Magnus Strøm Mellingsæter

Meaning Making Through Use of Interactive Whiteboards During Physics Group Work

A Case Study from Engineering Education

Thesis for the degree of Philosophiae Doctor

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Norwegian University of Science and Technology
Faculty of Natural Sciences and Technology
Department of Physics

NTNU – Trondheim
Norwegian University of
Science and Technology

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During this time of working with the Ph.D., I've been told on several occasions that the process of accomplishing a Ph.D. will change me. And it has, most certainly. However, I would contend that any experience or encounter has the potential to change a person, no matter its significance in others' eyes. The willingness to be open to otherness brings with it a potential for a lifetime of rich, new experiences and reflections. These are thoughts that I have increasingly come to appreciate during the course of this work. The "downside" is that I might risk ending up somewhere (or someone) else than initially planned, but that is a risk well worth taking. With this in mind, there are several people who have, in their own ways, changed me for the better during this process, and who deserve credit.

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Magnus Strøm Mellingsæter

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Abstract

This thesis investigates physics group work among engineering students. A case study is presented, in which first-year engineering students attended physics group work as part of a basic physics course. Each student group had an interactive whiteboard at its disposal, which was used for writing and handing in solutions of physics tasks. The research interest guiding this study is how the collective meaning making process during the group work is influenced by the ways the students used the interactive whiteboard during the group work. Also, the nature of the subject matter is investigated from a theoretical perspective, in order to frame the exploration of the interaction between the teacher and the students during teacher interventions in this learning situation.

Based on qualitative analyses of video data from the group work, and audio data from a focus group interview, the results from this study show that the interactive whiteboard holds promising potential with regard to the students' collective meaning-making process during problem solving. However, this potential is not realised by itself, just as successful group work in general does not automatically occur by itself. The dynamics of teacher interventions, which has been investigated in light of what I argue is a fundamental epistemological feature of the subject matter, has characteristics that are attributed to an implicit agreement between the teacher and the students. This epistemological feature governs both the teacher's and the students' actions during teacher interventions, and I claim that this feature is of relevance to learning situations other than the one described in this thesis.

List of appended papers

Paper A:

Mellingsæter, M.S. & Bungum, B. (submitted). Students' use of the interactive whiteboard during physics group work. Paper submitted to European Journal of Engineering Education.

Paper B:

Mellingsæter, M. S. (2013). Engineering students' experiences from physics group work in learning labs. Paper published in Research in Science & Technological Education. doi: 10.1080/02635143.2013.853033

Paper C:

Mellingsæter, M.S. (submitted). On the right track: dynamics of teacher interventions during physics group work. Paper submitted to The International Journal of STEM Education.

Contents

1. Introduction

Collaboration with others on a joint problem has a great potential for advancing learning as well as for improving the quality of the solution that emerge as a result. Processes that constitute group work, such as conceptual discussions, where participants get the opportunity to make sense of their own and others' thoughts through negotiation, may in itself be valuable aspects of collaboration. Group work is a general concept, with the only limitation being that we understand it as involving groups of people working toward some shared goal (Prince, 2004). Within science and technological education, we find numerous kinds of group work, from small groups working together on laboratory exercises, project groups, and study groups, to spontaneously formed groups of students working together to solve a problem. The focus of this thesis is on group work as an organised learning activity.

There are several reasons for putting students into collaborative groups. It could be for practical reasons regarding more efficient assessment on the teacher's behalf (Christie & Ferdos, 2006). It could be related to social aspects, as a way for students to develop experience and skills of collaboration (Berge, Danielsson, & Ingerman, 2012), or as a way of facilitating retention through social integration (Cartney & Rouse, 2006). It could also be implemented to activate the students (Biggs & Tang, 2011). As a learning activity, group work is associated with enhanced learning outcomes and enhanced collaboration skills (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Springer, Stanne, & Donovan, 1999). It represents a context which offers some possibilities for learning that are more difficult to integrate into the realm of a large lecture hall, such as dialogue, which is of the upmost importance when it comes to meaning making in science.

In the past few decades, research fields have been established, dedicated to investigate the potential of using various information and communication technologies (ICT) in group-work contexts. One of the most prominent of these fields is perhaps *computer-supported collaborative learning* (CSCL), which is concerned with the possibilities offered by computer software with regard to fostering joint, intellectual activities (Stahl, Koschmann, & Suthers, 2006).

This thesis presents a study of group work in engineering education where the use of the interactive whiteboard (IWB) makes out an important constituent. The IWB is basically a big, touch-sensitive computer screen, which is connected to a computer and a projector, that offers all the functionalities of an online computer, along with the ability to use the touch-sensitive screen (combined with appropriate software) as a whiteboard. Furthermore, the touch-sensitive screen allows for the opportunity to use the fingers to move or manipulate objects on the screen. The IWB was originally not developed to be used in an educational context; it originated from office conference rooms (Greiffenhagen, 2002), but has now become increasingly widespread in classrooms, replacing the non-digital whiteboard or blackboard. In this study I have looked at how the collective meaning-making process during engineering students' group work could be influenced by the use of the IWB.

Background

Engineering education in Norway

Engineering education in Norway is a three-year, 180 credit points bachelor study, which encompasses a variety of study programmes such as mechanical engineering, chemical engineering, civil engineering, logistics engineering and electrical engineering. There exists an alternative where students with tertiary vocational education can graduate after only two years, but here we focus on the ordinary three-year engineering study. Admittance to ordinary engineering education can be accomplished in different ways, in order to allow admission for students with general university and college admissions certification as well as students with secondary vocational education. Admission for students with general university and college admissions certification requires that they have accomplished an introductory physics course and both an introductory and an advanced mathematics course in upper secondary school. Students with secondary vocational education can choose to accomplish a preparatory course in order to qualify for admission, which has a syllabus similar to upper secondary school. This means that first-year engineering students constitute a heterogeneous group, in terms of educational and professional background, which might imply a variety of students' initial motives and also their academic achievement (Andersson & Linder, 2010).

Engineering education in Norway comply with the national framework plan of engineering education, issued by the Norwegian ministry of education and research (Framework plan for engineering education, 2005). According to this framework plan, mathematics and science are defined as basic subjects in engineering education, which make out about a third of the study load. Further, more programme-specific technical subjects make out up to half of the study load. Finally, social science subjects, optional subjects and the final thesis make out the rest. The national framework plan does not dictate the order in which the different subjects should be organised within the study programmes. However, it is natural to include the basic subjects within the first semesters. Furthermore, the educational institutions are free to merge or divide these basic subjects into courses as appropriate.

There is an increasing emphasis on the need for the future engineer to be aware of the social, economic, environmental and humanistic aspects of society, as well as the technological aspects, and also to be able to communicate and cooperate with others across disciplines and nationalities (Baillie, 1998; Grasso & Burkins, 2010b). The rationale for this is that engineering tasks entail more than developing purely technological solutions (Grasso & Burkins, 2010b; Kabo & Baillie, 2009). These extensive and potentially complex demands call for flexibility and creativity on the engineer's behalf (Baillie & Walker, 1998). For engineering education, this would imply questioning the 'stem and branch' structure (Christiansen & Rump, 2007b), where basic disciplines such as physics are taught in isolation during the first terms, while more programme-specific technical courses are taught during year two and three. One proposed solution is to conceive engineering education in a holistic manner, which emphasises open-ended contextualised problem formulations, team-leading skills, communication skills across disciplines and life-long learning (Grasso & Burkins, 2010a).

The Norwegian ministry of Education and Research has responded to this challenge. In 2008, the Norwegian Agency for Quality Assurance in Education presented an evaluation report on engineering education in Norway. Among the recommendations in the report was that communication and collaboration skills should be more emphasised throughout the education (NOKUT, 2008). As a consequence, the national framework plan has been revised, and a new regulation on the framework plan was implemented from the autumn term of 2012, which implied a stronger emphasis on a more holistic, integrated engineering education (Regulation on framework plan for engineering education, 2011). However, data for this study was collected during the autumn term of 2011. Thus, in the following, only the framework plan of 2005 will be considered.

Physics in engineering education

Physics is included as one of the basic subjects in engineering education, consisting of at least ten credit points. What this means is that physics, along with the other basic subjects mathematics, statistics, information technology and chemistry, should provide the engineering student with "a robust scientific base for his/hers technical knowledge and understanding" (Framework plan for engineering education, 2005, p. 4, my translation).

How is this knowledge base important for engineering students? Goldberg (2010) sees the traditional basics of engineering education, i.e. science, mathematics and engineering science as necessary, but he finds engineering education (in the US) lacking in focus of what he terms the ‘missing basics’. By this he means skills associated with engineering, such as the ability to label challenges and ask appropriate questions regarding the task, modelling of tasks, methodological skills, and the ability to communicate solutions in written, oral or visual forms. The necessity of Goldberg’s traditional basics were explored by Christiansen and Rump (2007a), who investigated how groups of novice engineering students, so-called intermediates and experienced engineers each worked through a given problem. Their findings suggest that theoretical knowledge played a role when it comes to establishing cognitive structures, i.e. ways of perceiving a problem. However, theoretical knowledge was not in itself sufficient for effective problem solving skills.

Research focus and research questions

In this thesis I present a case study from Sør-Trøndelag University College, where first-year engineering students attended weekly group-work sessions as part of their basic physics course. The Department of General Science at the university college had designed rooms specifically for group work, where each group had access to an IWB, and was to write down and hand in solutions to the given physics problems by means of the IWB.

Language and talk are important, not only in terms of shaping and conveying one’s own thoughts, but also to interpret other’s ideas and the possibility to negotiate meanings through dialogue (Mortimer & Scott, 2003). Furthermore, any learning activity takes place within a certain context, by extensive use of meditational tools, both physical and abstract (Säljö, 1999). The aim of this thesis is to describe how students use the IWB during group work, and how this use relates to their collective meaning-making process. In addition, the interaction between teacher and students during teacher interventions has been investigated, in relation to an epistemological feature of science.

The research questions for this study are therefore as follows:

1. *How does the use of the IWB influence the collective meaning-making process during group work?*
2. *How does the nature of engineering physics influence the interaction between teacher and students during teacher interventions?*

These research questions are generalisations of the questions asked in the appended papers. By the term *engineering physics*, I refer to the standalone basic physics course that is a part of the basic subjects in many of the engineering programmes at Sør-Trøndelag University College.

Structure of the thesis

Chapter two, *The case: physics group work with interactive whiteboards*, offers an account of the initial aims for the group work, the group work setup, the physics course, of which the group work was a compulsory part, and a brief description of the physics problems the students were working on.

Chapter three*, Literature review*, aims to develop a theoretical account of the use of IWBs in group work in terms of its potential to contribute to collective meaning making. In addition, considerations of an epistemological feature of science are presented, which is of relevance to the interaction between teacher and students during teacher interventions.

In chapter four, the *Research methods* that were deployed during this case study are presented. Some considerations about the success of the methods used are also described.

Chapter five, *Summary of papers*, offers a brief description of the appended papers; the research questions and the results that were obtained from each of them.

In the sixth and final chapter, *Discussion and conclusions*, the results obtained from this study are discussed, in relation to the research questions for this thesis.

2. The case: physics group work with interactive whiteboards

The case concerns first-year engineering students at Sør-Trøndelag University College, attending organised group-work sessions as part of their physics course. The Department of General Science at the university college, which was responsible for the physics course, designed rooms for group work, so-called *learning labs*, equipped with an interactive whiteboard for each group. The intention was that the student groups should use the IWB to write down and hand in solutions to the given physics problems. As the IWBs were connected to the Internet, the students had access to online resources whenever necessary. From previous projects, the Department of General Science had built up experience with implementing ICT-tools for pedagogical means. The learning labs became a part of an R&D-project called HiST Mobile (http://www.histproject.no/node/256), which aims to develop new ways of teaching, learning and assessing, by means of different ICT-tools. One of the aims for the learning labs is to develop learning activities that could replace some of the lectures that typically make up the majority of teaching and learning activities in engineering physics courses. This is in line with the recommendations from the evaluation report from NOKUT (2008).

In the autumn term of 2010, group-work sessions in the learning labs were conducted for the first time. From informal conversations with students and teachers, I got the impression that the students' experiences were mixed. Some signalled that they did not see the point of using the IWB, as it was considered unnecessary extra work (the students wrote down their final solutions on paper, and then inserted it on to the IWB).

One year later, during the autumn term of 2011, group work sessions in the learning labs were conducted for the second time. These sessions are the ones on which the study presented in this thesis is based, where first-year mechanical and logistics engineering students attended group work in the learning labs as part of their physics course. This time, some changes were made to the setup compared to the year before. Drapes were installed, which served to separate the different groups into booths, and also to reduce noise. Two teachers were present at the exercise sessions, and were available for supervision upon request. These were experienced teachers, who both had an interest in trying out new ways of teaching physics. One of these teachers was the lecturer responsible for the physics course, which meant that he also gave the lectures that were part of the course. At the start of the term, the lecturer prepared the students for the group work, by informing them about some of the possible benefits associated with group work. Also, the lecturer provided the students with a video tutorial for how to use the IWBs. The students were free to organise their own work, i.e. they were not given additional instructions on how to behave or interact in a group-work setting.

The students met in the learning labs for about three hours once a week for a total of eleven weeks during the term. About 100 students participated in these group-work sessions, and the students chose for themselves who they would collaborate with. Due to the number of students and limited space, the groups were allocated into two different sessions each week, with eleven groups present at each session.

Aims for the learning labs

From the department's point of view, there were two reasons for equipping each group with an IWB. Firstly, the aim was to have the students to meet face to face to solve the tasks, in order to counter what was perceived as a discrepant strategy to collaborative group work, i.e. that the students divide the various tasks between them and work separately. By constraining the students to work face to face in an intended collaborative manner, the hope was that this would contribute to students working *as* a group, not just *in* a group (Mercer & Littleton, 2007). Secondly, the aim was to make the group work more efficient. By having the students handing in their solutions as proprietary whiteboard-files, the idea was that this would be more efficient, compared to having the students making a final paper-written solution, which has to be handed in physically somewhere on campus. Also, the teacher's aim was that the groups should complete the tasks within the three hours they had at their disposal in the learning labs. The students had limited options for completing the assignments outside the learning labs, owing to the process of handing in. Consequently, the students had an incentive to complete the assignments within the given time. By expecting the students to complete the tasks in time, the aim was that the students' spare-time workload should not be increased.

The physics course

At Sør-Trøndelag University College, most of the engineering programmes contain a basic physics course, which is taught during the first two terms. In accordance with the national framework plan (2005), some of the topics covered are common throughout these courses (e.g. classical mechanics), while other topics are included or excluded according to the specific study programme. Thus, electrical engineering students are being taught electromagnetism, while this is absent from the physics curriculum in the mechanical engineering programme. The course description for the physics course that forms the empirical setting for this study states that the course should: "provide knowledge about key concepts within mechanics, basic statics, thermodynamics and fluid mechanics, and also practice in mathematical descriptions of physical processes" (Mechanical engineering, Course description for 2011-2012, 2011, p. 104, my translation). Some of these physics topics should in principle be familiar to the students, as they need to have accomplished a physics course with a syllabus identical or similar to the syllabus from upper secondary school. Other topics, such as fluid mechanics, may appear more unfamiliar to the students. The overall aim for the physics course is for the students to learn conceptual knowledge and later on being able to use these concepts to solve problems in technological contexts.

The physics problems

The weekly exercises consisted of three to four physics problems, which were strongly linked to the curriculum. The bulk of the physics problems were given as pure textual problems, where some required mere calculation, whereas others required estimation of relevant quantities. The teacher also strived to give a problem in each exercise which required some practical work, i.e., the students had to carry out a semi-structured experiment in order to solve the given problem. Examples of this were tug of war in order to find out how Newton's third law come into play, and being pushed down the hallway on a wheel-based office chair holding a pendulum in order to calculate the acceleration. Other problems were accompanied with a video clip made by the teacher. These clips demonstrated some sort of experimental setup, and the quantities relevant for the problem solving were displayed in the video, which the students watched on the IWB.

