Master's Thesis

The devil is in the detail

A study on quantifying socially shared metacognitive regulation of learning in face-to-face group work

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AALBORG UNIVERSITY
STUDENT REPORT

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Summary

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In this thesis we study and identify processes of socially shared metacognitive regulation within collaborative group work, with the intent of attaining knowledge of how such processes can be measured and quantified, and in turn be utilized with learning analytics to afford better collaboration within the group. The study started with a broad focus on understanding the practice of collaborating and was, through an extensive literature, narrowed down to focusing on socially shared regulation of learning, and from then further down do socially shared metacognitive regulation which is part of the former.

To study the processes to be quantified, we have coded, transcribed and analysed four hours of video recordings of an international group of five students working on their semester project under the educational approach of problem-based learning. In order to analyse the video data, we utilised different methods of inductive analysis and selection of the materiel. To narrow down a large corpus of video data, macro-level coding was employed to assess which parts of the recordings were relevant to us. From the coded clips we then picked three that we found to be representative of different regulatory processes. Two of the chosen clips were transcribed textually with a focus on two separate modalities of interaction, namely bodily and verbal interaction. This transcription was carried out using parts of the Jeffersonian notation system, which was appropriated to fit our research goal. Lastly, a small planning sequence was transcribed using a graphical transcript in order to properly represent the visual aspects of interaction.

During the analysis of the recording which was conducted, it became clear that the identified regulatory processes could be looked at from different levels of abstraction. At a macro-level we were able to observe the overall processes of socially shared metacognitive regulation, planning, monitoring and evaluation. At a meso-level we identified further mechanisms within planning, such as negotiating the purpose and nature of tasks. When looking at a micro-level, we further discussed the meso-level mechanisms through different modalities of interaction: verbal and nonverbal language, eye gaze and bodily gestures.

This analysis allowed us to infer that insights gathered on different levels of metacognitive regulation of learning can be used for assessment of the quality of collaboration. We further discuss how our observations related to modalities of interactions could be used for creation of indicators of successful socially shared metacognitive regulation (SSMR). The main contribution of this thesis comes with the reflections related to the application of multimodal learning analytics to measure aspects of SSMR. Our work describes opportunities and challenges that come both from using data from single modalities and from combining multimodal datasets.

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Introduction

Background information

The research described in this thesis was conducted as a part of the Information Studies program at Aalborg University. We will start from shortly providing some basic information on problem-based learning (PBL), the educational model used by Aalborg University, as it is our belief that giving a description of the context in which study was conducted is valuable for understanding how our educational background inspired and directed our research. PBL is a learning approach that has its roots in constructivist learning, the learning theory that largely changed the way that learning was perceived, and that started the view of learners as active constructors of their own learning. Constructivism follows a few basic principles: *active learning, learning-by-doing, scaffolded learning* and *collaborative learning* (Harasim, 2012). All of them are very much present within problem-based learning approach implemented at AAU. Students work in groups over the course of three to four months to collaboratively solve real-life problems that they pick for themselves within a frame defined by the module requirements. They are largely responsible for their own work process, they plan and manage all the steps of the project completion, with teachers providing expertise and offering advice when needed, guiding students until they are ready to tackle the tasks on their own (scaffolding).

Our current research is a continuation of the work we performed during our internship at e-Learning Lab (eLL), a research group that belongs to the Department of Communication at Aalborg University. Information studies, the study program that the internship was part of, aims to "educate graduates who are capable of adapting and developing ICT solutions that have been considered in relation to a wide spectrum of solutions and variables, including their adaptation to users and the organisational contexts into which they will enter" ("Regulations and curriculum for the master's programme in information technology," 2016, p. 4). In our case the ICT aspect that we got particularly interested in was related to learning analytics, a concept that has been gaining more and more popularity in educational research (Siemens, 2012). In this work we will view learning analytics (LA) the way it was defined during the first Learning Analytics and Knowledge conference as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" (Siemens, 2010). We will now shortly describe our internship study, to help the reader understand what the research conducted as a part of this thesis was built upon.

Previous work

LA, although a very promising field, is also a fairly new one (Ferguson, 2012) and is thus facing many challenges. We got inspiration from a thought paper written by Rebecca Ferguson, one of the key researchers in the area of LA, and a chair at Learning Analytics & Knowledge conference. In 2012 Ferguson argued in her article that future research in the field of LA needs to face or acknowledge several challenges. Although several years have passed and some of the challenges have since been addressed by LA community, we claim that they do remain relevant nowadays. What follows is a short outline of those issues, a more detailed description can be found in section 1.4.2. One of them would be giving more attention to the perspective of the learners. She pointed out that the data collected on students is rarely given back to them, with the access being restricted to the teachers or faculty. Moreover, existing implementations of LA often do not take into consideration learning theories, or at least fail to properly acknowledge the theoretical bases. Ferguson claimed that the field should attempt to make the connections to learning theories more explicit. Finally, a shift has to be made from focusing on data collected in LMS to other environments that student actually use in their learning, as LMS systems are frequently used just for grades checking and downloading of the learning materials, and thus reflect only small part of students' learning process (Ferguson, 2012; Kruse & Pongsajapan, 2012; Siemens, 2012; Thomsen, Sørensen, & Ryberg, 2016).

Taking all of those challenges into considerations, we decided to attempt to answer the question of how learning analytics can be used by students to improve ICT supported collaboration within problem-based learning model (Kilińska, Kobbelgaard, & Ryberg, 2016)[1]. Specifically, the study focused on collaborative writing practices within Google Docs, attempting to build an understanding of how data collected in Google Docs, a service found to be useful for group work (Zhou, Simpson, & Domizi, 2012), that is already often utilised by students, and the adoption of which is growing (McNely, Gestwicki, Hill, Parli-Horne, & Johnson, 2012; Thomsen et al., 2016), could be turned into LA features to improve the quality of collaborative work of students. Coming from the PBL background, we see students as active constructors of their own knowledge, and thus we fully agreed with Ferguson (2012) about the importance of granting learners access to their own data - the data they can themselves reflect upon and use how they see fit, to shape their collaborative practices. Our PBL mindset also influenced the decision to focus rather on collaborative than individual learning. The field of learning analytics has been so far focused primarily on an individual, or individuals within a group, but the last two or three years have seen

[1] See Appendix 1

an emergence of research aimed to gained insights into collaborative learning (Wise, n.d.). Even though the focus of our research changed to some extent when working on thesis, the collaborative practices remained to be the central element of our study.

The data collection consisted of two co-design workshops that we conducted with students from AAU. In line with the practices of eLL researchers, we used a participatory approach and considered the students to be active co-creators of the design. Our goal was more that of collection of insights, than coming up with a final solution. The analysis of data collected through the workshops revealed several organising themes, each of them related to different aspects of design and use of learning analytics that could support students' collaborative writing practices. The themes included "guidelines for visualisation, importance of the context in which data was collected for interpretation, influence that data can have on collaborative writing practice, and who should be granted access to the analytics" (Kilińska et al., 2016, p.1).

