collaboratively, since *'everyone is paying attention to what is happening on the screen, nobody is sitting at the corner of the table and calculating on their own. It "glues" the group together'*.

Practical experiments were always a part of the tasks at the innovative learning area, where real-time graphs of the measured quantities were shown on the screen. The students acknowledged the experience of working with their own measurements, where they could make connections between the experiments and the corresponding theoretical descriptions. *'You see the concepts in real life, not just from a page in a book.'*

To further promote the use of the screen as a joint focus, all exercises were available in one file. In the exercises we asked as open questions as possible. We would for instance ask the students how they could measure a particular quantity, rather than telling them how to do it. The students expressed a perception that *'in physics, you can discuss much more'* as compared to other subjects. Also, for *'difficult calculus exercises you have to discuss what to do, and someone might say something which is wrong, then you have to discuss why this is wrong and what is right'*.

The students had noticed that the large screen also made it easier for the teacher to see how a group is performing. *'They enter (the cubicle), look at the screen and engage'*, and *'it is easier for the teachers to be active here (in the innovative learning area). In the (conventional) classroom they have to watch over your shoulder and look at what we are writing'*. In the innovative learning area, it was easier for the teacher to align the response to each group. *'The teachers are becoming a bit like a supervisor. When we ask for help, they not only tell us* *how to do it but say how we should think.'* The supervision from the teacher was adapted to the situation within each cubicle. *'They spend more time with us in the innovative learning area. Here they have to sit down and ask themselves: Why don't they understand this?'* and *'They spend more time on each of us and I think they have started to see what people know'*. On a more personal level, the students felt recognized: *'They are very good at remembering names and have started picking up on how people work and how to approach them'*.

When designing the tasks, we as teachers worked collaboratively ourselves, something which we found fruitful and engaging. This engagement was noticed by the students: *'You notice that Trine and Guri have worked with this and have discussed a lot themselves'*, and that *'they believe in this'*.

Another, though low-tech, characteristic of the innovative learning area is the curtains between the cubicles. When the students visited a similar area without curtains, they all recognised a noisier work environment. For some students this did not affect the work process, while others expressed that they became distracted: *'At least me, I become more distracted when I see people talking as compared to if I just hear them'*.

Students' roles and behaviour in group work

The students mentioned that they tended to become more unfocused being in the same group as their friends, as opposed to working together with random classmates. Further, they said the best discussions occurred when all group members had the same starting point: *'Even if everyone is uncertain how to do it, together the uncertainty becomes less when everyone tries to understand.'* On the other hand, especially at the end of the year, the level of achievement seemed to differ more, and it appeared challenging for some students to work with students at another level of performance. Some students said they *'do not dare to ask'* other students when they needed help. Conversely, other students *'do not bother to explain the very basic things'* because they thought it should be known by everyone by this point.

When collaborating, the students took on different roles: Finding the right formulas, doing calculations, guiding as a teacher, and writing on the screen. These roles often overlapped, and the students shifted roles during the session. Because there were only three to four students per group, *'it is difficult to hide in the group'*, and everybody participated. To be the student writing on the screen could sometimes be challenging since *'this student becomes very visible when standing there, it's completely impossible not to see you'*. This role could be taken by a student who was guiding the group as a teacher, or on the other hand a student who needed guidance from the group on what to write. In the latter case, a student reported: *'You get a bit of a nasty feeling, you almost feel "naked"'*. This might be one of the reasons why the students emphasized the positive aspect of changing the groups every week, as this made it easier to change roles and experience new group dynamics.

Theoretical analysis and discussion

We created a learning design where teaching and learning activities consisted of alternating phases of teacher-driven lectures with an introduction to the theory, and group work sessions that were student-driven with a structure defined by the teachers. During the group work, the students reported using their own everyday-life language to make sense of observations from the hands-on activities, they commented that it was *'easier to understand when someone at your level talks about it rather than the teacher'*. As explained by Knain et al. (2017) this is a way to open the third space, which helps the students to create and develop a scientific understanding of the concepts. To ensure the students reach their full potential of the third space, it is crucial for the teacher to carefully facilitate this encounter between the students, the physical phenomena, and the scientific theories. Being two teachers available secured a high teacher-student ratio and allowed each teacher to adapt and evaluate interventions to the students' needs, as advised by Chiu (2004). Further, being two teachers present meant that we could discuss between us and thereby answer challenging questions from the students more effectively and at a deeper level. In the innovative learning area, the curtains made it easier to support one group at a time, since we were not disturbed by the other groups.