3. Literature review

Theoretical perspectives on learning science

A constructivist perspective states that knowledge is a result of the learner's active construction (Quale, 2002). Furthermore, the construction of new knowledge is based on the individual learner's established knowledge (Scott, Asoko, & Leach, 2007). Critics of the constructivist paradigm have argued that conceptualising learning merely as individual construction based on experience is essentially empiristic, and furthermore that an emphasis on sense making yields a relativistic view of scientific knowledge, inasmuch as the process of personal sense making is emphasised over the obtained result, i.e., the knowledge (Matthews, 1993). This criticism is partly countered by acknowledging that learning science is not so much about grappling with natural phenomena themselves as it is about grappling with quite specific *ideas* about those phenomena, validated through "complex empirical and social processes" (Leach & Scott, 2003, p. 94). Established scientific knowledge do not pop up from merely observing natural phenomena, it is the result of hundreds of years of checking, perhaps disregarding, accumulating and refining the ideas of natural philosophers and scientists. This knowledge is expressed through specific symbols and a specific language. Mortimer and Scott (2003) sums up this perspective:

> *Science can [...] be seen as a product of the scientific community, a distinctive way of talking and thinking about the natural world, which must be consistent with the happenings and phenomena of that world. Learning science therefore involves being introduced to the language of the scientific community* (p. 13).

In addition, the need to be precise and explicit about one's theories or ideas is a key characteristic of science (Driver, Asoko, Leach, Scott, & Mortimer, 1994), a characteristic that is also naturally shared by school science.

A sociocultural approach to science learning stems from the works of Vygotsky, whose key proposal was that "higher mental functioning in the individual derives from social life" (Scott, 1998, p. 47). In other words, the social, or intermental, plane is not merely the context for individual, or intramental, meaning making, but the plane in which meaningful learning originates (Hodson & Hodson, 1998), by means of dialogues. A sociocultural perspective conceptualises learning through the social, cultural and contextual aspects which are inherent parts of any learning situation (Wertsch, 1998). This means that what is taught and learned is conceived as products of a specific culture, into which the students need to become initiated.

These perspectives reinforce the importance of the teacher as the skilled person who guides students into the conceptual framework that constitutes science.

Vygotsky developed the concept *zone of proximal development* (ZPD), which he described as "the distance between the actual development level as determined by individual problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, cited in Scott, 1997, p. 19). Mercer and Littleton (2007), see the ZPD as static inasmuch as it represents "the mental state of an individual learner at any one time, rather than the dynamics of development through dialogue" (p. 21). They argue that since dialogue is a dynamic process that involves at least two perspectives, so must the concepts associated with the outcome of that dialogue be. They propose that the *intermental developmental zone* (IDZ) (Mercer, 2000) represents such a dynamic concept, suited to describe the dynamic intermental process that constitutes a dialogue between teacher and learner. Where the ZPD can be said to have a fixed reference point of departure, represented by the learner's initial capabilities, the IDZ is continually reconstituted as a consequence of the progressing dialogue.

Talking science

Spoken words, which in turn constitute a dialogue can be regarded most central to the process of collective meaning making, although amplified and augmented by other modes, such as facial or bodily gestures (Scherr & Hammer, 2009), and complemented by the use and manipulation of cultural artefacts (Säljö, 1999). Conceived this way, engaging in a dialogue in order to give ideas or concepts meaning can thus be seen as a prerequisite for learning (Mortimer & Scott, 2003). Group work can be a suitable context for enhancing meaning making. By putting students in a situation where they are to collaborate on solving physics problems, much of this collaboration will have the form of dialogue, where ideally the purpose of the task is agreed upon, scientific concepts are negotiated and new understandings emerge.

Knowledge in science can be conveyed through other forms of representation than verbal language, such as diagrams, mathematical equations and graphical images. However, all these different forms of non-verbal *texts* can be conceived as specific cultural artefacts (Säljö, 1999), and the information contained in these representations rarely speaks for itself. Novice learners will therefore have difficulties accessing these artefacts, in terms of making valid interpretations of their meaning, making the presence of a more skilled person necessary. Thus language, spoken as written, is the bridge not only between existing knowledge and new knowledge, but also the primary vehicle to use when initiating newcomers to make sense of and ultimately master the cultural artefacts that constitute scientific knowledge (Scott et al., 2007).

Meaning making

Collective meaning making is a process where the learner rehearses and negotiates his or her own interpretation of a phenomenon or idea with others. The intended result from this process is that what has been discussed makes sense to the learner, which in turn is a prerequisite for individual learning (Mortimer & Scott, 2003). In science, an additional aim is to strive for consensus (Duschl & Osborne, 2002), which is also an important feature of science in education. Meaning making can be perceived as the gateway between the social plane and the individual plane. Collective meaning making must by necessity involve a process of verbal interaction between at least two participants, whereas individual meaning making is a process of continuously comparing new information to established individual knowledge or experience. Thus, individual meaning making also occurs when a learner interprets a text in solitude.

An important feature of meaning making is that it is a *dialogic* process, which imply recognition of *the other*, a recognition that stems from Bakhtin (Mortimer & Scott, 2003). In other words, dialogic implies a realisation that there are always at least two perspectives involved in a dialogue (using a broad conception of the concept dialogue). Any utterance, either spoken or written, can be seen as unique due to its historical, social and cultural situatedness (Mortimer & Scott, 2003), which implies that there can be no fixed meaning (Wegerif, 2007), as meaning arises in the gap between utterances (or perspectives) (Coulter, 1999). Therefore, every utterance is dialogic. For instance, chances are that these lines of text will mean something different to me in years to come than they do now, even though I have written these words myself. Taken to the extreme, this perspective implies a relativistic view on meaning making (Coulter, 1999), which would make it impossible to gain joint meanings between people and across space and time. However, language is governed by two opposing forces: Firstly, *centripetal forces* serve to centralise meaning (Bakhtin, 1981), which can be seen as a prerequisite for joint sense making. On the other hand, *centrifugal forces* act to decentralise and therefore destabilise meaning.

In the classroom, meaning making as a learning process is closely related to the concept of dialogic *teaching*. In a model developed by Mortimer and Scott (2003), a teacher's communicative approach towards the students is described as possibly *authoritative* or possibly *dialogic*. The purpose of an authoritative teaching approach is to exclude all but one perspective, namely the scientific perspective. A dialogic teaching approach, on the other hand, aims to take more than one perspective into consideration, i.e. the students' thoughts (Scott, Mortimer, & Aguiar, 2006). The essential point for Mortimer and Scott (2003) is that good science teaching involves appropriate switching between dialogic and authoritative communicative approaches. Students should be given the opportunity to make sense of what is being taught through dialogic teaching. However, as it is the teacher's overarching responsibility to present learners to a specific way of perceiving and thinking about the natural world (Scott, 1998), the teacher must use an authoritative approach to draw the students towards the scientific perspective.

Wegerif (2007, 2008) emphasises the distinction between the concept dialogic and the concept *dialectic*. One of the reasons for this is that he perceives the merge of these two frameworks, namely in the synthesis of perspectives from Bakhtin and Vygotsky, respectively, as theoretically incompatible: "Dialogic presupposes that meaning arises only in the context of difference, whereas dialectic presupposes that differences are contradictions leading to a movement of overcoming" (Wegerif, 2008, p. 359). Further, Wegerif states that: "dialogic refers to the interanimation of real voices where there is no necessary 'overcoming' or 'synthesis'" (Wegerif, 2007, p. 36). The term interanimation is according to Wegerif used by Bakhtin to indicate that "the meaning of an utterance is not reducible to the intentions of the speaker or the response from the addressee but emerges between these two" (Wegerif, 2006, p. 144). The point here is that meaning making, conceived this way, opens up a space of unbounded possibilities (Wegerif, 2006). This *dialogic* space is a metaphor that is associated with a certain kind of educationally desirable dialogue, namely exploratory talk, where learners "engage critically but constructively with each other's ideas" (Mercer, 2004, p. 146). To Wegerif, the explicitness of the talk is not necessarily the key marker of successful dialogue; the *dialogic space of reflection* (Wegerif, 2008) could just as much make room for progression. As I interpret Wegerif's dialogic space, it is associated with learners being immersed in a conversation, while possessing a constructive attitude towards the other partners of the discussion, reflected in the questions being asked or statements being made, and the pace of the dialogue. Another key point for Wegerif is that to foster creativity and learning to learn, it is important to treat dialogue not only as a means to an end but also as an end in itself (Wegerif, 2007).

It is not difficult to see the potential pedagogical value of Wegerif's perspective. However, a question arises whether facilitating the creation of a dialogic space of unbounded potential is appropriate with regard to the subject matter being taught. As science educators, our principal interest lies in investigating teaching and learning practices which leads to meaningful learning of science (Scott, Ametller, Mortimer, & Emberton, 2010). Nevertheless, Wegerif's perspective is important in the sense that it forces us to reflect upon the theoretical basis on which we perceive science teaching and learning.

The hierarchical knowledge structure of science

Although science and scientific knowledge undoubtedly are the results of cultural and social processes (Lemke, 2001), the *aim* of science is the struggle to describe and explain the universe. In education, this struggle takes the form of introducing students to a specific way of knowing about the world (Scott, 1998), which needs to be consistent with empirical data, and also with the already accumulated body of scientific knowledge, thus leaving little room for ambiguity. This possible unequivocal appearance of science in education (Osborne & Chin, 2010) can be seen as a consequence of science having a *hierarchical knowledge structure*, as Bernstein (2000) characterises it, by which he means that: "this form of knowledge attempts to create very general propositions and theories, which integrate knowledge at lower levels, and in this way shows underlying uniformities across an expanding range of apparently different phenomena" (p. 161). On the other hand, the social sciences adhere to what Bernstein terms a *horizontal knowledge structure*, which is characterised by multiple potential valid interpretations of a phenomenon. Although debates within the scientific community are far from unequivocal, the inherent need to reach consensus is ever present (Duschl & Osborne, 2002). The hierarchical knowledge structure is a feature that is shared between science and science in education. However, this epistemological feature does not seem to be apparent in literature on the nature of science and its relevance for science in education (see McComas, Almazroa, & Clough, 1998).

The hierarchical knowledge structure of science is reflected in the studies of what has been termed misconceptions (e.g. Gilbert & Watts, 1983), preconceptions (e.g. Clement, 1982) or alternative conceptions (e.g. Wandersee, Mintzes, & Novak, 1994) within science education. The main reason for being concerned with students' conceptions is to get some impression of their thoughts about the physical world (before or after being taught), which in turn can inform how teaching of science could be designed. Even though the concepts misconceptions and alternative conceptions may differ with regard to epistemological stance (Gilbert & Watts, 1983), the students' ideas of the world are nevertheless projected on to the body of established scientific knowledge. In other words, regardless of whether one sees scientific knowledge as 'true' or 'fruitful', there is no room for any in-between interpretations when it comes to scientific knowledge. As Scott (1998) indicates, the overarching goal of teaching science is to introduce students to a particular way of knowing. This implies that the desired learning outcome of a physics course in terms of knowledge and skills is highly predictable, although the *actual* outcome may not be so (Wandersee et al., 1994).

In their book "Meaning Making in Secondary Science Classrooms", Mortimer and Scott (2003) introductorily describe the default way of science teaching in schools, which mainly involves the teacher talking and the students listening. Further, they believe that "lots of science teachers adopt the more presentational style, simply because it represents the existing, invisible, taken-for-granted practice of science teaching" (p. 2). There is reason to believe that this concern is relevant for other courses, like engineering physics. Mortimer and Scott's aim is to challenge this, and from a theoretical perspective to advocate more verbal interaction (i.e. an interactive approach) in science classrooms, in terms of an appropriate mix of authoritative and dialogic teaching approaches. Their model of communicative approaches distinguishes between an authoritative or dialogic approach, and an interactive or non-interactive approach. Focussing on the authoritative/dialogic dimension of this model, the consequences of switching between an authoritative and dialogic act of communication have been investigated further by Scott, Mortimer and Aguiar (2006). Here, they look at the *tension* that exists between these two approaches, as multiple ideas are being considered at one instance, while only one perspective is prevailing in the next. Within a dialogical approach lies the seed for an authoritative approach and vice versa. The point here is that the necessity for an authoritative approach is unavoidable in science, given that the aim is to facilitate learning of content knowledge. This point echoes the hierarchical knowledge structure of science proposed by Bernstein (2000).

The interactive whiteboard as a tool in education

When the conventional personal computer was introduced in schools, it was regarded as the perfect toolkit for creating personalised instruction for students (Mercer & Littleton, 2007). As the awareness of the social dimension of teaching and learning increased (Leach & Scott, 2003; Scott, 1998), it became apparent that the personal computer on its own was not particularly appropriate for joint activities in the classroom: The relatively small size of the screen limited how many students who could see the screen at once. Furthermore, the mouse and the keyboard were also designed to be used primarily by one person at a time (Mercer &

Littleton, 2007). Although web-based solutions exist for interaction and collaboration, which may extend far outside the boundaries of the classroom, the IWB is a more appropriate tool to support a joint teaching and learning activities in the physical classroom, both with respect to small-group learning and to whole-class teaching (Mercer, Warwick, Kershner, & Staarman, 2010). Due to the sheer size of the IWB screen, it allows for collective scrutiny and negotiation (Hennessy, 2011), as will a non-digital board. The IWB differs from an ordinary whiteboard not only because its affordance to draw virtually seamlessly on multiple resources (Gillen, Staarman, Littleton, Mercer, & Twiner, 2007), but also because objects can remain more stable, as opposed to a non-digital board where artefacts literally have to be wiped off in order to make space for new ones (Hennessy, 2011).

The IWB has been introduced in classrooms as a tool primarily to be used and controlled by the teacher, which can also be seen in the bulk of research on the use of IWBs. Many of the studies published have investigated the potential and limitations of the IWB from the perspective of teaching (e.g. Hennessy, Deaney, Ruthven, & Winterbottom, 2007; Miller & Glover, 2007; Smith, Higgins, Wall, & Miller, 2005). IWBs have been advocated due to their affordance to easily and efficiently switch between different modes of representation, the ability to re-use and recall previously taught material and the ability to enhance both technical and pedagogical interactivity in the classroom (see Smith et al., 2005 for a review). It should be noted that these potential benefits are crucially dependent on the skill and will of the teacher orchestrating the lessons (Gillen et al., 2007; Hennessy et al., 2007; Kennewell & Beauchamp, 2007), as early reports on the use of IWBs in the classroom found that the IWB might enhance a presentational, teacher-centred teaching practice (Higgins, Beauchamp, & Miller, 2007). A possible reason could be that teachers had planned extensive multimodal presentations, with little possibility to include initiatives from the students. Although the IWB represents a powerful tool with regard to multimodality, it does not necessarily require any significant training for usage or change in planning or execution of lessons, i.e., it can be used more or less as one would use a non-digital whiteboard, and this might explain the proliferation of the IWB in schools. However, it may also explain why the introduction of the IWB has not led to a transformation of classroom teaching (Gillen et al., 2007; Kershner, Mercer, Warwick, & Kleine Staarman, 2010; Warwick & Kershner, 2008), in terms of a more interactive (Hennessy et al., 2007) or dialogic (Mercer et al., 2010) approach to teaching. Also, studies have shown that teachers can be reluctant to alter their preferred teaching practices to the introduction of new pedagogical tools (see Hennessy, 2006).

While there exists evidence for enhanced teaching possibilities, there is little conclusive evidence of IWBs leading to enhanced *learning* (Higgins et al., 2005; Smith et al., 2005). Initially, the IWB was promoted as a motivational tool for the students (Higgins et al., 2007), primarily owing to the affordance of multimodality and the opportunity to interact with artefacts on the touch-sensitive screen. Even though there exists evidence of enhanced motivation in learners due to the introduction of the IWB (see Glover, Miller, Averis, & Door, 2005), the long-term effects seem to be negligible (Higgins et al., 2005).

Little research has been done on the potential of IWBs in group-work contexts. There are a few exceptions where the use of IWBs has been investigated in collaborative contexts in primary education (see Kershner et al., 2010; Mercer et al., 2010; Warwick, Mercer, Kershner, & Staarman, 2010). In these studies, the IWB seemed to enhance on-task interaction between the pupils. These findings were attributed to a dialogic teaching approach, in combination with the use of the IWB.

Group work

Group-based learning activities can roughly be divided into two strands: collaborative group work and cooperative group work. Collaborative and cooperative learning are described somewhat different by different authors. Prince (2004) sees collaborative learning as an umbrella term, “encompassing all group-based instructional methods, including cooperative learning” (p. 231). Mercer and Littleton (2007), however, conceptualise collaborative learning as clearly distinct from cooperative learning, inasmuch as they see collaborative learning offering a possibility for the students to think together, rather than just act together. Others see cooperative group work as more structured than collaborative group work, where the overarching aim is to create structures to enhance constructive interdependence and reduce competition among the participants (Maceiras, Cancela, Urréjola, & Sánchez, 2011; Springer et al., 1999).