While the insights that emerged through data analysis were interesting, they were also more general than we had expected, an issue that we attributed to unsatisfactory research design. During the workshops, students often had problems to differentiate between new functionalities of the software, and data features. The data they were interested in seeing seemed to be mainly focused on monitoring the work done by individuals, and ensuring that everyone puts in similar effort by making comparisons of the amount of changes done in the text. The workshop failed to elicit more complex reflection and consideration on collaborative practices. Even though we provided materials explaining different types of data and charts, students had difficulties imagining whether and how information they need could be represented. Due to unsatisfactory nature of insights and designs gathered during the data collection, we aimed to modify the participatory workshops that were to be conducted during the thesis research. Originally, during our thesis work we wished to keep the research question that guided our research during internship, while improving the research design:

How can Learning Analytics be used by students to improve ICT supported collaboration within problem based learning model?

How can data collected from Google Docs facilitate group collaboration?

Which LA features are considered, by students, to be helpful in improving the quality of their collaborative work?

How do students think that the data should be visualized?

Current work

In order to address the challenges that we encountered during our internship work, we conducted another literature review, trying to find how to frame the collaborative learning process in a way that would make it possible to apply learning analytics to support collaboration. Throughout our research process we honed the research question twice, as a result of grounding the study in another theory, and analysis of data. While the overall problem that guided our efforts was that of whether and what type of data collected on groups' collaborative activities could be used to facilitate collaboration, we decided to focus only on a certain dimension of collaboration, which was metacognitive aspects of the socially shared regulation of learning (SSRL), "the processes by which multiple others regulate their collective activity" (Hadwin & Oshige, 2011, p. 253).

Problem statement

The process of narrowing down the research focus will be described later throughout the thesis, but its final product is the following problem statement:

How can metacognitive regulatory processes within face-to-face collaborative group work be measured and quantified, allowing for learning analytics to be employed to facilitate collaboration?

> How can assessment of collaboration be supported by observing socially shared metacognitive regulation?
>
> What data collected on socially shared metacognitive regulation of learning could support collective regulation of learning?

Reading guide

Adjustments of the problem statement are not uncommon in research, but especially in our case we find that the changes that occurred clearly mark the significant turns of the study. We therefore decided that the best way to describe our process is to organise this thesis through use of chapters dedicated to different problem statements. What follows is a short reading guide explaining the structure of the report.

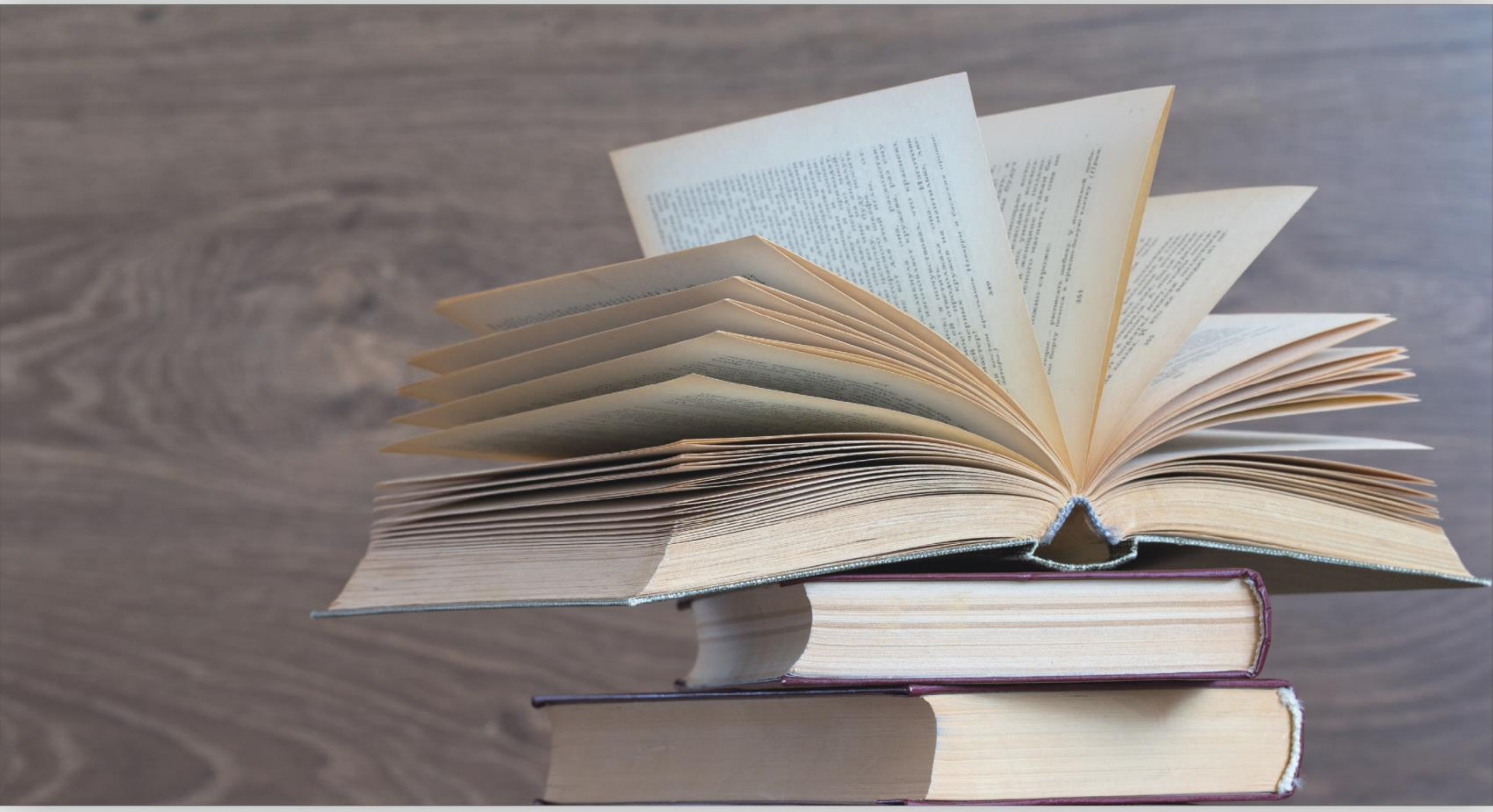
The first chapter shows our progress from the first problem statement (adapted from the internship study) onto the second one. It elaborates on the literature review that we conducted with an aim of finding a theoretical framework that would help us frame our investigation. We describe our search for a field that focuses on learning in relation to technology, and that could be used to help us view collaboration in a way that would make it possible to be described with use of learning analytics - quantified. What follows is a description of the field of computer-supported collaborative learning, a concept of socially-shared regulation of learning, and overview of the current state of the research on learning analytics relevant to our study. The chapter ends with an explanation of how our literature review influenced the modification of the problem statement.

The second chapter elaborates on the analysis of the video recordings of the group collaboration. In this, we describe the 3-stage process of transcription that we decided to utilise in our study and further analysis. The adjustments of the problem statement made in this phase was a result of the first stages of the analysis of the data - as the complexity of the collaborative processes became evident, we realised that we will not be able to provide a sufficient answer the problem statement we had at that time. The elaboration of the changes made conclude the chapter.

The third and final chapter includes the description and the discussion of the obtained results and recommendations for the future research. We end the report with reflections on our research process.

Chapter

1



Literature Review

During this chapter, we will discuss the different theory that was uncovered during the literature review conducted for the project. Literature review itself was based on the initial problem statement was conducted inductively in order to narrow our scope towards the knowledge needed to continue onto our analysis. In the end, the knowledge gained through the literature review helped us in the reiteration of our problem statement, and thereby guided our research towards understanding collaboration rather than explicitly designing learning analytics features.