In addition to the curtains, there are other aspects regarding the room which contribute to a different teaching and learning approach in comparison to a conventional classroom. An important element in the innovative learning area is the interactive screens. Both students and teachers must know how to use the screen in order for it to create a joint focus and thereby improve the learning process. As a student commented *'remove it, and you have an ordinary group room with students working on their own'*. In the design of the tasks, the screen is essential to support collaborative learning. We deliberately designed tasks for the students to be challenging and open-ended, as suggested by Cohen (1994), for the students to work collaboratively as opposed to cooperatively, where the students divide the exercises between the group members. The students' commented that *'in physics, you can discuss much more'*. Of course, discussions and collaborative group work are possible in other subjects too, the teachers just need to scaffold for this to happen.

Participation in these learning activities was voluntary, this seems to have strengthened the expectations among the students that everyone present should participate actively in the group work. The teachers composed the groups, which was appreciated by the students, who said they experienced a more focused collaboration when they were not working with their closest friends.

The learning activities designed for the innovative learning area may induce elements conducive to cognitive apprenticeship (Brown et al., 1989) as expressed by a student *'they not only tell us how to do it but say how we should think'*. We found from the interviews that the students solved problems collectively and displayed multiple roles also found by Mellingsæter and Bungum (2014). The students got confronted with ineffective strategies and became aware of their misconceptions, and they got to practice their collaborative working skills, all features of group work proposed by Brown et al. (1989) for cognitive apprenticeship to occur. This is facilitated by the teacher, who also took part in the group work as a discussion partner, showing the students how to use dialogue to develop a shared understanding, and shifting between a dialogic and an authoritative approach when needed as recommended by Scott et al. (2006). Designing and implementing this kind of teaching and learning activities are challenging, as the teachers are more available, and must also be flexible in terms of adapting their support towards the students' needs, at any level.

Conclusion

In this article, we describe how the scaffolding of the learning activities makes students work collaboratively. The students' reports from the focus-group interviews are in line with findings found in the literature that genuine collaborative learning is dependent on careful planning, design, and implementation. This study identifies several factors which the students report promote collaborative learning. One of these factors is the interactive screen, which functions as a joint focus for the group. Also, the tasks themselves are designed for the interactive screen, which contributes to collaboration, since all students in the group are working on the same task at the same time. Further, the separate cubicles in the innovative learning area, where disturbance from neighbouring groups is reduced, were reported to improve the concentration for some students.

For both the innovative learning area and the conventional classroom, practical experiments are reported to foster collaboration. However, elements conducive to collaborative learning are found to depend on the facility of the room, i.e. whether answering the tasks is confined to the interactive screen.

According to the students, the teachers are also found to be a factor when supporting and actively encouraging collaborative learning among the students. When the teachers engage in group discussions by asking questions and implicitly conveying how physicists work and think during problem-solving, this not only opens a third space but also creates an arena for cognitive apprenticeship.

Finally, the students see that their roles and behaviour in the group work affect their collaboration. To avoid unproductive group constellations evolving, we decided on the group compositions, which were changed every week. The students seemed to prefer this as they claimed they worked better when they were not in a group with their friends. The students also reported a preference for working with peers at the same level of performance. We intended to improve the learning environment by actively working with the group constellations. However, we could have focussed more on the different roles in the group to better support the group work.

The conclusions from this study have some limitations since only ten students who participated in the voluntary activities were interviewed. For further research, observations and recordings of the group work would give an extended understanding and insight into how the everyday life experiences of the students meet the scientific discourse and create a third space.

The results presented in this article suggest several success factors when scaffolding teaching and learning activities for collaborative learning. One of these factors is creating a joint focus for the group through the interactive screen. When designing the tasks, it is important to consider whether the design fosters collaborative learning or not. Finally, when scaffolding for collaborative learning the teacher becomes a facilitator and supervisor, as well as an expert.

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