Evidence exists for the value of group work as a learning activity, in terms of learning outcome and students’ attitudes towards learning (Springer et al., 1999). However, as Mercer and Littleton (2007) and several others argue, putting students into groups does not automatically yield successful group work. For one, successful group work is an issue of appropriate design and implementation (Oakley, Felder, Brent, & Elhajj, 2004; Pauli, Mohiyeddini, Bray, Michie, & Street, 2007). Another issue is students’ and teachers’ attitudes towards group work, which may not be entirely positive, based on prior experience (Pauli et al., 2007). Furthermore, the conclusions underpinning the value of group work often stem from experimental research, where teachers have been subject to extensive training, and where the setup and implementation of the group work have followed fairly specific guidelines (Blatchford, Kutnick, Baines, & Galton, 2003). While this research is important in revealing the potential of group work, the direct applicability to an everyday, authentic setting is perhaps more questionable.

Understanding what actually happens during authentic student group work is a prerequisite in order to inform further development of the aims, setup and implementation of group work (Stahl et al., 2006). From a sociocultural perspective, knowledge about the dynamics of group work is interesting due to the cultural and social aspects which influence the learning situation. For example, students being regarded by their peers as high-performers will be more inclined to influence the outcome of the task at hand (Blumenfeld et al., 1996). On the other hand, students being regarded by their peers as low-performers or "clowns" will be less inclined to influence the group work outcome, even if their contributions are fruitful (Bang, 2001). Also, students' perceptions of the on-task situation, and their motives for accomplishing a given task influence the interaction between the students (Berge & Danielsson, 2013; Scherr & Hammer, 2009).

Teacher interventions during group work

The teacher plays a key role for successful group work. Careful consideration needs to be taken with regard to the aims for the group work, planning and designing of the tasks or problems, considering the size and composition of the groups, informing and instructing students about group work as a learning method, and assessment, be it of whole groups or individual participants. Also of key importance is how teacher interventions during the group work are performed. Collaborating students are to a high degree responsible for their own progress in terms of making sense of the problems at hand and accomplishing the tasks (Cohen, 1986), and thus the teacher is not in control of the progress or pace. This could represent a cause for concern for teachers at lower levels, as they may be hesitant to leave the control of the progress and outcome to the students (Blatchford et al., 2003). However, the issue of teacher control is perhaps more relevant to primary and secondary school than higher education, where students are expected to be more autonomous.

During group work, the teacher typically has to serve many groups within a limited time, and is therefore hindered from spending much time observing each group before intervening (Dekker & Elshout-Mohr, 2004). This calls for flexibility and pedagogical skills from the teacher, as (s)he does not really know what to expect when approaching a student group. The successful teacher interventions are primarily characterised by the extent to which the teacher manages to gain insight into the students' needs (Webb, 2009), and also the extent to which the teacher manages to adapt his or her support to these needs (Chiu, 2004; Ding, Li, Piccolo, & Kulm, 2007; Webb, 2009). The kind of help that the teacher provides can influence the group work process. For instance, the teacher may choose to explicitly instruct the students, or (s)he can try to guide the students towards a satisfactory solution by posing questions (Chiu, 2004). Furthermore, the teacher's support can be focussed on the product, i.e., the solution of the task at hand, or it can be focussed on the process, that is, the interaction between the students in the group (Dekker & Elshout-Mohr, 2004). Also of importance is the students' ability to identify their own needs, and being able to request help specifically aimed towards those needs, be it directed to the teacher or the other students in their group (Chiu, 2004; Webb, 2009).

4. Research methods

A case study represents a research strategy concerned with the study of a phenomenon within its real life context, using multiple methods of data collection (Robson, 2002). According to Yin (2003), a case study is particularly appropriate when “a ”how” or “why” question is being asked about a contemporary set of events, over which the investigator has little or no control” (p. 9). This study is concerned with exploring a rather specific group-work setup, involving groups of engineering students using IWBs to solve physics problems. The aim is to investigate particular aspects of this learning situation, namely the use of IWBs and the characteristics of the interaction between teacher and students, events that were neither straightforward nor desirable to exert control over. A case study was therefore considered as an appropriate design to deploy when investigating this learning situation.

Data collection

Data were collected for three consecutive autumn terms during this project, all covering group-work activity in the learning labs. Data were for the most part collected as video recordings, supported by direct observation, focus group interviews, and informal conversations with the participating teachers and students. However, the results presented in this thesis stem from only one of these data collection sessions, in the following named *main data collection*.

Pilot

Group work in the learning labs was conducted for the first time during the autumn term of 2010. Some initial video data were collected from one group as a pilot during these group-work sessions. The point was to get some initial impressions of which aspects of group work that could be worthwhile pursuing at a later stage. Four group-work sessions were video recorded. This material was not subject to in-depth analysis, but was reviewed. Furthermore, the students involved were not formally interviewed. Instead, informal conversations made out the basis for the impressions gained during this pilot project. The review of the video material suggested that the students solved the physics problems with little use of the IWB. The students seemed to be sitting at the table, bent over their own notebooks. There were seemingly few sustained discussions that involved more than two persons. The presence of a student taking on a secretary’s role seemed evident, which meant that one student was standing up at the IWB inserting solutions while being instructed by another student sitting at the table. This preliminary finding could be seen as a consequence of the students not being willing to move away from the ordinary way of solving physics problems, which implied completing the problems on paper.

Main data collection

The data that makes out the empirical basis for this study were collected during the fall term of 2011, where first-year mechanical and logistics engineering students participated in weekly group-work sessions as a compulsory part of a physics course. One student group was selected, and was video recorded during eight out of eleven group-work sessions. The video material from the main data collection made out about 23 hours of film, which then became subject to data reduction and analysis. I was present at every session, to observe all of the groups. In addition, a focus group interview was conducted towards the end of the term, where the students were interviewed about their experiences with the group work and the learning lab setup.

Additional data collection

A third round of data collection was done during the fall term of 2012, with one new group of first-year students. This time, however, the group work in the learning labs was part of a mathematics class. Data were collected by means of video recordings of one selected group during the sessions in the learning lab. In addition, a focus group interview was conducted towards the end of the term. The reason why I chose to collect data from these sessions was that I initially thought that the material I already had did not suffice. However, by the time this data collection was completed, my research focus suggested that mixing group work in mathematics and physics was not appropriate. Also, due to time constraints, the choice was made only to consider the data material from the fall term of 2011 for in-depth analysis, while using the material from the other collections as background material.

Selection of participants

In the following, only the main data collection from the fall term of 2011 is described, although the same principles for selection and approach towards the students were also applied to the additional data collection. For this case, one group of five male students was selected; Terry, Toby, Henry, Eric and Andrew, all in their 20s. All groups were observed during three consecutive group-work sessions, in order to decide which group to select. This particular group was selected on the basis that they appeared representative to the other groups in terms of engagement towards the exercises and the other students in the group. This meant that there were other groups in the class that appeared more “noisy” and yet other groups that seemed much more quiet than the selected group.

During one of the first lectures that term I informed all students about my project, that I was going to be present at the group-work sessions as an observer, and further that I would be asking one of the groups to participate in my project. When I had decided on which group to select, the students were asked specifically to participate, and was further asked to sign a written consent that informed them about the aims of the project and the scope of their participation, which entailed video recording and participation in a group interview. All students agreed to participate. Initially, there was a female student in this group, but she quit before any video data was recorded. However, since less than 10 % of the students were women, the selected group was still perceived as a cross-section of the student mass with regard to gender distribution.

Video recording

When gathering data from this learning situation, the aim was to document what was happening, with minimal intrusion. Furthermore, the research approach can be termed inductive, inasmuch that I initially did not operate with any strong, theory-informed questions to guide the data collection. Rather, my enquiry was guided by broad questions (Derry et al., 2010), such as “how do the students use the IWB?” Group work is a complex learning situation, which implies that direct observation and note taking inevitably will delimit what is collected and what is disregarded. A researcher needs to have a pre-defined and clear plan of what aspects to adhere to. At the same time the researcher also needs to be aware of unexpected events, which may be of importance. In addition, there is a risk of an observing researcher acting as an intrusion to those participants being observed. These considerations implied that choosing video as a method for data collection was deemed appropriate. Pure audio recordings could have been an alternative solution, given that the research interest lies mainly in the oral interaction between the participants. With video recordings, however, it becomes easier to infer what is going on, i.e., what is meant, because of the opportunity to see and investigate also the non-verbal communication, such as gestures, gazes and the use of artefacts. On a more practical note, it also becomes easier to infer who is talking, which can be more difficult with pure audio recordings.

Although a video camera does not altogether bypass the problem of intrusiveness, it can be perceived as less intrusive than a person observing and taking notes. Furthermore, video data can be perceived as raw data compared to data collected from direct observation and note taking, and as such it implies some benefits and potential drawbacks. Video recording allows for an accurate memory keeping, inasmuch as the recordings very much preserve the complexity of the phenomenon being recorded, which the researcher can retrieve as many times as (s)he likes. This makes it possible for the researcher to have a flexible approach to the material, thus allowing for openness with regard to unexpected events, which is appropriate for exploratory studies. However, one must be aware whether the presence of a researcher or a camera affects the participants being recorded (Scherr, 2009). In my case, the students seemed to habituate to the camera rather quickly. The students made a few remarks about the presence of the camera, but seemed to have forgotten all about it the next minute. Furthermore, when one possesses a data source with synchronised vision and audio, there is almost no limit as to how fine-grained an analysis can be (e.g. Lindwall & Lymer, 2011), or what events or phenomena to investigate. The preservation of complexity does come at a price, namely the risk of being overwhelmed by hours of footage, without a clear idea of what to look for and what to disregard.

Practical and technical issues of video recording

Although video data can be perceived as the closest one can come to raw data, there are still issues that can potentially affect the result. The choice of position of the video camera will inevitably capture some events, on the cost of leaving other events out. For the main data collection, I chose to set up a stationary camera right beside the IWB facing the table were the students were sitting. This choice of position and angle gave a good impression of the dynamics between the group members, the students' facial and bodily expressions and their dialogues. However, this choice of position did not capture what the students were doing on the IWB in real time. This problem could have been overcome by setting up another stationary camera in the opposite position, facing the IWB, or, alternatively, using a hand held camera to capture the events at the IWB more precisely. However, setting up a second stationary camera was practically impossible due to the narrow space each group had within their respective booth. The narrow space also made it impractical to use a handheld camera, as I would have to stand literally among the students, thus risking interrupting them, or otherwise appear intrusive.

For the additional round of data collection, I chose to change the angle of the video camera, this time facing the IWB. The reason was that I wanted to test how this angle worked, compared to the main round of data collection. The overall impression was that it did not work particularly well. The narrow space around where the group was sitting restricted how much the camera was able to capture of the group while at the same time capturing the IWB, thus reducing good access to the interaction among the students sitting at the table. Another issue was that the camera that I used was difficult to adjust with regard to exposure. The result was that the brightness from the IWB resulted in underexposure, thus reducing the students in the videos to silhouettes. This meant that it was difficult to see the more subtle non-verbal communication between the students, such as gaze or other facial gestures.

Also, for the additional round of data collection, I made screen recordings of the IWB, using a recording function built into the Notebook™-software in the IWB's computer. The idea was to synchronise the screen recordings with the video recordings at a later stage, thus being able to both look at the students' interactions and what was happening on the IWB in real time. Due to technical issues, however, this screen recording only lasted a couple of sessions before it was abandoned: Initially, one of the students had to log on to the computer with his or her own username in order to hand in the group's solutions and to have access to relevant resources. When the group-work session was over, I had to ask them to save the resulting file containing the screen recording and then e-mail it to me. This was a cumbersome and time-consuming process, not least because of the large file size, and the students clearly became a bit frustrated by this. Therefore, in order to avoid any more unnecessary intrusion, screen recording was abandoned.

On the whole, the video camera that was used functioned well, and was able to capture adequate data for this study. In retrospect, however, I should have considered using an external microphone during the video recordings. Although the built-in microphone on the video camera functioned surprisingly well, it was not always able to capture mumbling among the students sitting at the table, especially when there was a lot of noise in the background.

Direct observation

During the exercise sessions I was present observing and taking notes of all the groups. This was done as a means to get some impression of whether the selected group continued to appear representative to the other groups, and to observe the other groups in their own right. This meant that I did not observe the selected group particularly, but rather that I tried to get an impression of how all the groups worked. As with the video recording, the aim was to appear as unobtrusive (Robson, 2002) as possible. Given that there were up to eleven groups present at each group-work session, I did not spend much time observing each group before moving on. These data have not been subject to analysis, but have served as background material which has been used when analysing the video data. During the focus group interview (see below), considerations and questions that emerged from the observations were used to investigate the students' experiences with the learning labs.

Focus group interview
The selected student group also participated in a focus group interview immediately after the last exercise session, where the aim was to investigate the students' experiences with the learning labs. A focus group interview is a specific research method, where the researcher has a specific agenda for the theme (i.e. focus) of the interview and where data is collected through interaction between the participants (Wibeck, 2011). A focus group interview is an appropriate way of collecting data when one is interested in investigating the participants' expressed motives that have guided their actions (Wibeck, 2011). A central challenge associated with focus group interviews, is that making it a *focus* group interview is not a straightforward process (Robson, 2002). Ideally, the moderator should to little extent steer the participants' focus, although the initial focus is controlled by the moderator. Also, the moderator needs to ensure that every participant gets to participate.

The interview took place in a meeting room at the university college. As I had been present at each group work session, setting up and taking down the camera, and also been wandering around between the groups observing them, the students should in principle have become accustomed to me, thus diminishing the possibility that I would come across as a stranger, or imposing an authoritative researcher style during the interview. The students were informed that the aim for the interview was to investigate their experiences from the learning labs that were not evident from the video data, and also their opinions on what they had gained from the group work. They were further informed that as they were there voluntarily, they were free to talk about what they wanted, and that they could end the interview when they wanted to. I told them that the estimated time for the interview was about 90 minutes (which also happened to be the result), but that it was up to them, and how much they had to tell and discuss. Finally I invited the students to discuss among themselves, and urged everyone to join in the discussions.

In the interview guide that was used, the guiding questions were divided into three subtopics: the tasks, the group work and the learning outcome. Introductorily the students were asked to talk about what their general impressions with the learning labs were. By the time the interview was conducted, the students had come to get well acquainted, and the discussions between them seemed to go well, without too many interventions from my side. During the interview, it turned out that the students had most to say about the tasks and the group work, and not so much about their perceived learning outcome. One student, however, did not seem to participate very much in the conversation. This student had also been absent from some of the group-work sessions, and it was challenging to get him to participate in the on-going discussions during the interview.

Analysis of video data

Data reduction was first done by selecting events that involved the students' direct use of the IWB, with the intention of further analysing these clips inductively. During the first viewing of these video clips, a summary of each clip was created, which described the chronological sequence of events during the clip. In these summaries, the emphasis was on who were involved in discussions or explicit problem solving, at what stage of the problem solving the students were, and more concretely what the students were discussing and what they were doing on the IWB. The last point had to be inferred from the talk between the students. The selected clips were then viewed once again, and new summaries were written for each clip, without looking at the first summary. Additional iterations were performed, without summarising each clip, but through labelling of each clip. Some of the clips were also viewed and interpreted by another researcher. Eventually, these clip labels were clustered into categories, and finally, the clips that were selected to illustrate the findings were transcribed, for the purpose of presentation.

A second round of data reduction was performed, but this time with the intention of selecting events were the teacher was present for support or supervision. The strategy of analysis was different to the first video analysis: the selected video clips were fully transcribed, and these transcriptions were the primary source for further analysis, supported by repeated viewings of the original video clips.

Analysis of interview

The focus group interview was fully transcribed. After transcription of the interview, the transcript was read several times, in order to gain a consistent interpretation of what the students were saying, i.e. what their experiences were with the learning lab and the group work. An inductive approach was appropriate also here, as the analysis was guided by the broad question: "What were the students' experiences with the group work?" The iterative reading of the transcript resulted in some preliminary categories. A method of analysis, which resembles the constant comparative method (Merriam, 1998), was then applied, which in this case implied comparisons between the interview transcript and the video material. This comparison led to considerable alterations of the preliminary categories, as it became clear that my initial analysis of the interview transcript was too descriptive and that the preliminary categories did not really capture the emerging research focus that came from comparing both data sources. New categories that were more appropriate with regard to analytical depth were created. Along with selected sequences from the transcript, these categories made out the final presentation of the results.