Our literature review was conducted in three iterations, each of which in itself narrowed our scope. Throughout the literature review, different methods were used in order to find sources that are suited for the project. First and foremost, the literature involved searching in academic databases with sets of predefined search terms that we collectively decided upon. Terms that were used include: “Collaboration”, “measure”, “learning analytics” and so on, each used separately and as search algorithms. Our second method, was to look at journals and find authors that were doing research that could contribute to our project, whenever an interesting researcher was discovered, we would read through the articles and further look into the sources listed. Finally, the last way of finding articles for our literature repository was through the network that we had built up at e-Learning Lab during our internship.

In the next section we will describe the different theories and fields of inquiry that were researched throughout the literature review. At the end of this section, we have added networked learning as additional theory. This is because, although we did not use networked learning explicitly, it helped guide our ontological understanding of collaboration, specifically in regards to the complexity of such.

1.1 History of CSCL

The research described in this thesis was conducted within the field of Computer-Supported Collaborative Learning (CSCL), “a field of study centrally concerned with meaning and the practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artefacts“ (Koschmann, 2002, p. 20). Another definition, similar, but emphasising the importance of learning within CSCL was proposed over a decade ago by Stahl, Korshmann & Suthers (2006), who suggested looking at CSCL as an “emerging branch of the learning sciences concerned with studying how people can learn together with the help of computers” (p. 409). As one may infer from this description, CSCL is a relatively new field, with its origins being traced to a workshop held in Maratea in 1989, first international and public event that used the term “Computer-Supported Collaborative Learning” in its title.

Before continuing with description of field of CSCL, we will shortly discuss the evolution that use of computers in education has undergone over the course of the last 50 years. In the times preceding the birth of CSCL, introduction of computers into classroom was looked upon with certain criticism (Stahl et al., 2006). Computers were considered to be promoting "inhumane form of training" (p. 2) and seen as essentially anti-social. The beginning of CSCL can be associated with an attempt to oppose this view of technology - this field of study originated as a reaction to software that treated students as isolated individuals. In its understanding of learning and technology CSCL stands out from the ways that technology was used in education. The difference between approaches was so extensive that when analysing their historical sequence, Koschmann (1996) uses the term "paradigm shifts". According to Koschmann in its relatively short history the field of instructional technology went through several paradigm shifts, namely: Computer-Assisted Instruction (CAI), Intelligent Tutoring Systems (ITS), Logo-as-Latin, and CSCL. This sequence of approaches reflects the order in which the main theories of learning came to life.

CAI is based on the principles set by behaviourist theories of learning. Behaviourism follows the objectivist epistemology, and thus sees learning as a passive process in which students receive and assimilate knowledge from others (Harasim, 2012, p. 7). The teacher is supposed to gather the knowledge and then find a way to efficiently pass it to students, train them for new behaviour (Harasim, 2012). CAI tries to answer the question of how knowledge can be successfully transferred by creating applications that "utilize a strategy of identifying a specific set of learning goals, decomposing these goals into a set of simpler component tasks, and, finally, developing a sequence of activities designed to eventually lead to the achievement of the original learning objectives" (Koschmann, 1996, p. 6).

After CAI came Intelligent Tutoring Systems which were strongly influenced by cognitive learning theory. Unlike behaviourists who believe that "what is in the mind is not accessible for study, and hence irrelevant and should not be considered in research" (Harasim, 2012, p. 32), cognitivists attempt to shed some light onto the processes of the mind by filling in the gap between stimulus and response. ITSs used mental models to create more efficient ways of transferring knowledge to students. This was based on a belief that in order to create systems capable of supporting learning, it is necessary to understand how knowledge is represented and processed (Stahl, Koschmann, & Suthers, 2014). Koschmann points out that the role of technology does not differ significantly between CAI and ITS paradigms, as he puts it "the differences are more in degree than in kind" (Koschmann, 1996, p. 8). The software designed in both paradigms works in a similar way - presents learners with problems and provides feedback. ITSs are more interactive and consider a wider set of skills. In the end both of those approaches take on an objectivist epistemological stance. They see knowledge as given, consider teacher to be the final authority (Schommer, 1990, as cited in Koschmann, 1996), and view teaching as a process of delivery.

The third approach listed by Koschmann (1996) had its roots in constructivist learning theories that emerged in Europe in the 1970s (Harasim, 2012). Constructivist learning theories assumed a different epistemological stance than the learning theories that came before. According to constructivists, learners build their own understanding or knowledge based on the interaction between what they already believe and new activities or ideas that they encounter (Ultanir, 2012). Learning is then making meaning by doing, while teaching is facilitation of that process (Harasim, 2012). That interpretation of the nature of learning was reflected in teaching of the Logo programming language in the 1980s. The assumption was that programming was an activity that allowed the learner to construct their own knowledge, and fostered development of general learning and problem-solving skills (Koschmann, 1996).

CSCL is the fourth and a continuously relevant approach to using computers in education, one that is typically placed outside of the accepted canon of theories of learning, which consists of behaviourism, cognitivism and constructivism (Jones, 2015). CSCL offers an alternative view of learning that is not linked to a specific learning theory, with research in the field being informed by several learning theories. This approach for usage of technology in education is strongly motivated by social constructivism, a perspective based on the work of Lev Vygotsky. Social constructivism, unlike cognitive constructivism, emphasised “the social essence of knowledge construction” (Harasim, 2012, p. 61). CSCL follows that tradition and sees learning as meaning negotiation that is “carried out in the social world rather than in individuals’ heads” (Stahl et al., 2006, p. 489). In this work we will follow the example set by Jones (2015), who places CSCL within social learning theories. He explains this theoretical choice by pointing out to the strong ties that CSCL has with the concept of collaboration, a process that is a central focus of this work. CSCL assumes a situated view of learning, one that is “located in the world of everyday affairs” (Stahl et al., 2014, p. 489), drawing from such socially oriented learning theories like Lave and Wenger’s communities of practice theory (Stahl & Hesse, 2009) that helped understand collaborative learning in terms of social practices.

1.2 Collaborative learning

For a long time, learning was seen as purely an individual phenomenon. Whether it was understood in a behaviourist way as “performing new behavior”, or through the cognitivist eyes as “processing of information” (Harasim, 2012, p. 14), the change that learning brought happened to individuals (Koschmann, 2002, as cited in Stahl et al., 2014). The interest in group learning, although relatively new, does precede CSCL by many years, as pointed out by Stahl et al. (2014) - cooperative learning began being a focus of research in the 1960, and small groups were investigated even before that.