Validity

During the exercise sessions in the learning labs, video recording was the primary source for data collection. Internal validity was attended to by direct observation of the other groups working in the learning labs. While both video data and direct observation are seen as observational methods, the focus group interview that was conducted after the last exercise session can be seen as a more direct inquiry, in terms of method of data collection. Together, these three sources constitute data triangulation for this study.

Although the video data and the interview transcript have been the only subjects for in-depth analysis, the field notes from the direct observation, files of the students' solutions, documents describing engineering education and the particular physics course, informal conversations with the teachers and students have made out additional sources of background data. These additional sources have been valuable, not only as sources for enhanced insight into the case, but also in terms of checking findings and interpretations from the primary sources. I have done most of the analysis of interview and video data on my own. However, another researcher viewed some of the selected clips independently, as a means to check the internal validity of the findings.

Given that the learning labs have a quite specific setup, and that this is a single case study, the generalizability of this study is limited. However, I believe that the theoretical considerations that are presented in in this thesis are of relevance with regard to analytical generalisation (Robson, 2002) to learning contexts beyond this particular case.

In retrospect, I should have considered to include at least two groups during the main data collection. This would have made it possible to make comparisons between the groups within the same context, thus enhancing the validity of the findings. Although the notes that were taken from the field observations suggest that the selected group kept appearing representative to the other groups, it is impossible to thoroughly assess how the concrete findings in this study can relate to the other groups present. Looking back, including more than one group from the same class would have been potentially more fruitful than collecting data across different terms, with different students and different tasks (and different subjects).

Ethical considerations

In all phases of data collection, all of the students participating in the learning labs were informed about the aims and the content of the study. The groups that eventually were selected were explicitly asked to participate, and they were once again presented to the aims and content of the study. They were further asked to sign individually on a written consent where each student gave permission to video recording during the group work sessions. This consent contained the same information as had been presented to them orally. In addition, they were asked to (both orally and written) to participate in group interviews. The consent also stated that the students would be given fictitious names in the resulting papers, in order to secure each participants' anonymity, and further that each participant could withdraw from the study at any moment without giving any specific reason. Lastly, the consent stated that each member of the group would be given a gift voucher of 500 NOK, as a compensation for their participation. This voucher was given to them after all the data had been collected.

The consents were handed out during the third group work sessions and the students were expected to hand them in again during the same session. I got one of the teachers to receive the consents. In retrospect, I should perhaps have considered asking the students individually, as the approach chosen could have been conceived as intrusive by the students, because they would risk feeling subject to peer pressure from the others. During the group interviews, the students were once again reminded that they could withdraw from the interview at any moment without giving any specific reason.

The resulting files containing the video material and the sound recordings from the interviews were transferred to my own laptop before they were deleted from the memory units in the recording devices. In addition, copies of the original data material and derivatives from it were stored on two external backup drives.

The researcher's role

I participated in the planning of the physical setup of the learning labs, together with the lecturer responsible for the physics course and other staff members. Apart from that, I did not intervene in any of the planning or implementation of the exercises sessions. Being present at the exercise sessions to observe the groups, I was in practice available for support when called upon by the students. However, because I was there primarily to observe the groups, I tried to avoid taking a teacher's role as I wandered between the groups, referring the students to one of the other teachers when called upon.

5. Summary of papers

Summary of paper A

Mellingsæter, M.S. & Bungum, B. (submitted). Students' use of the interactive whiteboard during physics group work. Paper submitted to European Journal of Engineering Education.

In this paper, we investigated how students used the interactive whiteboard during group work in the learning labs. Four ways of using the IWB were identified as processes during the problem solving. *Exploratory processes* were characterised by the students using the IWB to explore ideas together, without any significant preparation. In *explanatory processes*, one or two students explained their reasoning to the rest of the group, using the IWB. *Clarifying processes* occurred when what had been written on the IWB became subject to discussions among the students, which served to clarify terms or mathematical procedures. Finally, the events termed *insertion* were characterised by little interaction between the students, as typically one student inserted the group's final answer on the IWB.

The main benefit of the IWB in this context was that it made arguments and calculations available to the whole group. The events termed exploratory processes, explanatory processes and clarifying processes shared a common feature, namely sustained on-task discussions. The concept *joint workspace* was established to describe an environment where the students shared and developed their ideas.

Summary of paper B

Mellingsæter, M.S. (2013). Engineering students' experiences from physics group work in learning labs. Paper published in Research in Science & Technological Education. doi: 10.1080/02635143.2013.853033.

The empirical basis for this paper was a focus group interview with the student group, in combination with the video material from the group work sessions. The goal was to create an understanding of the students' experiences with the group work and other aspects surrounding it. From the video material of the group work sessions, it was observed that the occurrences of what was termed *joint workspace* decreased over the course of the term. Less time was spent working on the IWB, and there were fewer sustained discussions between the students. It was difficult to infer the reasons for this decline based on the video material alone. Thus, an additional aim for this paper was to point to possible reasons for the decline of the joint workspace.

Research questions:

1. Which aspects are important in how the students experience the learning labs?
2. How do these aspects relate to the emergence of a joint workspace?

The students' experiences were categorised as internal aspects and external aspects, where the internal aspects pointed to the group members' interaction or other issues that seemed to have their origin within the learning labs. These included different common and personal goals among the students, which led to a group-work dynamics that did not always include the entire group in the solution process. The group-work dynamics can be characterised by an internal and informal competition between the students in the group. The external aspects referred to the choices and boundaries that the teacher had made, which the students did not control. The students seemed to appreciate what they saw as a structured group-work setup, as opposed to how they perceived teacher-assistant classes in other courses. Furthermore, they appreciated what was termed a close link between the lectures and the exercises. However, they pointed out that there was a too close temporal link between the lectures and the exercises, which led to rudimentary problem solving. The close temporal proximity between the lectures and the exercises, along with informal competition, seems to be aspects that inhibit the occurrences of joint workspace.

Summary of paper C

Mellingsæter, M.S. (submitted). On the right track: Dynamics of teacher interventions during physics group work. Paper submitted to International Journal of STEM Education.

This paper investigates teacher interventions during students' group work. A theoretical interpretative framework is established, which conceives knowledge in engineering physics as dialectic. It is argued that this framework can contribute to explain the characteristics of the meaning making process between teacher and students during teacher interventions.

Research questions:

1. How can the interaction between teacher and students during teacher interventions be characterised?
2. How is the interaction influenced by the dialectical nature of engineering physics?

The results show that the teacher interventions can be separated into four categories: *Clarification* was characterised by the students asking an explicit, specific question, which the teacher responded to in a concise manner. Occurrences termed *review* implied that the students asked the teacher to check their solution or reasoning. Either the teacher just confirmed that their solution was satisfactory, or he provided some corrections. Thirdly was *explanation*, where the students more explicitly signalled that they were unsure of how to solve the problems. Finally was a special case of explanation, termed evaluation, where the students were probing a bit deeper into the physics behind the problems. A similar structure of the teacher interventions was observed for the categories review, explanation and evaluation: The students introduced the teacher to the problem in question and started presenting their reasoning, while the teacher signalled that he understood. Then a turning point occurred, where the teacher provided evaluative feedback, which resulted in the teacher and the students switching roles, in terms of presenting arguments and signalling understanding, respectively.

It seems as the students were searching for the correct interpretation and finally the correct answer to the physics problems. They seemed aware that there was no room for any in-between interpretations to the problems. There appeared to be an implicit, mutual understanding between the students and the teacher about what was going on, and what the aims of the group-work activity were, which is attributed to an awareness of the dialectic nature of knowledge in engineering physics.

6. Discussion and conclusions

In this study, engineering students' group work in physics with use of IWBs has been subject to inquiry. First, the students' use of the IWB was investigated (paper A). The findings suggest that the IWB has a potential for enhancing the students' collective meaning making, by means of the big, touch-sensitive screen enabling each student to gain access to the solution of the problem at any instant. From this, the construct joint workspace was established, referring to extensive, on-task discussions that emerged from what had been written on the IWB. The empirical results showed that the occurrences of joint workspace decreased during the course of the term, i.e. the occurrences of in-depth discussions decreased. Also, less time was spent using the IWB. The possible reasons for this decrease were investigated by looking at the students' experiences from the group work (paper B). The findings suggest that the students found the learning labs motivating in the sense that it was an organised, structured part of the physics course. To the students, the IWB was a tool that helped them attain good grades on their exercises. Furthermore, the students found problem solving increasingly difficult during the term, as the relevant theories and concepts were unfamiliar to them, thus reducing problem solving to individual trial and error rather than joint conceptual discussions. Also, the students had different personal aims for the outcome of the group work, which led to solution of the problems being provided by those who were the quickest.

Finally, the teacher interventions during group work were investigated (paper C). By arguing that engineering physics is dialectic, that is, by perceiving the students' ideas and the scientific theories within the curriculum as contradictions needed to be overcome (Hennessy, 2011), the findings suggest that the students and the teacher had an implicit agreement that there was a final interpretation and answer to be reached.

The results from the three papers will now be discussed with regard to the research questions presented in chapter 1.

How does the use of the IWB influence meaning making in group work?

The findings from paper A show that the students' use of the IWB during the group work varied. Some of the time, the student(s) using the IWB explicitly addressed (some of) the other students, either to discuss the solution of the problem at hand (hence the category *exploration*), or to present an argument (hence the category *explanation*). However, it could be that the student using the IWB did not address the others, that he simply was writing the solution on the IWB for himself (hence the category *insertion*). But since the solution was available to the whole group, the other students still had the opportunity to address the "writer" to discuss what was being written (hence the category *clarification*). The findings suggest that the IWB does not on its own transform the collective meaning making process in unique ways. The IWB is primarily contributing to the collective meaning making process by providing a common space of reference, which makes the problem solving available to the whole group, which in turn can function as a catalyst for queries, questions, corrections and discussions. This interpretation is in line with Gillen, Littleton, Twiner, Staarman and Mercer (2008), who states that: "the IWB forms a cumulative backdrop as an updating source of reference and attention for the development of ideas" (p. 356), referring to the use of IWBs in the classroom.

Zones, spaces and the joint workspace

The concept of joint workspace developed in paper A, is described as a social realm within which the students' on-task discussions emerge and are maintained. The IWB served to support the maintenance of the joint workspace as a mediating artefact. Several "zones" and "spaces" have been suggested as metaphorical constructs for considering pedagogical interaction. These constructs are meant to describe social states in which people are situated and within which they can move. However, *zone* and *space* can be perceived as somewhat different to each other. Vygotsky's *zone of proximal development* (ZPD, see Scott, 1998) is primarily characterised by a learner's movement from an initial state to a goal state, under the guidance of a teacher or a more competent peer. A space, like Wegerif's *dialogic space*, is not characterised primarily by movement between states, but by being a desirable social state in itself that needs to be maintained. The *intermental development zone* (IDZ, see Mercer, 2000; Mercer & Littleton, 2007) does perhaps have more in common with the construct of space rather than zone, as it is continuously reconstituted during the course of a dialogue, thus representing a desirable state in which teacher and student are situated. However, both the ZPD and the IDZ are primarily associated with the interaction between learner and a more skilled person, i.e., a teacher. Wegerif's dialogic space is a construct that encompasses interaction between peers. It is described as a desirable social state, which is reflected in exploratory talk among the students (Wegerif, 2010). Taking into consideration the learning situation in this study, conceptualising the interaction between the students in terms of a desirable social state seems appropriate.

The concept of joint workspace was originally inspired from the concept of dialogic space, as described by Wegerif (2007), although with an emphasis on a dialectic perspective rather than a dialogic perspective. After completion of the analysis of paper A, I became aware of the concept *joint problem space*, which is described by Hmelo, Nagarajan and Day (2000) as a “shared conceptual structure that supports learning and problem-solving activities” (p. 37). According to Sarmiento and Stahl (2008), the joint problem space is characterised by integration of goals and a shared awareness of the current problem state and the strategies suitable for solving the problem. The concept originates from studies on computer-supported collaborative learning (see Roschelle, 1992), where the computer software seem to support the maintenance of the joint problem space by means of mediation.

The concept joint workspace, construed in this study, appears very similar to the joint problem space, although the importance of the IWB for the maintenance of joint workspace is primarily attributed to its presence, and not explicitly the software. The built-in software of the IWB which was used during the group work (SMART Notebook), served as an incentive for the students to use the board, a prerequisite for making the problem solving available to the whole group. But otherwise, the concept joint workspace is essentially a validation of the already established concept of joint problem space.

How does the nature of engineering physics influence the interaction between teacher and students?

In paper C, the findings suggested that the teacher interventions were characterised by the students initially introducing the teacher to the task and their reasoning about how to solve it. Then a turning point occurred, where the teacher took over, in terms of being the one who provided the arguments. It seemed clear from the teacher interventions that the students were searching for the correct interpretation of the problem, and they called upon the teacher when they needed to get their reasoning checked (hence the categories *clarification* and *review*), or when they were in need for help (hence the category *explanation*). In addition, they called upon the teacher when they wanted to test their own reasoning (hence the category *evaluation*). Although the category *evaluation* was very rare, it is very interesting, because the students “confronted” the teacher with arguments of their own, which could be interpreted as the students challenging the teacher. While there could be several reasons for why the students did this, the students quickly acknowledged the teacher’s evaluation of their argument, which to me suggests that they wanted to test their own reasoning, and not the teacher.

Following Wegerif’s perspectives on dialogic and dialectic (2007), it seems clear that engineering physics is not truly dialogic, in the sense that ideas that do not fit within the scientific canon ultimately are valued only as a means to appropriate the scientific perspective. The same interpretation can be made from the less stringent definitions of dialogic (e.g.

Mortimer & Scott, 2003). The hierarchical knowledge structure of science (Bernstein, 2000) implies that ideas diverging from the dogma of science can claim little validity, at least in the realm of science classrooms. Rather, *dialectic* is a concept that better describes the aim and epistemological nature of engineering physics, which implies that divergent ideas are conceived as contradictions needed to be overcome (Hennessy, 2011). Although the dialogic perspective has an emancipatory appeal, as opposed to the perhaps more constricting and instrumental prospects of the dialectic perspective, the proposition of engineering physics as dialectic is not an attempt to close down the variety of perspectives advocating for the dialogic possibilities associated with science education. Rather, it is a reminder of what can be seen as the common denominator of any approach to science education: to introduce learners to a specific perspective of the natural world (Scott, 1998), an aspect which ultimately governs both the teacher's and the students' actions.

Scott et al. (2006) describes an authoritative and a dialogic teaching approach as two necessary but opposite approaches to science teaching in the classroom, creating a tension. In this sense, the point made by Mortimer and Scott (2003) about switching between dialogic and authoritative approaches seems implicitly very much attentive to the dialectic nature of science in education, and can thus be seen as an appropriate way to think about science teaching, given that the aim is to facilitate meaningful learning of disciplinary knowledge. A similar tension might exist between the engineering students engaging in a dialogic, collective meaning-making process during group work on one hand, and the epistemological restriction that are at play within engineering physics on the other. This tension is diminished by assuming that the students are implicitly aware of the dialectic nature of engineering physics, and, more importantly, that they acknowledge it. In other words, the students are assumed to acknowledge on some level that there is a limited set of appropriate interpretations to the problems that they are dealing with, and furthermore that there may be only one appropriate answer to them. Also, the students are assumed to perceive the teacher as the more knowledgeable person, who is allowed to evaluate their arguments. In paper C, I proposed that the students' awareness and acknowledgement of the dialectic nature of engineering physics appears as a clause in the *didactical contract* (Black & Wiliam, 1998; Brousseau & Balacheff, 1997) between the teacher and the students, as an implicit, mutual agreement about *what is going on*. This agreement is a prerequisite for the students to accept that their initial arguments may be flawed. Together with appropriate argumentation from the teacher, it may also contribute to students' understanding of *why* their thoughts were not appropriate.

Interaction between teacher and students has been conceived by others in terms of a power relation (e.g. Jamieson & Thomas, 1974). The perspective of engineering physics as dialectic might serve as a supplement to this by emphasising that also the dialectic nature of engineering physics influences the dynamics between students and the teacher, i.e. the students' acknowledgement of the teacher's evaluations.

Similarities between categories in paper A and paper C

The names of the categories from paper C resemble some of those presented in paper A, where the point was to describe how the students used the interactive whiteboard during the group work. The analysis in paper A resulted in four categories, namely *explanatory processes*, *exploratory processes*, *clarifying processes* and *insertion*. In paper C, characterisation of the interaction between teacher and students during teacher interventions, resulted in the categories *clarification*, *review*, *explanation* and *evaluation*.

In paper A, the category *explanatory processes* included occurrences where one or two students seemed to have a clear idea on how to solve a problem, and where they used the IWB to convey their solution to the others in the group, almost taking on a teacher's role. In paper C, the category *explanation* depicted interventions where the students struggled with the problem at hand, and where they called upon the teacher for help. Once the teacher had managed to gain an overview of the students' progress, he provided an explanation. Furthermore, the category *clarifying processes* presented in paper A referred to events where what had been written on the IWB became subject to clarifying queries. It could also result in more elaborate discussions. In paper C, *clarification* denoted interventions where the students asked fairly concrete questions, which the teacher responded to in an equally concise manner.

Although these respective categories in paper A and C denote different phenomena, their characteristics are similar. The *explanatory processes* in paper A were described as students taking on a teacher's role towards the rest of the group, a situation with close resemblance to the occurrences named *explanation* in paper C. The *clarifying processes* presented in paper A also share similar features with the category clarification in paper C, inasmuch that the intention initially seemed to be to clarify specific terms of the problems or the solution of it. However, in both cases, the question asked or the answer given could make way for an elaborate discussion.

Implications for teaching and further research

This study has explored students' use of the IWB during physics group work, and the interaction between teacher and students during teacher interventions. Firstly, the findings from paper A and B showed that although some of the students' use of the IWB seemed to contribute to the collective meaning making process, this use decreased during the course of the term. The findings from the focus group interview with the students suggested some possible reasons for this decrease.

I believe that the potential of the IWB is noteworthy in terms of mere presence, as a common frame of reference for the group. However, the students may not immediately see it that way. The impression I got from the pilot project of 2010 suggested that although the IWB may appear as a new and exciting tool, the students do not necessarily give up on their existing way of solving and handing in physics problems on paper. Providing the students with arguments on how the use of IWBs might be more effective than pen and paper seems like a necessary first step for the students to accept why the IWB is there in the first place. Furthermore, thorough information and instruction should be given about the potential benefits associated with collective meaning making, and how the IWB could be used to facilitate this, in order to enhance the use of the IWB as a tool for solving tasks collaboratively. Since working with an IWB yields restrictions in terms of flexibility to complete the assignments, care should be taken not to hand out tasks that are too comprehensive. There is a potential advantage to this restriction, inasmuch that the group-work scheme becomes structured, which the students in this case seemed to appreciate. Although not investigated in this study, the kinds of talk among the students are important to the process of group work, as they contribute to the students' framing of what they are doing in any given moment (Berge & Danielsson, 2013; Scherr & Hammer, 2009). When being on-task, the occurrences of exploratory talk (see Enghag, Gustafsson, & Jonsson, 2007), may be a valuable to support, as this kind of talk is associated with constructive discussions and dialogic meaning making (Wegerif, 2007).

In this study I have not been exploring the possibilities that exist for utilising the IWB to run computer simulations or other software appropriate for collaborative work. In the context of engineering education, working with simulations that are able to mimic realistic situations would be of great relevance. Also, considering the hardware that is available for making quite sophisticated experiments (e.g. Pasco®), which one is readily able to connect to a computer for real-time display and editing of results, there are many possibilities for utilising the IWB for more than just a digital whiteboard. The size of the IWB and the possibility to manipulate it through the touch-sensitive screen would make it an appropriate tool for collaborative work, because of the opportunity for every member of a group to see what is going on and to participate, which is a prerequisite for collective meaning making. These possibilities make out interesting areas for further research on the use of IWBs in collaborative settings.

Secondly, the implications of conceiving engineering physics as dialectic is perhaps less evident in terms of teaching. Scott et al. (2006) ask what the point of promoting dialogic approaches is when ultimately, the students will be introduced to the authoritative science view. Their answer is that a dialogic approach offers an "opportunity for students to express their everyday views and then later to see how these views relate to the science perspective" (p. 622). I believe a similar answer is relevant to a group-work context: group work offers an opportunity for the students to engage in collective meaning making in order to make sense of problems and their solutions, albeit being confined within a dialectical epistemology. Even when looking for the correct answer during group work, dissenting voices in discussions are valuable, because of the possibility to provoke reflection (Kelly, Crawford, & Green, 2001). Argumentation (Duschl & Osborne, 2002) becomes an important component in science education for inhibiting an instrumental learning approach, as argumentation contributes not only to reach an appropriate solution, but also to understand *why* this solution is appropriate.

Paper C focused on the interaction between the teacher and the students. What was not explored was the on-task interaction between the students themselves. Therefore, it would be of interest to further investigate how students interact in the absence of the teacher, in light of a dialectic epistemology of science.

Limitations of the study

As this is a single case study, there are clear limitations to the validity of the findings and the arguments being put forward here. As Roschelle (1992) puts it: "A case study cannot prove or disprove a theory, but it can clarify the meaning and import a set of ideas. Moreover, it can attract attention to problems that have been overlooked, and create awareness of powerful theories that have not been fully tapped" (p. 268). The idea being put forward in this thesis about the dialectic epistemology of engineering physics is in my opinion relevant to science in education more generally. However, more research needs to be done in order to investigate the viability and the fruitfulness of this idea.

Only one group was followed in this study, which represents the most significant limitation. The selection of the group was discretional, based on my impression from the first three group-work sessions of the apparent interaction within the different groups and their use of the IWB. The results obtained in this study are heavily influenced by both the apparent and more subtle characteristics of the selected group, which means that choosing another group would probably have led to somewhat different results. The selected group in this study consisted of males only (as the female student in the group decided to quit between selection and data recording). Although the group can be seen as representative to the other groups present in the case in terms of gender distribution, there are clear limitations of the findings to other group contexts, where the ratio between males and females are more equal. Furthermore, the selected students appeared to get along well, which was apparent from their lively off-topic conversations. Other groups that were observed appeared more quiet, thus choosing one of these groups for investigation would probably have altered the results. Ideally, data could have been collected from at least one additional group during the autumn term of 2011. Data from an additional group would have enabled me to make extensive comparisons of the findings, thus enhancing the validity of the results. However, due to time restrictions, complete analyses of more than one group were not possible.

Final conclusion

The study has explored important aspects of group work in physics education, and results show that the use of IWBs in group work contexts holds promising potential, in terms of acting as a joint frame of reference for the students. This is important for collective meaning making, as they are able to readily discuss problems and their solutions with reference to the IWB. However, desirable interaction between group members is not easily maintained, there are complexly integrated aspects associated with group work that serves to support or inhibit effective and extensive discussions among the students. One of the aspects explored in this study was the dialectic nature of the subject area, which played an important role in the dynamics between teacher and students during teacher interventions. The dialectic nature of engineering physics contributes with a demarcation line to the students' meaning-making process.

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Paper A

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Students' use of the interactive whiteboard during physics group work

Magnus Strøm Mellingsæter[a] and Berit Bungum[b]

[a]*Department of General Science, Sør-Trøndelag University College, Trondheim, Norway;* [b]*Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway*

This paper presents a case study of how the interactive whiteboard (IWB) may facilitate collective meaning-making processes in group work in engineering education. In the case, first-year students attended group work sessions as an organised part of a basic physics course at a Norwegian university college. Each student group was equipped with an IWB, which the groups used to write down and hand in their solutions to the physics problems. Based on a Vygotskian, dialectical stance, this study investigates how the students used the IWB in the group work situation. From qualitative analysis of video data, we identified four group-work processes where the IWB played a key role: exploratory, explanatory, clarifying and insertion. The results show that the IWB may facilitate a 'joint workspace', a social realm in which the students' dialogues are situated.

Keywords: interactive whiteboard; group work; physics; dialogic space; joint workspace

1. Introduction: the interactive whiteboard as an educational tool

Interactive whiteboards (IWBs) have become increasingly more common and popular as an educational tool in schools as well as in higher education, and the research interest in the use and benefits of IWBs in education is emerging accordingly. Mostly, IWBs are used due to their affordance to easily integrate or switch between different modes of representation during a lecture (video clips, simulations, static displays, ready-made presentations). In addition, IWBs are used for improving the logistics of teaching, through the ability to store and share the teacher's lecture notes. In a review paper, Smith, Higgins, Wall and Miller (2005) identified a number of potential benefits IWBs have as a tool to enhance teaching and support learning in teacher-led contexts. Some of these benefits are of a technical nature, such as opportunities for multimedia presentations, the touch-sensitive facilities making the IWB simple and efficient in use and the possibilities to store, share and re-use teaching material. The most important advantage, as described by Smith et al. is, however, the opportunities IWBs provide for student interactivity and participation in a technical as well as in a pedagogical sense. The potential IWBs provide for interactivity and participation has been explored by Hennessy (2011) in the context of teacher-led classroom dialogues. She finds that IWBs may open up opportunities for learners to generate, modify, and evaluate new ideas through multimodal interaction along with talk.

The focus of this paper, however, is how IWBs can contribute to student collaboration and learning in small groups. Previous studies in this field have investigated how IWBs can enhance collaborative learning activities in groups of children in primary school science (e.g. Kershner et al. 2010, Mercer et al. 2010). The pedagogical value of group work for students in higher education is also widely researched in terms of learning outcomes (see Springer et al. 1999), and to some extent with regard to the dynamics of group work (e.g. Ingerman et al. 2009, Scherr and Hammer 2009). There is, however, very little research on how the use of IWBs can benefit student group work in higher education.

This paper contributes to the field by investigating the ways in which engineering students use an IWB in collaboration processes, and how the IWB may contribute to the collective meaning making. We also discuss potential benefits the IWB have that could not be matched by an ordinary blackboard in a group work context.

In the study, mechanical and logistics engineering students at Sør-Trøndelag University College met once a week in classrooms specifically designed for group work, where each student group was equipped with an IWB. Based on analysis of video recordings of these students' collaborative work, we establish a conceptual framework for how the IWB facilitates the kind of dialogues and actions that enhance students' learning. Through this investigation, we gain some understanding as to whether and how the IWB, in terms of mere presence and technical affordances, can facilitate the mediation of thoughts and ideas and thus contribute to the collective meaning making process.

2. Theoretical stance: a Vygotskian approach

Our epistemological stance is situated in a sociocultural framework. In this particular study we have been influenced by a Vygotskian approach, which at its core states that meaning-making is developed in the social plane through the use of cultural tools, and where language is seen as the key vehicle for development and mediation for thoughts and ideas, and ultimately teaching and learning (Mercer and Littleton 2007). Strongly related to this is dialogue, from which different perspectives emerge and meaning making can occur (Mortimer and Scott 2003).

The underlying notions of what learning is, and implicitly how learning emerges, has been described by Sfard (1998) as two metaphors: the *acquisition metaphor* and the *participation metaphor*. The acquisition metaphor assumes that knowledge is something that the *individual* acquires from some external source. The participation metaphor conceives learning as the act of knowing, which emerges in knowledge communities by means of participation. Paavola and Hakkarainen (2005) have suggested a third metaphor that is of relevance to the present study: the *knowledge creation metaphor*. This metaphor describes learning as interaction taking place through a *mediating artefact* (see Säljö 1999). The knowledge becomes embodied in the mediating artefacts and practices, rather than being acquired by individuals or merely constructed through social interactions (Hennessy 2011).

The three metaphors may serve as foundational guidelines for the various theories of teaching and learning. The metaphors cross the boundaries between scientific arguments and intuitive, everyday thinking, and it will inevitably shape the framing of teaching and learning as well as research (Paavola and Hakkarainen 2005). Also, one framework of learning can assume more than one metaphor of learning. An augmented Vygotskian framework may for instance assume a mix of the participation metaphor (meaning making in the social plane), the acquisition metaphor (individual construction of knowledge) and the knowledge construction metaphor (the use of mediating artefacts). In this paper, the artefact of particular interest is the IWB, as it may facilitate the dialogues between the students, which in turn can be perceived as mediating practices, in the group work situation.

In discussions of the role of dialogues in a sociocultural framework, Mikhail Bakhtin is often regarded as one of the most prominent thinkers (e.g. Mortimer and Scott 2003, Wertsch 1998). His thoughts on dialogue have been appropriated to a Vygotskian framework. Wegerif (2006, 2008) questions this appropriation on the basis that the Vygotskian framework takes on a *dialectic* approach, while the Bakhtinian framework takes on a *dialogic* approach. The main difference between these two approaches is that a dialectic perspective yields a *synthesis* or an *overcoming* between different, competing voices. In a dialogical perspective, "there can be no 'overcoming' or 'synthesis'," as "meaning itself only arises when different perspectives are brought together in a way that allows them to 'inter-animate' or 'inter-illuminate' each other" (Wegerif 2006, p. 146). As we interpret this difference, the outcome of an encounter between different voices is more unpredictable in a dialogic perspective than in a dialectic perspective.

Wegerif points to fundamental philosophical discrepancies between Vygotsky and Bakhtin that are relevant to the present study. The chosen perspective shapes how we perceive the learning situation, i.e., whether we frame the desired learning outcome as an inter-animation or as an overcoming between the voices of the students and the voice of physics. In the case investigated in this paper the main task for the engineering students is to learn basic physics of relevance to engineering. This involves becoming familiar with the various theories of physics, and the use of mathematics in applications in engineering contexts. In this respect, the desired outcome actually *is* a synthesis or an overcoming between the voices of the students and the scientific theories of physics. This applies for novices, while at a later stage the educated engineers will have developed a range of strategies and ways of reasoning in dealing with new problems (Christiansen and Rump 2007). Consequently, a Vygotskian, dialectical approach seems as an appropriate perspective for our case involving engineering students in an early phase of their study.

Within the dialogic perspective, Wegerif (2007) has introduced the concept of a ‘dialogic space’, which is used as a theoretical construct with regard to the use of IWBs in whole-class teaching (Hennessy 2011, Littleton 2010), as well as in small-group learning (Mercer et al. 2010, Warwick et al. 2010). This ‘space’ does not refer to a physical space, but rather to a social realm within which dialogue emerges and is sustained. According to Wegerif, the dialogic space “opens up when two or more perspectives are held together in tension” (2007, p. 4). In the present paper, a parallel notion to the dialogic space with a dialectic rather than a dialogic perspective will be established based on our empirical results of investigating group work with the use of IWBs.

3. The case: introductory physics for engineering students

The case concerns first-year mechanical and logistics engineering students at Sør-Trøndelag University College attending organised group work sessions during the fall term of 2011. In 2008, the Norwegian Agency for Quality Assurance in Education presented an evaluation report on the engineering education in Norway. Among the recommendations from the report was that communication and collaboration skills should be more emphasised throughout the education (NOKUT 2008). As a consequence of these recommendations, the University College designed rooms for group work, so-called ‘learning labs’, equipped with an interactive whiteboard for each group.

From the university college's point of view, the reason for equipping each group with an IWB is dual: for one, it's about efficiency. Instead of having each member of a group making a draft of the tasks so that one of them can insert it on paper for handing in, the groups were to write their solutions on the IWB in a collaborative manner and hand in the final file via e-mail or a learning platform. Related to the issue of efficiency, the teacher's aim was that the groups should complete the tasks within the three hours they had at their disposal in the learning labs. Given that the students had to hand in their solutions as a proprietary "whiteboard"-file, their options for completing the assignment outside these rooms were limited, and so the students had an incentive to complete the assignments in time, and also an incentive to use the IWB during their work. This was thought to yield two consequences: firstly that the students' "spare time"-workload was not increased with yet another assignment, and second that the groups had to meet face to face in order to complete the assignments. This leads to the second vision: there was a concern that ordinary group assignments were solved in an unintended cooperative manner, i.e., the students divided the various tasks between them and worked separately. By constraining the students to work face to face, the hope was that this would encourage them to work *as* a group, not just *in* a group.

The students met for about three hours once a week for a total of eleven times throughout the term in the learning labs. Each group were assigned to a booth, which was closed off by drapes, thus dampening the noise from the other groups. About 100 students participated in these group-work sessions. Due to the number of students and limited space, eleven groups with five to six students each were present at each of the two sessions that were arranged each week. There were two teachers present at the exercise sessions, who were available for supervision upon request.

At the start of the term, one of the teachers provided the students with an introductory video tutorial on how to use the IWBs. Other than this technical video tutorial, the students were given very few instructions on how they could or should use the IWB in the group work situation, i.e., they were free to use it in their own manner. The only requirement was that the students had to hand in their solutions electronically, thus requiring a minimum of activity on the IWB.