The difference between CSCL and those earlier investigations, can be described by making a distinction between cooperation and collaboration. *Encyclopedia of Sciences of Learning* (Seel, 2012) defines collaborative learning as “a process by which students interact in dyads or small groups of no more than six members with intent to solicit and respect the abilities and contributions of individual members” (p. 631). This definition does not however seem to consider the criterion of division of labour mentioned by Dillenbourg (1999): “collaboration and cooperation are sometimes used as synonymous terms, while other scholars use these terms distinctively according the degree of division of labour. In cooperation, partners split the work, solve sub-tasks individually and then assemble the partial results into the final output. In collaboration, partners do the work 'together'” (p. 8). The definition provided by Steel not only does not provide a clear distinction between collaboration and cooperation, but also limits the size of the group to maximum of six members. This limitation does not seem to be a universal characteristic describing collaborative learning, as Dillenbourg points out that while some empirical research follows small groups of students, CSCL is sometimes concerned with learning that occurs in groups as big as 40 members. Because of those differences in understanding, in this work we will apply a broader definition that describes collaborative learning as “a *situation* in which *two or more* people *learn* or attempt to learn something *together”* (Dillenbourg, 1999, p. 1). As Dillenbourg points that elements of this definition can be interpreted in different ways, we will further specify that in the specific context of this research we will be concerned with small groups of students working together over a course of several months to solve a problem within PBL setting, mainly in face-to-face settings. In our work, we will make a distinction between cooperation and collaboration, following the distinction made by Dillenbourg. However, it is important to point out that while in collaboration students work together, it does not mean that they do not divide labour. Miyake (1986, as cited in Dillenbourg, Baker, Blaye & O’Malley, 1996) points out that the group member who has more knowledge on a certain topic, may be the one to perform it, while others observe or monitor. The way in which tasks are divided may depend on many factors, such as nature of the task or distribution of knowledge and skills. Dillenbourg et al. explain the issue of labour distribution saying that difference between collaboration and cooperation boils down to not whether the tasks are divided but to how they are divided. Coordination in cooperation is needed only when tasks are put together, but it plays much bigger role in collaboration. Roschelle & Teasley (1995, as cited in Dillenbourg et al., 1996, p. 190) view collaboration as "...a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem". When analysing group processes, we followed that distinction, considering their activity collaborative, if it possessed abovementioned characteristics, such as frequent coordination and monitoring, even if the members decided to divide the problem into subtasks.

1.2.1 From socio-cognitivism to shared cognition

Even after defining the process of collaboration, the question remains: what should the focus be when studying the learning that occurs when groups collaborate? Dillenbourg et al., (1996) argue that for a long time research on group learning was in fact mainly concerned with how individuals act or function in a group setting. This was due to the dominant learning theory being cognitivism, which resulted in the focus in educational research being put on the information processing happening in the head of an individual learner. Later on, the way learning was understood changed, and thus "the group itself has become the unit of analysis and the focus has shifted to more emergent, socially constructed, properties of the interaction" (p. 189). Dillenbourg et al. (1996) claim that a dyad in collaborative learning can be seen as either two independent cognitive systems exchanging messages or as a single cognitive system. These two ways of understanding "serve to anchor the two ends of the theoretical axis. At one end, the unit of analysis is the individual. The goal for research is to understand how one cognitive system is transformed by messages received from another. At the other end of the axis, the unit of analysis is the group. The challenge is to understand how these cognitive systems merge to produce a shared understanding of the problem" (Dillenbourg et al., 1996, p. 191). There are three approaches that can be placed on alongside the axis: socio-cognitive, sociocultural and shared cognition. Socio-cognitive approach is inspired by the theories developed by Jean Piaget, who mainly focused on the individual learner and how he "understands the world, in terms of biological development stages" (Harasim, 2012, p. 61). Some of the researchers continued his work by looking at how social interactions may influence individual development: "Individual cognitive development is seen as the result of a spiral of causality: a given level of individual development allows participation in certain social interactions which produce new individual states which, in turn, make possible more sophisticated social interaction, and so on" (Dillenbourg et al., 1996, p. 191). The studies conducted within this approach often included performing pre- and post-tests in order to investigates whether students perform better in certain academic tasks after individual training vs. working in pairs.

Sociocultural approach was strongly influenced by Lev Vygotsky and his concept of the "zone of proximal development" (1978, as cited in Dillenbourg et al, 1996). Although similarly to socio-cognitive approach, sociocultural one is interested in individual cognition, "the basic unit of analysis is social activity, from which individual mental functioning develops" (Dillenbourg et al., 1996, p. 193). Researchers working within sociocultural perspective, try to determine the causal relationship that occurs between social interaction and cognitive development of an individual. From methodological standpoint, this approach typically includes employment of detailed analyses of processes that constitute social interaction. In contrast, socio-cognitivism tends to go towards usage of experiments, viewing collaboration as a black box, and putting emphasis on the outcomes of experimental manipulation of independent variables, such as size or composition of a group.

The shared cognition approach is concerned with the situated cognition theory (Dillenbourg et al., 1996). As we have already mentioned, CSCL has its roots in situated learning theories, meaning that it puts big emphasis on the role of environment. Environment, understood as both social and physical context, is a crucial aspect of cognitive activity. Researchers working within situated cognition theory give a lot of attention to the social communities in which collaboration is taking place, pointing out that certain communities come with specific culture, including changes in language, social meanings and relationships. Experiments that aim to extend control over environment, tend to overlook the cultural aspect of communities. Shared cognition approaches do not make a clear distinction between social and cognitive aspects. The biggest difference comes from moving away from individual cognition and moving to a group one: "while the previous approaches were concerned with the inter-individual plane, the shared cognition approach focuses on the social plane, where emergent conceptions are analysed as a group product" (Dillenbourg et al., 1996, p. 195). Dillenbourg et al. do emphasise that it is not their goal to imply that any of the viewpoints is the correct one, and that the approach used depends on the goal of the research. In our study, as we work within field of CSCL, we follow the shared cognition perspective. We analyse the interactions between group members, but our focus is not on the individual. Instead, our goal is to see how a group as a whole attempts to regulate their collaborative processes within their specific work context.

1.2.2 Computer support

The strong emphasis that CSCL puts on collaboration means that the field assigns different role to computers in education, if compared to the earlier approaches (Stahl et al., 2014). The purpose of technology shifted from providing instruction and facilitating feedback from the teacher, to influencing learning that happens between students. The main goal of designing technology for classroom is that of creating software to support collaboration, i.e. by enabling communication and productive interaction. But the focus of CSCL exceeds that of simply providing ICT solution, CSCL aims to “create artifacts, activities, and environments that enhance the practices of group meaning making” (Stahl et al., 2014, p. 489). As noted by Stahl et al. even though technology advanced significantly in the recent decades, providing new opportunities and introducing big changes into most spheres of people’s lives, including workplace, leisure time, and education. But even considering those advancements, technology is still not capable to change practice on its own. Even if different practice theories may not agree on the elements that together build a practice (Reckwitz, 2002; Shove, Pantzar, & Watson, 2012), they do acknowledge the significant complexity of practices. Hove et al. (2012) see practice as a combination of three main components, namely: meaning, material, and competences. When attempting to enhance work practices of groups by introducing technology, one needs to keep all those components in mind. The design associated with CSCL is then multifaceted, and may include changes in e.g. curriculum, resources, tools, and even spaces within which the technology is to be used.

The elements that CSCL aims to create do not define practice, but are constituted within them (Stahl et al., 2014) - meaning that artifacts and environments are only artifacts and environments “in the ways they are oriented to and made relevant by participants in directed practice” (p. 490). Groups appropriate - adopt, adapt and incorporate into practice (Dourish, 2003, p. 467) - different artifacts and tools that are available to them. It is then not enough to know what tools and artifacts the group uses to build understanding of group collaborative practices. In order to design technology that could support collaboration, it is first necessary to understand how groups use different artifacts or media to make shared meaning (Stahl et al., 2014). Similarly, as our goal was that of answering the question of whether data collected on students’ collaborative regulatory practices could support those regulatory activities if presented back to students, we first needed to build an understanding of how students regulate their learning while collaboratively solving a problem. This included seeing what artefacts and media were part of those practices and how they were used.