The weekly exercises consisted of three to four physics problems, which were strongly linked to the curriculum. Often the physics problems were linked to parts of the curriculum that the teacher had lectured about recently. Most of the physics problems were given as pure textual problems, where some required mere calculation, whereas others required estimation of relevant quantities. The IWBs were connected to the Internet, so the students had access to online resources. However, the teacher strived to give a problem in each exercise which required some 'doing', i.e., the students had to carry out a semi-structured experiment in order to solve the given problem. Examples of this were tug of war in order to find out how Newton's third law come into play, and being pushed down the hallway on a wheel-based office chair holding a pendulum in order to calculate the acceleration. Other problems were accompanied with a video clip made by the teacher. These clips demonstrated some sort of experimental setup, and the quantities relevant for the problem solving were displayed in the video, which the students watched on the IWB.

4. Research methods

One of the researchers followed the group work sessions closely throughout the term, and was in contact both with the student groups and the teachers. Data were collected by means of video recording of one of the student groups during the last eight exercise sessions of the term. The selected group consisted of five male students: Henry, Terry, Andrew, Eric and Toby, all in the beginning of their 20s. Originally there was a female student in this group, but she decided to quit before we got to record any data from the group work sessions. Given that fewer than 10% of the students in the physics class were women, the group that was recorded can still be seen as representative for the whole class with regard to gender distribution. Furthermore, the group was chosen on the basis that it seemed representative for the student mass with regard to age and level of engagement in the exercises. The latter criterion implied that the group members should show a certain engagement towards the exercises and the other group members.

The video camera was set up on a tripod beside the IWB, facing the table where the students were sitting. There was limited space in the booth, which made it practically impossible to set up another camera behind the students, facing the IWB. The choice of angle gave a good impression of the dynamics between group members, the students' facial expressions and their dialogues, on the cost of losing information of what the students were doing on the IWB in real time. This problem could to some extent have been overcome by using a hand-held camera in addition to the stationary camera. However, in order to avoid unnecessary interference with the group work situation, only the stationary camera was used. We also had access to the final documents students submitted on the IWB, which gave a fairly good impression of what the students were discussing during the group work. Furthermore, there are methodological issues regarding the use of a hand-held camera. By moving the camera or zooming in on occurrences that are of immediate interest, one quickly runs the risk of losing important information (Heath et al. 2010).

The video material makes out about 23 hours of film. In the first phase of analysis data reduction was done by identifying sequences where the students interacted directly with the IWB. These sequences made out a total of about 12 hours of film. The material has been analysed qualitatively by means of the software Transana™, using an inductive approach, which resembles the *constant comparative method* (Merriam 1998). The video sequences were viewed several times, and during each viewing each sequence was summarised and labelled with a category. During the first viewing, the categories were close to the material, i.e. more descriptive, and throughout this iterative process the category construction yielded fewer and more generic categories. The authors have viewed some of the clips separately, which resulted in some adjustments of the categories. This was done in order to ensure reliability of the findings. Finally, the sequences that were picked out for presentation were transcribed.

5. Results

In the following we present the results from our analysis of the collaborative processes in the selected group of engineering students. We have identified four main categories for how the students use the IWB in the group work situation: exploratory processes, explanatory processes, clarifying processes and insertion. In addition the students occasionally used the IWB to search for relevant resources on the web, but just as often they used their own laptops for this purpose. Consequently, this use of the IWB is not presented as a category on its own in this study. The excerpts and the categories presented are representative in terms of a substantial fraction of occurrences in the material. The excerpts are 'best case'-scenarios, which serves to highlight the essence of each category.

5.1. Exploratory processes

On some occasions the students may decide to try out their ideas, using the IWB. The dialogue between the students is characterised by mutual questioning, answering and suggesting. In contrast to the clarifying and explanatory processes, the exploratory processes are not characterised by any clear power relations between the students; anyone's suggestion is open for exploration, but also for critique.

An example of an exploratory process is when Henry and Eric start to work on the physics problem shown in figure 1. They decide to just try and draw a figure on the IWB of the human body as if it was constituted by different symmetrical objects; the head is represented by a sphere, the torso and legs by a single cylinder and the arms by a rod. Henry is drawing on the IWB, while Eric is standing in the back of the booth, facing the IWB, and comes with encouraging comments as Henry goes along. The rest of the group is working on another problem on paper while Henry and Eric are making their model on the IWB.

> Estimate the moment of inertia of a human body along a vertical axis through the centre of the head, when standing straight with the arms stretched out and the legs together. (Hint: the moments of inertia to the different parts of the body through the axis can be added together)

Figure 1. The physics problem "The human moment of inertia".

Together Henry and Eric talk their way through the modelling of the body. Eric is also stretching his arms out at some point, as to demonstrate how Henry should draw the figure. This also has another function: Eric uses his own body to estimate different lengths: the arms, his torso and his legs. Finally Henry and Eric decide to model the human body as one big cylinder, with a rod for arms, thus not treating the head as a sphere.

What is interesting about this situation is that neither Henry nor Eric seem to have made any notes before they start drawing the figure on the IWB. They use the IWB to explore ideas and arguments.

5.2. Explanatory processes

When a student has an idea on how to solve a problem, or has already reached a solution on paper, he may go up to the IWB. To the majority of the group, however, a solution seems to be out of reach. In these explanatory processes, the student at the IWB talks the rest of the group through his suggested solution while he writes it up on the IWB. The questions from the group gravitate toward the student at the IWB, and have a clear reference to what is written on the IWB. The student at the IWB takes on a teacher-like role when he explains and when he asks questions.

In the following two excerpts, one student, Andrew, has got up to the IWB, carrying his notes. The group is working on a problem that involves a sled, which is pulled up a tilted plane with the help of a weight (see figure 2a and 2b). Andrew has been working on the problem on paper before going up to the IWB. Throughout the excerpt, Andrew is talking primarily to Henry, who is sitting at the table with the others. Before this clip Henry has drawn a figure of the scenario on the IWB.

> An engineering student is about to put peat on the roof of his cottage. In order to transport the peat up on the roof, the student has made a sled that slides on two boards, and that is pulled up the tilted plane by a weight that is released from resting position.
>
> The string that connects the weight to the sled is regarded as massless, and slides through the pulley without friction.
>
> The sled with the peat has a mass of 6,5 kg. The boards on which the sled slides makes an angle a = 59° with the horizontal plane. The kinetic friction coefficient between the sled and the boards is 0,35. The weight has a mass of 8,0 kg.
>
> What is the acceleration of the sled up the tilted plane?

Figure 2a. The physics problem "Sled on a tilted plane".

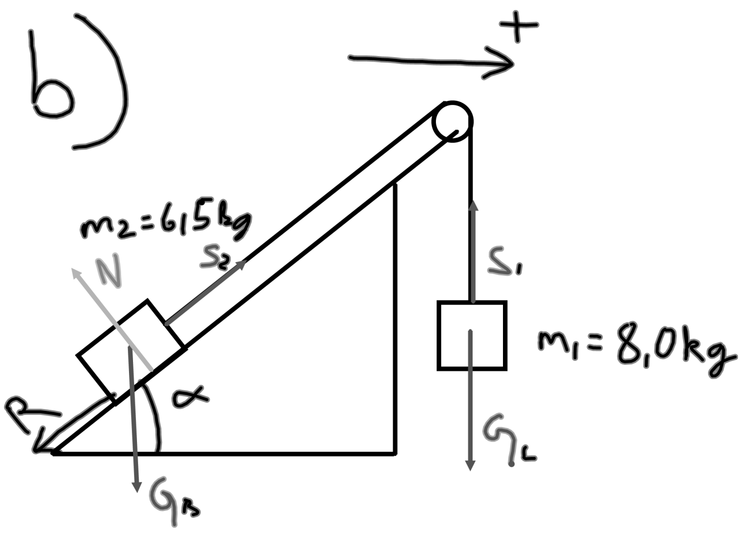

Figure 2b. Student's drawing of the physics problem "Sled on a tilted plane".

101	Andrew:	But anyway, then these (internal string tensions) cancel each other.. Gone! And then we get.. G equals.. let’s call it the mass (inaudible).. The mass of.. the sled.. weight	Andrew is pointing on the IWB with the marker. Andrew is writing on the IWB, turning away from the group.
102	Henry:	What were we supposed to find? (to Terry)	Henry turns from Andrew to Terry.
103	Terry:	We were to find the acceleration	
104	Henry:	A (the acceleration).. Then we must follow this	Henry is referring to his own notes.
105	Terry:	Ye.. Uh, no. There is friction	Terry looks at Henry’s notes.
106	Henry:	Yes (inaudible)	
107	Andrew:	Look at this equation, do we agree on this?	Andrew turns to the rest of the group, referring to what he has just written.
108	NN	(inaudible)	
109	Terry:	I think it looks a bit simple, uh..	Terry is looking toward the IWB.
110	Andrew:	It *is* very simple, that’s what’s so lovely about it!	

In this excerpt, Andrew seems to have a clear idea on how the problem should be solved. Even his question to the group (line 107) can be interpreted more in terms of securing that the others follow his trail of thought than a signal of insecurity. Terry seems a little sceptical to Andrew’s solution, and remarks that the solution looks a bit too simple. Andrew, still confident in his idea for a solution, ensures that: “It *is* very simple, that’s what’s so lovely about it!” This way he tries to convince his peers that his solution is right.

When Andrew turns away from the group and toward the IWB to continue writing (line 101), Henry turns to Terry for clarifications about what they should find and how they should find it (line 102 - 106). This passage has no direct reference to what is happening on the IWB. However, this reaction from Henry seems to be induced by what Andrew has been writing and explaining on the IWB.

Henry does not seem to fully grasp Andrew's solution and suggests that they should solve the problem according to an example from a lecture:

201	Henry	Shouldn't we do it like this?	Henry is asking Andrew, referring to his own notes.
202	Andrew:	What are *you* doing?	Andrew is leaning over Henry's notes.
203	Henry:	(Inaudible) the example he (the teacher) showed us	
204	Terry:	No, it'll turn out the same	
205	Andrew:	It'll probably turn out the same	
206	Henry:	What did you get then? F (the force)..	Henry is still facing Andrew.
207	Andrew:	Okay, hold on. What.. What I've been thinking.. First, we put up the sum of F. We've chosen positive direction that way, so then we have.. minus R, plus S, let's see.. how is it.. minus R there plus S.. minus S, which goes the other way.. and plus G.. for the weight. The S's cancel each other, and then we have G-weight minus R, which is the friction	Andrew is turning towards the IWB again, pointing on the screen in accordance with his explanation.

Both Andrew and Terry conclude that Henry's suggestion leads to the same result as the one Andrew has been writing on the IWB. Andrew then goes through the whole solution on the IWB, taking on a teacher-like role towards the group.

Seeing the two excerpts together, we see that Henry, and also Terry, come with inputs and questions to what Andrew has been saying and writing on the IWB. These inputs, however, seem to suggest that particularly Henry doesn't quite follow Andrew in his argumentation. Furthermore, most of the questions and queries addressed to Andrew have a reference to what is written on the IWB.

It is also interesting to note that the students sitting at the table ask Andrew questions or otherwise comment on Andrew's work as he is doing it. What is written on the IWB is readily perceivable to the others on the group. This is not to say that what is written is readily understandable (as the excerpts clearly show), but it is readily available for questions or queries. Looking at the IWB, the other students can immediately see how Andrew solves the problem at hand.

5.3. Clarifying processes

From the video material it turns out that more often than not, the students prefer to sketch a solution on paper before writing it up on the IWB. At some point a student switch from writing on paper to writing on the IWB. This gives rise to clarifying processes, which can occur when the students are faced with a problem that to the students has no straightforward solution, or when one student feels he has reached a solution to the problem at hand. In the first instance, the students may decide to write what they've got so far on the IWB.

If some of the other students don't understand the solution, or that they have not reached the same solution as the writer, a discussion may emerge, which serves to clarify terms of the solution, to explain parts of the solution or to adjust or even alter the solution on the IWB. To some extent this category resembles the 'explanatory processes'-category, but it differs in that the initiatives from the writer and the rest of the group are more equally distributed.

A rollercoaster called “The Loop” in Tusenfryd [an amusement park] has a loop with a diameter of 15 m. We can regard the loop as circular (it is really a bit drop-shaped in order to reduce the forces that the passengers are exposed to). In this exercise we disregard friction, air resistance etc.

What is the normal force on the passenger in the highest point in the loop? Give the answer as a factor of the gravitational force.

Figure 3. The physics problem “The rollercoaster”.

In the following excerpt, Eric have been writing parts of a solution to a physics problem on the IWB, see figure 3. He asks Toby if he agrees with what he has written. Toby questions Eric’s solution, and Eric tries to explain. After some discussion between Eric and Toby, Henry also joins in:

301	Henry:	Oh shit, this is messy!	Henry is sitting at the table, looking toward the IWB.
302	Eric:	(Giggles and says something inaudible to Henry)	Eric is facing Henry.
303	Henry:	Yes (giggles). But when you do it like this, you don’t eliminate the m (the mass)	
304	Eric:	What do you mean?	
305	Henry:	E-k (kinetic energy)	
306	Eric:	Yes?	
307	Henry:	Yes	
308	Toby:	It won’t be E-k if you eliminate the m (inaudible)	Toby is sitting at the table, facing the IWB and Eric.
309	Eric:	What do you mean?	Eric is addressing both Toby and Henry.
310	Henry:	Exactly!	Henry is speaking to Eric.

After this discussion, Toby goes up to the IWB with his notes and starts to write an alternative solution to the problem. Eric is standing next to him and pays attention to what Toby is doing. Eric eventually seems to acknowledge that his own solution was somewhat misguided.

Clarifying processes also occur when the students have been struggling with the same problem for some time. A student is working on the IWB while another student comments on what is being written. The dialogue between them is characterised by mutual questioning, answering and suggesting. However, the mood of the dialogue seems a little more critical. This is perhaps due to the fact that the students already have followed at least one thread of argument before, i.e. they already have some ideas on how parts of the problem should be solved. There is perhaps not so much direct interaction with the IWB, but what has been written on the IWB is the point of reference in the discussion between the students.

In the following short excerpt, Henry has been working on the same exercise as shown in figure 3, the only difference being that he's trying to work out the normal force on the passenger in the lowest part of the loop. Terry walks up to the IWB where Henry is standing. Terry points toward the screen and is obviously disagreeing with what Henry has written, see figure 4 (note that figure 4 depict their *final* solution).

401	Terry:	But, but you cannot divide, you can't just decide to divide.. this with all of, all of this with all of that, and parts of this with parts of that. That is completely illegal!	Terry and Henry are both standing in front of the IWB. Terry is pointing to the screen to illustrate his points.

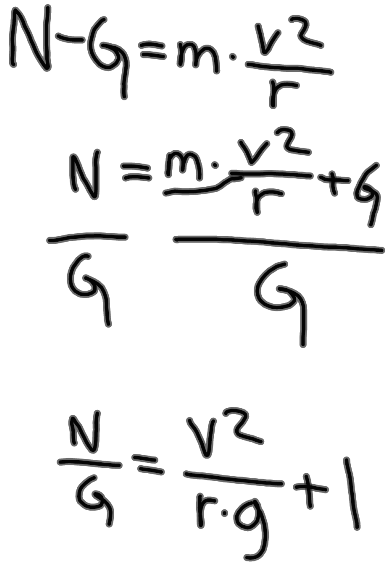

Figure 4. Excerpt from the group's final solution to the problem "The rollercoaster".

What this excerpt also shows is that the dialogues between the students in these occasions tend to focus on mathematical operations, and not so much on conceptual themes. This again could be due to the fact that the students have been working on the physics problem for some time, and that they therefore have reached a certain point in the collective meaning making process.

Seeing these two examples together, we see that inserting a solution, or parts of it, on the IWB, makes the arguments visible to the whole group. However, the physical constraints of the booth where the students were sitting and the physical arrangement of the IWB, sometimes resulted in a 'bottleneck' effect that was observed in the case when a student was writing or drawing on the IWB. This student would inevitably stand in the way of the others, making it difficult for them to see what was being done on the IWB.

5.4. Insertion

A natural part of the work process is the insertion of a solution on the IWB, and there are numerous examples of 'insertion' in the video material. In fact, about one third of the time the students spent interacting with the IWB were categorised as ‘insertion’. One student brings his notes with him and starts to insert a solution to the problem at hand. Here the dialogues between the one writing the solution on the IWB and the rest of the group are scarce, and much more limited than is the case during the ‘clarifying processes’. However, insertion can quickly turn into discussions that serve to clarify what is written on the IWB, i.e. clarifying processes. In this respect insertion can also form an important part of the collaborative work process.