1.3 Self-regulated learning theory

Combination of CSCL and learning analytics, a feat that we were set to achieve in our current study, brings with it a great potential to make the research within CSCL more actionable, meaning that it can accelerate the impact that it has on the practice (Fischer, 2015). However, Wise et al. argue that connection of this fields requires something more than just applying previous findings to the new settings. What is needed is, perhaps, "the generation of previously unexplored kinds of insights into CSCL" (p. 1). A direction that they suggest, which would allow for introduction of LA into CSCL in a way that could ensure high impact and theoretical advances of CSCL, is pursuing a merge between CSCL and a growing research area of self-regulated learning (SRL), that aims to investigate how students regulate their own learning. We followed the proposal made by Wise et al. and included SRL into our literature review. We will now present an overview of the concept of SRL and its place in our research.

Similarly to a group in collaborative learning, which, as we discussed, can be seen as a set of independent cognitive systems that are exchanging messages, or as a single cognitive system (Hadwin & Oshige, 2011), there is not just one way of viewing SRL. While almost all researchers agree that the social aspect should be included in the model of SRL, their opinions tend to differ when the role of the social is to be defined. Where the differences can be found, is where the social is placed on the axis, on one end of which we have social as "peripheral contextual input for individual" (Hadwin & Oshige, 2011, p. 242) and "socially shared process" on the other end (p. 242). What we wanted to focus on in our work is the socio-constructionist side of the axis, namely socially shared regulation of learning (SSRL). We will however shortly discuss also two other perspectives on the social aspect of SRL, namely self-regulation and co-regulation.

1.3.1 Self-regulation

In the section 1.2.1 we described how collaboration can be seen from a socio-cognitive perspective - now we will discuss how this perspective influences the way of viewing SRL. First of all, a socio-cognitive approach to learning is where the term self-regulated learning, understood as "strategic and metacognitive behaviour, motivation, and cognition aimed toward a goal" (p. 243), emerged from. That means that, historically, first understanding of SRL focused largely on an individual, with students being perceived "as self-regulated to the degree that they are metacognitively, motivationally, and behaviourally active participants in their own learning process" (Zimmerman, 1989, p. 329). The term "metacognitive" in this definition refers to "decision-making processes that regulate the selection and the use of various forms of knowledge (p. 329). Bandura (as cited in Zimmerman, 1989) created a model according to which self-regulation consisted of three subprocesses, namely: self-observation, self-judgment, and self-reaction.

1.3.1.1 Self-regulation cycle

Zimmerman (2002) built on Bandura's model and in turn proposed that self-regulatory processes can presented in a form of a cyclical model consisting of three phases: forethought, performance, and self-reflection. As equivalents of those phases, or at least their elements, can be found also in SSRL models, what follows is their short description. Forethought phase occurs even before efforts to learn and consists of two classes of processes: task analysis and self-motivation (Zimmerman, 2002). During task analysis, self-regulated learners perform such activities as goal settings and strategic planning. Self-motivation is based on learners' beliefs related to learning, and can be connected to such aspects like being interested in the topic to be learned, or convictions related to one's abilities. Performance phase includes processes that happen during the behavioural implementation of learning efforts, as Zimmerman calls them.

Similarly, to forethought the processes that happen in the performance phase can be categorised into two classes: self-control and self-observation (Zimmerman, 2002). Self-control of a learner means that he proceeds to deploy strategies or methods that were decided upon during the forethought planning processes. Self-observation, on the other hand "refers to self-recording personal events or self-experimentation to find out the cause of these events" (Zimmerman, 2002, p. 68). This self-experimentation could be, for example, trying out different strategies based on a hypothesis that one of them could work more efficiently in a certain situation. Self-monitoring processes fall into self-observation category and refer to "one's cognitive tracking of personal functioning" (p. 68), which could be a number of mistakes made while solving a task.

Self-reflection is a term Zimmerman (2002) uses to describe two classes of processes that happen after learning effort: self-judgment and self-reaction. Self-evaluation and causal attribution are some of the types that belong to the former. Self-evaluation refers to making comparisons between self-observed performance and some standard, such as performance of others or one's past performance. Causal attribution refers to explanation that a learner makes about the cause of his successes or errors, such as attributing a bad score in a test to picking a wrong strategy. The attribution may have a strong influence on motivation level, e.g. if cause is identified as something that student he has no control over, his motivation may drop. One of the forms of self-reaction mentioned by Zimmerman relates to the feelings of self-satisfaction about one's performance. The increase or drop in self-satisfaction is another factor that can cause change of the motivation level. Self-reaction may also involve defensive or adaptive responses, such as withdrawing to avoid failure, or making adjustments in the learning process in order to improve efficiency.

The cyclical shape of the model means that the previous cycles influence future ones, meaning that self-reflection from the earlier process can used in the forethought of the next cycle (Zimmerman, 2002). It is important to note that the actual use of the model may differ significantly between expert and novice learners, with less experienced students often having a lower-quality of forethought, meaning that they do not set specific goals, while also not engaging in systematic self-monitoring.

1.3.1.2 Social aspect in SRL from socio-cognitive perspective

Having explained the concept of self-regulation in an individual learner, we can now proceed to address the topic of social aspect of SRL. It is important to note that no matter which perspective is considered, the concept of self-regulated learning is based in contemporary views of learning, where learner is not just passive recipient of knowledge. All models of SRL acknowledge the active role of a learner and the social nature of learning. When viewing it from a socio-cognitive perspective, "self-regulated learning is a developing process within the individual, who is assisted by task modelling and feedback provided by others" (Hadwin & Oshige, 2011, p. 244). As it can be seen from this definition, socio-cognitive SRL models focus on an individual, while trying to understand how social context and environment influence development of an internal regulatory processes (Panadero & Järvelä, 2015). SRL, viewed from this perspective, is situation specific - the self-regulatory strategies employed by students can thus differ significantly.

In socio-cognitive research about SRL the unit of analysis is typically individual, with data being collected on such aspects as individual performance, behaviours, self-evaluation, or strategies (Hadwin & Oshige, 2011). When it comes to social aspect, it is sometimes not included at all, but it can also be used as manipulated independent variable. An example of the latter could be the research conducted by Kitsantas, Zimmerman & Cleary (2000) that examined how social feedback and modelling influence acquisition of athletic skills, specifically darth-throwing ones. They manipulated the modelling variable, assigning participants either to a group that witnessed mastery model of dart-throwing or a group that observed a model that gradually improved dart-throwing technique. Then the researchers compared groups in coping and mastery experimental conditions, discovering that being presented with coping model lead to acquiring better dart skills and displaying higher self-efficacy. The study then managed to confirm that social-learning has significant influence on development of SRL in individuals.

1.3.2 Coregulation

Hadwin & Oshige (2011) define coregulation as "a transitional process in a learner's acquisition of self-regulated learning, within which learners and others share a common problem-solving plane, and SRL is gradually appropriated by the individual learner through interactions" (p. 247). In coregulation the regulatory process of a student's learning is then shared between the student and another person, usually a more capable or knowledgeable one. Where in a socio-cognitive perspective the focus is given to the development of self-regulation in an individual with help of external modelling and feedback, "coregulation emphasizes social emergence and sharing of who actually does the regulation through a zone of proximal development" (p. 247). In that sense co-regulation comes from a sociocultural perspective, and is grounded in the work of Lev Vygotsky (as cited in Panadero & Järvelä, 2015). Self-regulation can then be seen as a stage in development, where learners need to share their co-regulatory processes in order to gradually transition towards more self-regulatory practice (Hadwin & Oshige, 2011). Hadwin & Oshige build on an example given by Zimmerman to explain the difference between social aspect as seen from socio-cognitive and sociocultural perspectives. The example follows a child learning to tie the shoelaces with support from his mother. In a sociocognitive perspective mother would be a model to follow and provide feedback on the child's performance. In coregulation mother would take on the regulation of the process of shoelace tying, monitor and evaluate, while asking the child questions that could help him plan, monitor and evaluate as well. Compared to research done from socio-cognitive perspective, sociocultural studies give more attention to social, while not excluding the individual, they focus "on interactions and transitions of power as the unit of analysis, rather than individual cognition, behaviour, motivation, or metacognition" (p. 253). We are not going to describe studies on coregulation in more detail, as the aim of this thesis is not to investigate coregulative processes. However, we deemed it worth mentioning, as coregulation is sometimes described as a less balanced version of collaborative regulation, when compared to socially shared regulation of learning (SSRL) that will be described in the section 1.3.3. In coregulation members regulate activities of other members, while in SSRL they go a step further, with group members jointly regulating the activity they share (Panadero & Järvelä, 2015).

1.3.3 Socially shared regulation of learning

SSRL refers to "the processes by which multiple others regulate their collective activity" (Hadwin & Oshige, 2011, p. 253). Looking at social in regulation from social constructionist perspective, goals and standards are constructed by group as a whole, and the group develops socially shared metacognition. The concept of SSRL is a relatively new thread in the SRL field that came to life with a shift in education inspired by the team work being one of the 21st century competences. The emerging research aiming to combine CSCL and SRL is focusing on the way that groups regulate their collaboration (Panadero & Järvelä, 2015). However, even with SSRL becoming more and more popular in different fields related to education, the empirical evidence on shared regulatory processes is so far minor, if compared to self-regulation and coregulation of learning.

1.3.3.1 Socially shared metacognitive regulation

When compared to research on regulation as seen from socio-cognitive and sociocultural perspectives, studies within SSRL pay less attention to individual or transfer of regulatory skills, but instead the focus is given to collective interactions and negotiation of meaning (Hadwin & Oshige, 2011). From the studies that have been so far conducted in relation to SSRL, it seems that SSRL can be described in terms of two types of shared regulatory activities: "(a) joint cognitive and metacognitive regulatory strategies (e.g., planning) and (b) group motivational efforts and emotion regulation" (Panadero & Järvelä, 2015, p. 12). In our research, we decided to narrow our focus, and further investigate only point (a) - metacognitive regulation that is part of SSRL, and which we will from now on refer to as socially shared metacognitive regulation (SSMR). The term "metacognitive" here means that research within SSMR focuses on regulation of cognition (Iiskala, 2015), or in other words "executive function for regulating cognitive abilities" (Brown et al., 1983; Flavell & Miller, 1998, as cited in Iiskala, 2015, p. 16). In SSMR regulation is built by student reacting and building upon regulative activities of their peers: "although initiated by individual students' metacognitive acts, SSMR is characterised by a subsequent involvement in metacognitive regulation of collaborating peers reciprocally operating on each other's regulative acts. SSMR is directed by a collectively negotiated understanding of group-level activities and demonstrated by students mutually reacting on each other's regulative activities in a spiral-like process" (Backer, Keer, & Valcke, 2015, p. 325). SSMR, as shown by research conducted so far is one of the key ingredients of successful collaborative learning (Backer et al., 2015).

Cognitive regulation is, alongside cognitive knowledge, one of the main metacognitive components (Lai, 2011). Cognitive knowledge concerns such aspects as knowledge about oneself as a learner or knowledge about certain cognitive strategies and when to use them. In our thesis, we will however solely focus on the second component of metacognition, which is cognitive regulation. Lai (2011) in her review on metacognition lists these types of regulation: planning, monitoring, and evaluation. Planning is “identification and selection of appropriate strategies and allocation of resources” (Lai, 2011, p. 7). Socially shared planning will then comprise of such activities as discussing how to solve the problems that learners are facing or designating tasks to specific group members, which can be seen as allocation of human resources (Rogat & Linnenbrink-Garcia, 2011). Monitoring can be understood as attending and reflecting upon task or performance (Lai, 2011). Part of joint monitoring could then be group members evaluating the progress that has been made in relation to what was planned and what else needs to be done (Hmelo-Silver et al., 2008, as cited in Iiskala, 2015). Evaluation is the process of assessing the products of learning, as well as, revising the goals (Lei, 2011). While some researchers identify also other subprocesses when analysing metacognitive regulation (Molenaar, 2011, Backer et al., 2015), planning, monitoring, and evaluation seem to be the most agreed on processes (Iiskala, 2015), and they are also the ones that we utilised in our work to investigate SSMR. It can be noticed that planning, monitoring, and evaluation are somewhat similar to the three phases from Zimmerman’s self-regulation cycle (1989) - respectively forethought, performance, and self-reflection.

The research within SSMR has so far focus largely on the verbal aspects of regulation (Iiskala, 2015). However, Iiskala claims that a line of inquiry focusing on the nonverbal behaviour, such as eye gaze, is very promising and should be given more attention. In our work we aim to combine different aspects of regulatory interactions, looking at both verbal and nonverbal behaviour of the group members. We argue that all the different modalities are crucial for understanding group’s collective regulation.

1.3.4 SRL and CSCL

Järvelä et al. (2016) argue that there is a need for research within CSCL to support regulatory processes in collaborative settings. They identify four lines in developing support for regulation in the field of CSCL. The first line is related to creating environments for sharing information and co-construction of knowledge, also in case of globally distributed participants, and investing quality and efficiency of the knowledge co-construction. The second line involves studies that examine support of group awareness and sociability. The third line refers to creation of tools that help students activate self-regulated learning when needed. It involves an adaptive systems that reacts to the current situation of students and provides targeted support. Finally, the fourth line, is the one that our research aimed to be part of, that “studies tools or widgets that can be used within CSCL environments to support students in becoming aware and understanding their own behaviour as well as the behaviour of their fellow students when working together on a task over a period of time" (p. 266).

1.3.5 Summary

The three types of regulation as seen from the three perspectives we described in earlier sections do not exclude one another. On the contrary, Järvelä, Hadwin & Malmberg (2016) argue that when it comes to collaborative tasks, all three regulation forms are needed if the success is to be achieved - self-regulation, coregulation and SSRL. Table 1 shows overview of the three types of regulatory processes. Our thesis is to focus on metacognitive aspects of socially shared regulation of learning.

Table 1.