6. Discussion

In this paper we have identified four categories of how students make use of the IWB during physics group work, that involves the students’ direct interaction with the IWB: exploratory processes, explanatory processes, clarifying processes and insertion. The exploratory process can be described as using the IWB for an initial inquiry of the problem at hand; the explanatory process by a teacher-like performance of a student at the IWB, having an idea on how to solve a problem; the clarifying process is characterised by mutual questioning or critique between the students and may result in adjustment of what is already written on the IWB; and finally, the insertion process is described in terms of one student writing on the IWB in silence.

About half of the complete set of video material consisted of student interaction with the IWB, while a considerable amount of the rest consisted of situations where the students were sitting down at the table, sketching their individual solutions on paper. This illustrates that the students need time to gather their own thoughts around the problem at hand before embarking on a discussion about it. Similar results were found by Scherr and Hammer (2009). This shows that on its own, the IWB does not completely replace the need to make personal notes. This gives rise to the category ‘insertion’ in our analysis, where solutions are transferred from individual notes to the IWB.

The other three categories explanatory, clarifying and exploratory processes all have in common that what is written on the IWB draws and sustains the students' attention, in the sense that discussions arise, comments are made, or clarifications and explanations are given. What is written on the IWB is readily available to the group, a point also made by Hennessy (2011). This interpretation shows the importance of considering the mediating artefacts as well as the mediating practices in the learning situation as made explicit by the knowledge-creation metaphor.

This study indicates that the IWB supports the students' collaborative learning by providing an environment in which the students share and develop their ideas. We call this environment a *joint workspace*. The joint workspace is a space within which the students act, and where discussions arise and are sustained. The IWB plays a role as a physical artefact for the mediation of thoughts and ideas to emerge. To some extent, the joint workspace resembles Wegerif's *dialogic space* (2007), in the sense that neither the dialogic space nor the joint workspace is a physical space, but rather a social realm in which the students and their dialogues are situated. Further, both concepts are defined by the emergence of different perspectives within the dialogues. However, the theoretical underpinning of the 'dialogic space' diverges from a dialectical perspective. The joint workspace is a space to which the students' attention is drawn and sustained, but where the desired outcome actually *is* a synthesis or an overcoming between the students' own ideas and the scientific theories of physics. A good example of the joint workspace is when Andrew uses the IWB and guides the rest of the group through his suggested solution, presented under *Explanatory processes* (line 101 and 207). The group's attention is focused toward what Andrew says and what he has written on the IWB, and the dialogues between the students is characterised by finding a plausible solution and finally, the *right* answer.

Could the same outcome have been achieved with an old-fashioned, non-digital blackboard? This might be possible for some of the collaboration exemplified in this paper. However, taking the context of the case into account, we argue that the IWB contributes to enhance the processes described, to a greater extent than an ordinary blackboard would have done. Important in this context is that the physics teacher had made some requirements as to how and when the students could be able to complete the group work. The most important requirement was that the students had to hand in their solutions as a file, using the graphic processing program available on the IWB. This meant that the students had a powerful incentive to actually use the IWB. In addition, it also meant that the students had to meet face to face within the scheduled time set up in the learning labs, in order to have access to an IWB. The requirement for the students to hand in their solutions as a file is something that could not have been accomplished with a non-digital board, thus leaving a hypothetical blackboard group to hand in their solutions on paper. Thus the students would have no incentives to use an ordinary blackboard, and hence the settings would not encourage the collaboration processes to the same extent, as students are likely to prefer working in the same format (paper, computer, IWB) as the required final submission format. Therefore, in this case we can expect to observe certain behaviour and use of the IWB that we would not expect if the IWB was replaced by a blackboard.

7. Conclusion

The main benefit of the IWB in the processes described in this paper is that it makes the arguments and calculations from the physics problems available to the whole group. This is an important prerequisite for each member of the group, for them to get to clarify and question the solutions written on the IWB. The IWB, along with the incentives to use it during the learning situation, support the collective meaning making processes. The IWB contributes in establishing a joint workspace, where collective meaning making can occur through the dialogues between the students and what is written on the IWB. This does not mean that the IWB in a group work context transforms the students' learning in unique ways. What we argue is that the IWB may support some of the well-known valuable aspects of group work and make them more effective. However, the most appropriate use of the IWB is not equivalent to using the IWB most of the time.

Further research is required in order to validate the categories found in this study with student groups with different characteristics. It will also be worthwhile to investigate the students' experiences with the learning labs as well as the learning outcome in order to establish a deeper understanding of how group work in an IWB-context can be developed further.

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Paper B

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Engineering students' experiences from physics group work in learning labs

Magnus Strøm Mellingsæter*

Department of General Science, Sør-Trøndelag University College, Trondheim, Norway

Background: This paper presents a case study from a physics course at a Norwegian university college, investigating key aspects of a group-work project, so-called learning labs, from the participating students' perspective.
Purpose: In order to develop these learning labs further, the students' perspective is important. Which aspects are essential for how the students experience the learning labs, and how do these aspects relate to the emergence of occurrences termed joint workspace, i.e. the maintenance of content-related dialogues within the group?
Programme description: First year mechanical engineering students attended the learning labs as a compulsory part of the physics course. The student groups were instructed to solve physics problems using the interactive whiteboard and then submit their work as whiteboard files.
Sample: One group of five male students was followed during their work in these learning labs through one term.
Design and methods: Data were collected as video recordings and fieldwork observation. In this paper, a focus group interview with the students was the main source of analysis. The interpretations of the interview data were compared with the video material and the fieldwork observations.
Results: The results show that the students' overall experience with the learning labs was positive. They did, however, point to internal aspects of conflicting common and personal goals, which led to a group-work dynamics that seemed to inhibit elaborate discussions and collaboration. The students also pointed to external aspects, such as a close temporal proximity between lectures and exercises, which also seemed to inhibit occurrences termed joint workspace.
Conclusions: In order to increase the likelihood of a joint workspace throughout the term in the learning labs, careful considerations have to be made with regard to timing between lectures and exercises, but also with regard to raising the students' awareness about shared and personal goals.

Keywords: physics; group work; joint workspace; higher education

Introduction

That is so 1990!

This quote belongs to Andrew, one of the students who was interviewed about his experiences with a physics group-work project at a Norwegian university college. Once a week throughout a term, mechanical and logistics engineering students met in group-work rooms, so-called learning labs, to complete a set of physics problems in small groups. Each group had access to an interactive whiteboard (IWB) and was instructed to write down and hand in their

*Email: magnus.s.mellingsater@hist.no

solutions as whiteboard files. In this particular citation, Andrew was talking about the practical advantage of being able to hand in the solutions to the physics problems electronically, as opposed to having to walk from one end of campus to another in order to deliver a paper-written solution (hence the reference to the 1990s). Although this utterance was probably meant humorously, it reflects one aspect of the students' experiences with the group-work set-up: it was cool and future oriented. Apart from these quite short-lived attributions, the students' expressed experiences do shed light on more substantial aspects of the learning labs.

IWBs have become more common and popular as educational tools in schools as well as in higher education, but their effect is still little researched. For the most part, research has focused on the use and potential of IWBs in teacher-centred contexts (Smith et al. 2005), owing to their ability to integrate or easily switch between different modes of representation during a lecture (video clips, simulations, static displays, ready-made presentations). IWBs also have the potential for enhancing interactivity in the classroom between the teacher and the students (e.g. Hennessy 2011), as the students are able to manipulate objects on the big, touch-sensitive screen. However, the technical functionalities of the IWB may reinforce an authoritative teaching practice, as it could be used mainly for display or demonstration purposes (Springer, Stanne, and Donovan 1999).

Some studies have investigated how IWBs can enhance collaborative learning activities in groups of children in primary school science. Kershner et al. (2010) and Mercer et al. (2010), reporting from the same research project, both look at how primary children work collaboratively in a 'shared dynamic dialogic space', where the concept of dialogic space draws on Wegerif's (2007) understanding.

Group work in higher education is widely researched in terms of learning outcomes and students' attitudes towards this particular learning activity (Springer, Stanne, and Donovan 1999), and to some extent with regard to the dynamics of group work (Enghag, Gustafsson, and Jonsson 2007; Ingerman, Berge, and Booth 2009). However, few studies have looked at the use of IWBs in collaborative contexts in higher education.

This paper presents a case study concerning different aspects of the learning labs from the participating students' perspective. One student group consisting of five students was followed throughout one term, and during weekly exercise sessions, data were gathered through video recordings and field observation. The aspects investigated here emerged from a focus group interview conducted with the group towards the end of the term. The students' experiences and viewpoints were then combined with video data in order to shed light on how the use of IWBs in group work may facilitate students' learning.

Background

In Mellingsæter and Bungum (submitted), video data were analysed to investigate how students used the IWB in the group-work situation. Four ways of using the IWB were identified as processes during the problem solving: exploratory processes, explanatory processes, clarifying processes and insertion. Exploratory processes were characterised by students using the IWB to explore the physics problems without any significant preparation, i.e. note sketching. Explanatory processes involved one student taking on a teacher's role, explaining his idea of how to solve a problem to the others in the group using the IWB. Clarifying processes occurred when questions or inquiries about what had been written on the IWB resulted in clarification or perhaps alteration of the written solution. Finally, insertion described events where one student inserted a solution on the IWB, and where there was little interaction between the group members.

From the categories exploratory, explanatory and clarifying processes, the concept *joint workspace* was established as a social realm where the students' dialogues and attention remained focused on a physics problem. The IWB supported the emergence of a joint workspace by providing an overview of what had been written, thus helping the collective meaning-making process more effectively, as opposed to situations where the students were discussing while focusing on their own paper-written notes. The concept of a joint workspace was established within a dialectical, Vygotskian framework (Wegerif 2007), where the desired outcome of an encounter between the voices of the students and the voice of physics is a *synthesis* or an *overcoming*. What this means is that, ultimately, students should appropriate the scientific theories of physics, and not some hybrid, in-between understanding, although this may turn out to be quite different in practice (Wandersee, Mintzes, and Novak 1994). The possible reasons for how or why joint workspace occurred were not explored. In this paper, I will use the results obtained from the group interview to shed light on the video material and the field observation, and find some of the possible reasons for the emergence of the joint workspace. In addition, the interview tells us something about the students' experiences with the learning labs, which can point to aspects of the learning labs that should be preserved and aspects that need to be improved, or perhaps conveyed more clearly to the students in the future.

Scherr and Hammer (2009) and Berge and Danielsson (2013) have investigated physics group work in higher education and produced results that could be related to the joint workspace with regard to both the concept itself and possible reasons for its emergence. Scherr and Hammer (2009) investigated the variety of interactions within student groups working on physics tutorials. The authors identified four distinct patterns of interaction and interpreted these with regard to the students' epistemological framing as completing the worksheet, discussing, responding to a teacher assistant and joking.

The epistemological framing termed discussing is the most relevant one with regard to joint workspace. Here, the students are talking in an animated tone to each other while gesturing. Scherr and Hammer (2009) compared the students' tone of voice and their use of gestures with the content of their utterances, and found that there was a correlation between animated talk accompanied by gestures and the presentation of original, personal and intellectual demanding thoughts. The authors do not provide an explanation for why the students step in and out of these different epistemological framings. An interpretation that can be made from the excerpts of data presented in Scherr and Hammer's paper is that the students tend to be discussing more when they are dealing with tutorials on classical mechanics rather than electrostatics. It should be noted that their findings do not provide a direct comparison between the different tutorials.

Berge and Danielsson (2013) identified several storylines that emerged in the talk between engineering students during physics group work. Their students were dealing with a physics problem to reach a solution, to understand the physics or to prepare for the upcoming examination. The joint workspace could be related to all these storylines, as it is defined at a coarser grain level than Berge and Danielsson's categories. Furthermore, Berge and Danielsson identified storylines that go along the line of establishing 'insiders' and 'outsiders' of the group or the community of engineering students, either by rendering the physics problems easy or by making esoteric jokes. Both the Scherr and Hammer categories of epistemological framing and the Berge and Danielsson storylines can tell us something about how students go about solving physics problems in small groups. What seems to be missing are considerations of how these epistemological or interactional patterns evolve over the course of an entire term.

Research questions

This study investigates aspects that influence the students' experiences with the learning labs, and from these the possible reasons for the emergence of the joint workspace. The research questions are:

- Which aspects are important in how the students experience the learning labs?
- How do these aspects relate to the emergence of a joint workspace?

The students' experiences from the learning labs are important, as they may point to factors or issues that can shed light on the possible reasons for the emergence of the joint workspace during the course of the term. On a more concrete level, the students can point to factors that need to be addressed with regard to future design of the learning labs. The success of any one learning situation can be assessed based on whether different aspects influence each other and the persons involved in a coherent, constructive manner, or whether there are some aspects that are disruptive (Hodkinson, Biesta, and James 2008). The video material from the learning labs suggests that there is something that seems to inhibit elaborate, conceptual discussions over time. Based on the students' experiences from the learning labs, I will identify some of these aspects.

The learning labs

The case concerns first year mechanical and logistics engineering students at a Norwegian university college, attending organised group-work sessions once a week during the autumn term of 2011. The university college had designed rooms for group work, so-called 'learning labs', equipped with an IWB for each group. The groups were instructed to write their solutions on the IWB in a collaborative manner and hand in the final file electronically via email or a learning platform. The aim was that the groups should complete the tasks within the time they had at their disposal in the learning labs. Given that the students had to hand in their solutions as a proprietary whiteboard file, their options for completing the assignment outside these rooms were limited, and so the students had an incentive to complete the assignments in time and in collaboration with each other, and also to use the IWB during their work. This was thought to yield two benefits: first, that the students' spare time workload was not increased with yet another assignment; and secondly, that the groups had to meet face to face to complete the assignments. The latter relates to a concern that ordinary group assignments would be solved in an unintended cooperative manner, i.e. that the students would divide the various tasks between them and work separately. By constraining the students to work face to face, the hope was that they would be encouraged to work *as* a group, not just *in* a group.

The weekly exercises consisted of three or four physics problems, which were strongly linked to the curriculum. Often the physics problems were linked to parts of the curriculum that the teacher had lectured about recently. The groups' solutions were graded for each exercise, and the sum of these exercise grades counted for 20% of the students' final grade in the physics course.

About 100 students participated in these group-work sessions. Owing to the number of students and limited space, 11 groups with five to six students each were present at each of the two sessions that were arranged each week. The students were themselves responsible for forming groups at the beginning of the term. Two teachers were present at the exercise sessions, and were available for supervision upon request. One of these was the lecturer responsible for the physics course. Both were experienced teachers with a keen interest in trying out new ways of teaching physics.

Research methods

In this case study one student group was selected on the basis that it seemed representative of the student mass with regard to age and level of engagement in the exercises. The latter criterion implied that the group members should show a certain engagement with the exercises and collaboration. The group consisted of five male students: Henry, Terry, Andrew, Eric and Toby, all in their twenties. Originally, there was a female student in this group, but she left before any data from the group-work sessions had been recorded. Given that fewer than 10% of the students in the physics class were women, the selected group can still be seen as representative for the whole class with regard to gender distribution.

This study is based on three sources of data: video recordings, field observation and focus group interview. The field observations complemented the bulk of the data, which were collected by means of video recording of the student group during eight of the 11 exercise sessions of the term. The use of video over the course of a term made it possible to look for patterns of interaction or how the interaction developed for this specific group. Field observations were used as background information to assess whether what we observed in the video material was representative of what happened in the other groups. The focus group interview made it possible to investigate the possible reasons for what we observed in the video material. In this paper, the interview with the group was the main source of data.

The exercise sessions were followed closely throughout the term. The researcher was in contact with the student groups as well as the teachers, and gained general knowledge about the learning labs with regard to the different choices that were made, the restrictions that emerged, the teachers' immediate impression of how the students fared and how the exercises seemed to be received by the students.

The entire video material (23 hours) was analysed qualitatively by means of the software Transana™, using an inductive approach, which resembles the constant comparative method (Merriam 1998). A selection was made from the video material, where clips that consisted of direct interaction with the IWB were detected for further analysis. Two researchers viewed some of the clips separately to ensure reliability of the interpretations and findings.