Overview of the types of regulatory processes

	Self-regulated learning	**Coregulated learning**	**Socially shared regulation**
Definition	The process of becoming a strategic learner by actively monitoring and regulating metacognitive, motivational, and behavioral aspects of one's own learning.	Transitional processes in a learner's acquisition of SRL, during which members of a community share a common problem-solving plane, and SRL is gradually appropriated in response to and directed toward social and cultural contexts.	Processes by which multiple others regulate their collective activity. From this perspective, goals and standards are coconstructed, and the desired product is socially shared cognition.
Focus of data collected and analyzed	Individual focus on dependent variables -performance -motivation -strategies and skills -metacognitive awareness -self-reported behavior Social focus on instructional context and sometimes manipulated as independent variable	Discourse or dynamic interaction Interplay among individual, classroom, parental, and cultural influences	Discourse and dynamic exchange Individual roles and contributions but always in the context of others Evolution of idea units and regulatory activities
Data collected	Self-reports Performance measures Mental models Interview data Observations Think-aloud protocols	Discourse Frequency and content of interactions Observations of shared behaviors and sociocultural dynamics	Discourse Observed interaction (verbal and nonverbal) Individual roles and contributions to group Group product
Analytical techniques	Correlation of individual factors/measures	Discourse analysis Content analysis	Discourse analysis Network analysis

	Self-regulated learning	Coregulated learning	Socially shared regulation
	Content analysis Comparative methods (e.g., case study, ANOVA, etc.)	Correlational analyses Class-level factors/measures	

Note. From "Self-Regulation, Coregulation, and Socially Shared Regulation: Exploring Perspectives of Social in Self-Regulated Learning Theory" by A. Hadwin and M. Oshige, 2011, *Teachers College Record*, *113*, p. 258.

1.4 Learning analytics

Even though learning analytics is a young concept (Ferguson, 2012, Siemens, 2012), the research base related to it is a very fast developing one. The first Learning Analytics and Knowledge (LAK) conference, the main event concerned with LA field was first held in 2011 (Siemens, 2010). From 2011 to 2012 the number of submissions to the conference grew from 38 to 90 (Siemens, 2012). Five years later, LAK'17 received a total of 114 full papers, 81 short papers and 67 posters (Molenaar, Ochoa, & Dawson, 2017). LA, is getting more and more interest in different research fields, and is included in big projects funded by Erasmus+, such as ODEdu project.

Ferguson (2012) mentions several factors that are main drivers in the development that the field is experiencing. One of them is Big Data - data which size, “measured by volume, variety and velocity, becomes too complex to manage with traditional data tools” (Sclater, Webb, & Danson, 2017). As Sclater et al. (2017) put it “data is everywhere. Data about learners, researchers, lecturers and resources, about their interactions with each other, with institutional systems and with all the digitally-enabled services across the institution”. The increasing introduction of learning management systems (LMSs) into educational institutions brought with it a significant raise in the amount of data collected on learners and their activities (Ferguson, 2012). However, even though the software usually offered a generic feature of tracking events within the system and recording it, the challenge was (and still is) in visualising, aggregating and reporting the results - these functionalities were basic and absent in LMSs (Dawson, 2009, as cited in Ferguson, 2012) and often remained unsatisfactory. The first driver listed by Ferguson is then concerned with how value can be extracted from big data related to learning. Second driver comes with increase in popularity of online learning. Online learning comes with many problems, such as students feeling isolated, teachers struggling to assess quality of participation and learning (Ferguson, 2012). LA can help provide answer to how online learning can be optimised. The final driver is a political one, working on a national and international level and is related to the need of measuring, demonstrating and improving performance. This driver can be summarised as: “How can we optimise learning and educational results at national or international levels?” (Ferguson, 2012, p. 307). With these drivers come three main interest groups, governments, educational institutions and teachers/learners. The LA field “changes and develops as the balance between these three drivers and three interest groups shifts” (Ferguson, 2012, p. 307). In our work, the group whose interest are our main focus are learners, as we argue about the importance of them having access to their own data, and attempt to answer the question of which data could support the collaboration of a group of learners. It can then be claimed that the factor driving our work is the question of how value could be extracted from the data collected on activities, though we go even further by wondering whether the type of data that is already collected is sufficient for our goals, and if different aspects of collaboration can even be quantified.

1.4.1 Impact of learning analytics

Learning analytics concept brings with itself multiple opportunities, with some key areas of impact being (Sclater et al., 2017):

- Predictive analytics to enhance retention and academic success
- Analytics for pathway planning
- Adaptive learning

Until recently, the first area of impact was also the one that gained most attention from researchers working with LA, who focused on identification and support of at-risk students (Kruse & Pongsajapan, 2012; Siemens, 2012)In this intervention framework predictive analytics were used to inform staff responsible for supporting at-risk students about the need for intervention. This could be done with use of dashboard or some alert system (Sclater, Peasgood, & Mullan, 2016) that would urge the staff member to contact the student in need and provide help. Sclater et al. point out that proactive approach is better than waiting until students ask for assistance. Identification of at-risk students remains to be one of central interests of LA community, with LAK’17 running a session titled “Students at-risk - studies” (“LAK ’17,” 2017). One of the papers presented during the session addressed the problem of training machine models with use of a data from a current course instead of data from previous courses, that is a typical approach (Hlosta, Zdrahal, & Zendulka, 2017). The other research presented on the topic attempted to investigate whether there is a connection between the time students in blended settings obtain course materials and their performance (Agnihotri, Essa, & Baker, 2017). The continued interest in identifying at-risk students can be associated with political factors driving the development of the LA field - intervention framework happens to be one that can be associated with the biggest success record (Sclater et al., 2016), possibly because defining success as enhanced retention, makes it easily measurable. The success story most often mentioned is Course Signals project at Purdue (Arnold & Pistilli, 2012), where early intervention was provided through using color signalisation to indicate to students how well they are doing in the course.

Both analytics for pathway planning and adaptive learning can be associated with use of LA for personalisation. Personalised pathway planning allows for modifying the path that student takes in a course, e.g. by suggesting different modules that could be more appropriate to the needs of an individual, such as allowing him to take additional modules to strengthen an area that he finds particularly problematic (Sclater et al., 2016). Adaptive learning on the other hand “promises to be able to tailor individual learning experiences not just to competences and learning preferences but also to life contexts” (Atkinson, 2015, p. 1).

Among alternatives to using analytics for predictions, Sclater et al. (2016) mentions other systems, which goal is to “increase the effectiveness of student engagement in real-time” (p. 24). The example of such system that he gives is use of social network analysis in SNAPP project to visualise interactions in a forum in order to inform future learning design, as well as best ways of facilitating discussion by staff. While intervention frameworks and personalisation of learning are beyond the focus of this thesis, the contribution that our research is close to that of SNAPP. Even if the exact focus is different, our aim is that of increasing quality and effectiveness of collaborative learning through use of data.

1.4.2 Challenges

Learning analytics is a new field that is still facing many challenges (Ferguson, 2012), most of which were already mentioned in the Introduction, but will be now elaborated upon. Even if some of them were addressed in the research conducted in the last years, we argue that they remain relevant. First challenge mentioned by Ferguson was to “build strong connections with the learning sciences” (p. 313). She points out that research focused on cognition, metacognition and pedagogy had been underrepresented in the papers submitted to the LAK conference and references used in those papers. It is crucial to first understand how learning takes place, and what are the factors that influence it, in order to be able to support or optimise it. Siemens (2012) makes a similar point, voicing the need for analytical tools and techniques that consider pedagogical aspects of learning. According to him, many of the existing tools which are being adopted to education system were developed outside of it. As noted by Ferguson, the relationship between learning analytics and theories of learning could work both ways, with learning theories informing the design of LA implementations, and LA helping to create effective pedagogies.