Immediately after the last exercise session, the focus group interview was conducted. The students were interviewed mainly about their experiences in the learning labs. A focus group interview is potentially an effective way of obtaining the students' collective experiences from the learning labs (Robson 2002). In addition, owing to the openness of the focus group interview, the students may emphasise aspects that are not evident in the other data sources. As such, a focus group interview can provide a suitable supplement to the other data sources (Johannessen, Tufte, and Christoffersen 2004). After transcription of the interview, the different sections were coded, using codes that as much as possible reflected what was actually being said. The transcription was read and reread several times, which resulted in some adjustments to the codes. Furthermore, the codes were clustered into aspects. As an example, the following utterance from Andrew:

> Andrew: But often, the answer … Like, you get an explanation, but often when someone has asked me, or when I have asked others, then I've given a very half-assed explanation. And likewise when I've asked others as well. The explanation I've received has been very 'Chop-chop-chop-chop! Next problem'. You want to go on, right? You notice it a lot in the explanations you get.

underwent the following coding and topicalisation:

Code	Aspect	New code	New aspect
Explaining to each other	Time	Helping each other	Group dynamics

During the initial stages of the analysis, it could seem as though Andrew and the other students were focused mainly on time pressure during the group work. However, later iterations suggested that this time pressure might have been a social construct within the group due to the patterns of dynamics that had developed. This descriptive analysis (Wibeck 2011) resulted in aspects that do not represent the entire interview, but help to describe what the students find important, and furthermore how these aspects can relate to the evolvement of a joint workspace in the video material.

Results

Before presenting the aspects that emerged from the interview, I present findings obtained from the video recordings of the group. These are important as they shed additional light on the emergence of joint workspace. In the video material I found that the emergence of exploratory processes and especially explanatory processes dropped off during the term. Less time was used working on the IWB, and the students used it more for pure insertion and clarifying processes. This could be attributed to the demise of a temporary novelty effect of the presence and use of the IWB as a fancy new technological tool. But the video material and the field observation suggest that this was not necessarily the only reason why the students tended to spend more time in silence over their own notes. A further review of the video material indicates that the interactions and discussions between the students also changed in both character and content during the course of the term. Roughly, it is early on in the term that we find the more animated and conceptual discussions, or occurrences which resemble the epistemological framing termed 'discussing'

(Scherr and Hammer 2009). It is also here that we find the bulk of occurrences termed exploratory and explanatory processes. In the latter half of the video material, the occurrences of elaborate discussions between the students are more scarce and the content of the discussions more often deals with clarifying physical units or other basic topics. Although a necessary part of the collective meaning-making process, discussions of units can be perceived as superficial compared with the more in-depth discussions and inquiries that characterised the problem solving at the start of the term. On the whole, we can say that the occurrences termed joint workspace decreased during the term. The potential reasons for this are explored using the interview data.

The analysis of the interview resulted in two main aspects: internal and external aspects. The aspects that are termed internal refer to the group members' interaction or other issues that seem to have their origin within the learning labs. The external aspects can be perceived as organisational, i.e. referring to the choices and boundaries that the teacher had made.

Internal aspects

Common and personal goals

In the interview, the students express that a common goal is to get good grades on the exercises. Grades seem to be a motivational aspect in themselves, but Henry expresses that the grades are also important for further studies and career. The students also emphasise the written feedback provided by the teacher as an incentive to do well on the exercises. The teacher humorously compared the students' solutions to different popular movies, and the students appreciate what they recognise as an effort from the teacher, as opposed to merely marking the solution 'approved'. One example of this written feedback is: 'If this solution had been a Star Wars movie, it would definitely have been episode IV, which is chemically free from any ridiculously annoying characters'.

In addition, the students state that they want to perform better than certain other groups they are working along. Toby expresses that his personal goal is to learn as much as possible during the exercise sessions, by being an active participant. He also says that he becomes a little competitive when it comes to being the first to complete the problems. Henry and Andrew, to some extent, also make the same point. As Henry says: 'Everyone wants to show off their clever side'.

Another common goal is to get the exercises completed on time. This particular group had a timetable that did not allow them to start up before the scheduled time, as opposed to several other groups that could start early and consequently finish early. In addition, the group did not always manage to complete the exercises within time. This was a cause for some frustration in the group. However, the students also acknowledge that they did not utilise their time well, especially Terry, who stresses that they could have used the time more effectively, for instance, by reducing off-topic conversations. The video material supports Terry's view. The students tended to spend some time in each exercise session catching up on some off-topic issues. Although this could be said to strengthen the social bonding between the group members, the obvious consequence is that there was less time left to complete the physics problems.

Group dynamics

When asked about their overall impression of working in a group as opposed to working alone, the students talk about pros and cons between the two. Eric sums it up:

Eric:	I think that if it's a difficult problem, it's good to have many people thinking about it, who manage to provide other approaches than your own […] But when the problems are easy, I just think it is … [I] could have done it more effectively by myself.

Terry expresses that he does not work as fast as some of the others, and that his strategy has been to skip some problems and move ahead to problems that the others have not reached yet. Consequently, he was not as active in the collective problem solving, which according to him was centred around Henry and Toby, together with Andrew. Both Andrew and Terry express some frustration over the situations when the others apparently seemed to be well up to speed on the problem solving, but they themselves were not. Terry acknowledges that he (and others) could have been better at asking for help or support from the others, that it was not just a matter of offering help, but also seeking assistance. However, Andrew expresses a concern on this matter:

Andrew:	But often, the answer … Like, you get an explanation, but often when someone has asked me, or when I have asked others, then I've given a very half-assed explanation. And likewise when I've asked others as well. The explanation I've received has been very 'Chop-chop-chop-chop! Next problem'. You want to go on, right? You notice it a lot in the explanations you get.
Henry:	We rush.
Andrew:	Mm.
Henry:	Because you know that if … someone explains something to you, then the others will start on the next [problem], and then you'll be stuck behind, so it's like …
Andrew:	And you don't want that.
Henry:	No.

At one point during this discussion, Andrew makes a remark that resembles the finding from the video data:

Andrew:	It worked better in the beginning […] I remember that I, when I was up at the board and … actually, also when you were up at the board, it was … Then we explained while we wrote. Then the others would shut up and watch. But now it's more like, […] one goes up to write, and then there is one person who watches.

The combination of time limits, workload, effectiveness, and common and personal goals seemed to yield some consequences that are in conflict with each other: including the entire group in a collective problem-solving process, or asking for help, is omitted because it steals time from finishing the exercise on time. The easiest solution is to get the problems solved as quickly as possible, by those who are the quickest.

External aspects

External aspects also contributed to the students' experiences and to the decrease in occurrences termed joint workspace. In the following excerpt, Henry and Toby are talking about their general experiences with the physics problems:

Henry: I feel like … Before each exercise we have four lecture hours.
I: Mm.
Henry: And what is taught in the lectures comes on the exercises. There isn't any … from different parts of the curriculum. […] I think it could have been a bit more diverse, you know?
I: He [the teacher] could have included some problems from past curriculum?
Henry: Yes. Then you could, like … brush things up bit by bit.
I: Yes. Mm.
Henry: Now it's like, you learn something and then you move on.
I: Mm.
Henry: And then it's like, you put it behind you.

[…]
Toby: Another thing is … like, if you learn something new on Wednesday morning … then we have physics in the two first hours … and then, if you learn something completely new, for example like impulse or some other things that you've never dealt with before … And then you get a huge task about that on the exercise session. Then you sit there and look frenetically through your notes to find what it is, and then 'Yeah, what was meant by this', and then 'No, I don't remember', and then … it becomes sort of guesswork because you haven't … at least for me … full control over it yet.

The exercises dealt with topics that the teacher had lectured about recently, potentially even earlier the same day as the exercise sessions. This *close temporal proximity* between the lectures and the exercises can partly help to explain the decline in joint workspace, as found in the video material. The decreasing occurrences of elaborate, conceptual discussions could be caused by the fact that the students were not familiar with concepts necessary for discussing and solving the physics problems.

Some positive external aspects also emerged from the interview. The students' overall impression of the learning labs is positive and they talk about the learning lab and the activity there as the highlight of the week. In general, the students speak enthusiastically of the lecturer, both in the learning lab and in the lectures. He seems to influence the students' positive experiences with the learning labs. Furthermore, the students perceive the IWB as contributing to their overall positive impression of the learning labs. The students do seem to think of it as fun and future oriented. They also talk about the ease with which they can hand in their solutions, and of the advantages of being able to store their solutions for later retrieval (e.g. for exam preparation). Andrew, however, emphasises that during the sessions, 'There's nothing special about it [the IWB] that makes it: "Ooh, like, we learn much more". No, it's just fun!' However, they do recognise the ability of the IWB to make the problem solving visible and accessible to the whole group. Terry suggests that this visibility to a certain extent counterweights the fact that he was not always up to speed with the collective problem-solving process.

Structure

The students emphasise a structured, mandatory time and place being set up for the groups to complete the exercises as a positive aspect:

> Toby: That's the thing, that, the physics sessions are very structured, because you have … three hours where we are to complete the exercise. Compared to math and everything else it is … we must do that in our spare time. This is more structured and it's easier to focus on exactly [inaudible], because we are there, we are all there, around a table, and we do it.

This utterance from Toby is somewhat typical: the students tend to compare the learning lab to other exercise situations they have experienced in other courses, either contemporary or past. When talking about the learning labs in general, the students often compare them to voluntary exercise classes led by a teacher assistant, which they describe as somewhat unengaging:

> Henry: I don't feel that those Smartboard-classes in physics … I don't feel that they are teacher assistant classes.
>
> […]
> Henry: I feel, like … You're there to learn. There isn't any, like, just working through some problems, like in the other courses. This is more, this is scheduled from the start, and …
>
> […]
> I: Ok, so the fact that it's organised …
> Henry: Yes, absolutely.
> Toby: That's good.
> […]
> Henry: If it isn't, people so easily go 'Nah, this …'
> Terry: 'Haven't got time today'.
> Henry: 'Nah. I'll leave early'.

Looking at the students' comparison to the more informal teacher assistant classes in other courses, we see that at least two factors are missing in the teacher assistant classes. First, the teacher assistant classes are not compulsory, which means that the students can choose to attend these classes or they can choose to solve the exercises for themselves another time. Secondly, these teacher assistants are typically second or third year engineering students. When the students compare the learning labs led by the teacher and the teacher assistant classes, they may perceive the teacher as the more authoritative and knowledgeable person.

A close link between lectures and exercises

In addition to structure, the students seem to appreciate that there was a close link between the lectures and the exercise sessions, as Terry elaborates:

> Terry: Every time he [the teacher] mentions … Uh, brings us a bit into … a problem in the lectures, I think it's a bit more cool to start on the problem [in the exercise sessions], 'Oh yes, it was that problem! OK, but this we have already started on in the lecture' […] So every time he [the teacher]

has mentioned a problem that will be on the upcoming exercise […] in the preceding lectures, it is an advantage.

Henry: I've noticed in the lectures, if he [the teacher] says 'This here may be essential on the exercise', then you see all go, like from there, to THERE!

In the last sentence Henry enhances his verbal utterance by changing from sitting relaxed on the chair to sitting straight up on the edge of the chair, to illustrate the students' sudden heightened interest in the lectures. As Terry notes, the teacher linked the content of the lecture and the exercises closely together. In the video material there are numerous examples of the students making direct or more subtle references to the lectures. So while the students perceive the close link between the lectures and the exercises as a positive aspect of the learning labs, they also recognise an unfortunate effect of this, which is identified as a (too) close temporal proximity between them.

Discussion

We see in the video material a notable change in the interaction between the students during the term. While acknowledging that this interactional change could be due to a novelty effect of the learning lab and the use of the IWB, the students' own experiences help to identify aspects that may explain additional reasons for this change.

In the interview, the students pointed to aspects, both positive and negative, that are important in order to further develop the learning labs as an approach to learning in engineering education. How these aspects could help to explain the evolvement of occurrences termed joint workspace is now discussed.

When looking at the external aspects, the students describe a group-work scheme, which in principle is more structured than teacher assistant classes in other courses. Furthermore, they perceive the close link between the lectures and the exercise sessions as a positive aspect. The teacher also plays a role in this. He is the one who orchestrates both the lectures and the exercise sessions, and is also present at both events. He is also the one who grades and gives written feedback on the students' solutions, contrary to ordinary practice, where a teacher assistant (typically a second or third year engineering student) is used as a tutor in exercise sessions.

Scherr and Hammer (2009) make a connection between what they term 'green behaviour cluster' (discussion framing) and reasoning about causal mechanisms, as described by Russ et al. (2008). Scherr and Hammer (2009) conclude that reasoning about causal mechanisms correlates with animated speech and gestures, and they suggest that gesturing is a necessary part of making sense of mechanisms, as well as being a non-verbal way of communicating with others. However, Scherr and Hammer note that animated discussions are not always appropriate throughout the entire problem-solving process; students need to spend some time gathering their own thoughts (i.e. completing the worksheet) before they start discussing. In this case, however, the students seem to reach a 'discussing' framing to a decreasing degree. Toby said that problem solving was reduced to guesswork and attention to rudimentary details. He connected this to a close temporal proximity between the lectures and the exercises. This is in accordance with observations made in the video material of the group: towards the end of the term, the students seemed to spend more time on their own than in discussions with each other. The discussions that did arise tended to be more about definitions of units and concepts, rather than conceptual discussions. In this sense, the students rarely dealt with the physics problems 'in terms of reaching a solution' (Berge and Danielsson 2013), which is characterised by reducing, expanding and contextualising the problems.

However, this close temporal proximity existed from the very beginning of the term. The question is, then, why are there elaborate discussions at all? We can partly explain this by the fact that in the first half of the term, the students were working on physics problems dealing with classical, linear mechanics; a topic that at least in principle should be familiar to the students. In order to begin engineering studies, a student needs to have learned some basic physics and mathematics in advance, equivalent to the curriculum from upper secondary school. Later on in the term they had to solve problems dealing with rotational dynamics, fluid mechanics and thermodynamics, and these are topics that are not part of, or that are treated more superficially in the upper secondary curriculum. As a result, the students may very well take a more instrumental problem-solving approach (Bang 2001), characterised by concerns over rudimentary details, which may detract attention from the 'real' issue of the physics problem in question.

When looking at the internal aspects, the students describe a group-work situation, which is characterised by conflicting common and personal goals, resulting in a group-work dynamics that does not always include the entire group in the problem-solving process. The students' primary attention on finishing the exercises on time seems to indicate that the students felt that there were limited opportunities for giving or receiving any thorough explanations to the physics problems. Henry, in particular, was concerned that he could not take the time to thoroughly help others, as he would then risk falling behind. This could be related to the informal intragroup competition that some of the students mentioned. Competition, or a competitive situation, can be described as 'individuals [working] against each other to achieve a goal that only one or a few can attain' (Johnson and Johnson 1989, 4). However, in this case every group could 'win' in principle. The teacher did not grade the groups along a normal curve, and therefore a grade A was attainable for all of the groups. Furthermore, the video material shows that on some occasions, students belonging to different groups consulted each other. In a strictly competitive situation one would expect the students to withhold information or newly gained insights from other groups, if the goal really was to obtain high grades at the expense of others. If we instead turn our focus to the group in question here, and interpret the solution and understanding of the physics problems within the given time limit as a goal that only a few could attain, the picture changes. In this context, wasting time on giving other group members elaborate explanations of things that you already understand is clearly a hindrance for you in reaching your goal. As the groups were assessed solely based on the solutions they handed in, the students were not interdependent on each other in completing the exercises (Blumenfeld et al. 1996). A possible consequence of this is that the solution and understanding of the solution were left to those who were the quickest. In this perspective, the challenge of establishing a joint workspace can be attributed to what the students perceive as effective use of a limited time resource. In addition, the students' utilisation of the available time must be taken into consideration, as emphasised by Terry and also observed in the video material.

The close temporal proximity between lectures and exercise sessions, along with an informal competition that emerged within the group, are aspects that together may contribute to the decrease of occurrences which constitute a joint workspace. The lack of joint workspace can be seen as contradictory to the whole idea of group work, where interaction and elaborate discussions play a key role in the meaning-making process for each member of the group.

One major limitation of this case study is that it involved only one student group. Furthermore, this was an all-male group, which in this particular context can be seen as representative but in a broader perspective calls into question the validity of the findings with regard to gender distribution. The students in this case study seemed to appreciate that the learning labs were a structured, compulsory part of the physics course. The IWB was a tool for the students to achieve their goal, namely high grades. Other studies suggest that students prefer more informal, non-obligatory discussions as opposed to organised group work (Bungum, Hauge, and Rødseth 2012). Therefore, the findings from this study should be investigated further, not only with regard to gender, but also with regard to educational and institutional context.

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Paper C

Mellingsæter, M.S. (submitted). On the right track: dynamics of teacher interventions during physics group work. Paper submitted to The International Journal of STEM Education.

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