Second challenge was related to developing “methods of working with a wide range of datasets in order to optimise learning environments” (Ferguson, 2012, p. 314). Ferguson emphasises the importance of understanding the environments in which learning actually occurs, she argues that “increasingly, learners will be looking for support from learning analytics outside the VLE or LMS, whilst engaged in lifelong learning in open, informal or blended settings” (p. 314). The interaction that students have with LMSs is often limited, focused on actions such as checking scores or accessing materials (Kruse & Pongsajapan, 2012). The analysis of data on learning cannot then be limited to LMSs if it is to be comprehensive. According to Ferguson (2012), there is a need for use of combinations of different types of datasets, such as mobile, biometric or mood data. This challenge identified by Ferguson has been recently addressed with the growing interest and popularity of multimodal learning analytics (MMLA), understood as “multimodal data collection and analysis techniques” (Blikstein, 2013, p. 102). Especially in recent years, MMLA gained more focus and even had a session dedicated to them at LAK’17 (“LAK ’17,” 2017).

The third challenge listed by Ferguson (2012) was related to giving more focus to the learners’ perspective. She claimed that new LA implementations should try to pay more attention to the needs of learners, rather than to the needs of the institutions. This would mean looking not only at grades and retention, but also motivation, satisfaction and enjoyment. The assessment provided to learners should help them to develop and improve. In our work we go even further and argue that not only needs of the students should be included, but students should be given an active role in design of LA features. This is in line with what Kruse and Pongsajapan (2012) suggested in their thought paper, by saying that “an alternative to the existing intervention-centric approach to learning analytics might involve the student as a co-interpreter of his own data—and perhaps even as a participant in the identification and gathering of that data” (p. 4). Bodily and Verbert (2017) in their paper “Trends and issues in student-facing learning analytics reporting systems research” conducted a literature review that included 94 articles concerned systems that reported more than just assessment data directly to students. 35 of those had a goal of supporting awareness of reflection among students. This suggests that students are getting more control over their own data. Still, after inspection of papers accepted to LAK’17 we argue that perspective of learners’, although not entirely absent, remains underrepresented in the conference proceedings (“LAK ’17,” 2017).

The final challenge faced by the field of learning analytics is one to “develop and apply a clear set of ethical guidelines” (Ferguson, 2012, p. 314). This challenge requires preparing a set of rules in regards to who owns the data and what it can be used for. As pointed out by Ferguson, the key references from the field do not explicitly explain what are the right of learners to their data, how and whether a consent is needed, or what level of transparency is appropriate. It is unclear how and where collected data should be kept. There is also a question of what is concluded from the data and how it is further used. How does a mistake made by a LA system influence future learning of a student? The ethics challenge remains valid, with ethics being one of the main topics to be mentioned in a call for papers for LAK’17 conference (“General Call | Learning Analytics & Knowledge 2017,” n.d.).

1.4.3 Multimodal learning analytics

Blikstein and Worsley (2016) argue that learning analytics can support non-standardized approaches to learning in an ever-lasting battle where “the champions of the direct instruction of well-defined content [are] pitted against those who encourage student-centred exploration of ill-defined domains” (p. 220). The champions of the direct instruction are in this scenario those who favour behaviourist-inspired approaches, while their opponents are generally speaking, supporters of constructivist-based pedagogies. Learning analytics features that can be used to analyse and quantify those non-traditional approaches are important, Blikstein and Worsley argue, because the battlefield is not symmetrical. The behaviourist pedagogies are not only widely spread in education and have a longer history, but learning, in its behaviourist interpretation, is also easier to test and quantify. This gives those approaches an advantage, and results in public educational institutions that are “more dependent on high-profile research results” (p. 221) designing their courses and curriculums based on traditional views of learning. Blikstein and Worsley argue for the potential that MMLA hold when it comes to promoting more novel, student-centred, constructivist-based pedagogies. Worsley (2012)also specifically points out that MMLA bring significant promise of a possibility to assess learning in project-based learning settings. Use of multimodal data can provide researchers with tools that would actually allow them to examine and create insights into what happens in those complex learning environments. As our research was conducted within PBL context, the MMLA and the possibilities that come with it, are relevant to our work and thus must be mentioned. However, keeping in mind that our work is not technical and its goal is not coming up with a specific design, we will only shortly describe different techniques within MMLA.

The technologies that present interesting possibilities for multimodal analytics include collection of data through “logging of computer activities, wearable cameras, wearable sensors, biosensors (e.g., that permit measurements of skin conductivity, heartbeat, and electroencephalography), gesture sensing, infrared imaging, and eye tracking” (Blikstein, Worsley, 2016, p. 222). Not all of those technologies have already made their way into the learning analytics research, but they are present in other fields, and may eventually be applied to support learning. Blikstein and Worsley identify three assessment areas where MMLA can be currently used: assessing student knowledge, affect and physiology, and intentions or beliefs. All of those assessment forms are based on the same concept - generation of models from large datasets of quantitative nature. The difference boils down to where the raw data comes from and how it is processed into computable data. The list of techniques that could be used within MMLA is too long to include all of them here, so we will focus on some of the cutting-edge technologies described by Blikstein and Worsley. We will shortly discuss the techniques, giving examples of how they were used within educational settings in some of the previous research. As the computational aspect of using those techniques is beyond the scope of this thesis, we will not go into details regarding approaches and algorithms used for analysis. We are presenting those techniques as all of them are argued to pose a possibility of being used to analyse learning in open-ended learning settings. It is important to note that recent work at MMLA has been primarily conducted in controlled, experimental conditions, and thus much work still needs to be done in order to apply different techniques in authentic classrooms (Martinez-Maldonado et al., 2017). At this stage of the report we will not however attempt to relate most of the described techniques to our research, thus leaving the question of applicability temporarily open.

1.4.3.1 Text and speech analysis

One of the most prominent techniques that can be used with MMLA is text analysis. Even though text is not really multimodal, it still brings a big promise to MMLA (Blikstein, Worsley, 2016). It allows for interpretation of open writing tasks (as opposed to multiple choice tests, which are common in behaviourist approaches), and has a big advantage of accessibility of data for analysis - there are many places and activities that include creation of text chunks. There are many ways that text analysis can be used, depending on what the researcher is interested in, such as classifying students depending on their knowledge content (Rus, Lintean, Azevedo, 2009, as cited in Blikstein, 2011) or studying progression of students’ ideas (Sherin, 2013, as cited in Blikstein, Worsley, 2016). Another technique, similar in its goals to text analysis, is speech analysis. The advantage it has over text analysis, when it comes to analysing open-ended learning environments, is the fact that it can be applied in more natural settings, e.g. face-to-face group work. The problem that speech analysis brings with it is that it may be difficult to use in real-world educational context. Blikstein and Worsley point out that unlike other speech recognition usage, e.g. smartphones, where it can be used to perform some simple actions, applying speech recognition in education would mean dealing with such problems as background classroom noise, or several overlapping speakers. Those challenges are yet to be solved, but if technological difficulties are overcome, speech recognition will become a very promising technique of analysing learning.

1.4.3.2 Handwriting and sketch analysis

Two other techniques mentioned by Blikstein and Worsley (2016) are handwriting and sketch analysis. While handwriting analysis is concerned with words, sketch analysis focuses on more graphic-based representations. The authors point out that especially diagrams and concept maps are often used to elicit knowledge of students in science courses. An example of research on sketch analysis that is given by Blikstein and Worsley (2016) is work done by Jee, Gentner, Forbus, Sageman, and Uttal (2009), who designed CogSketch, a tool for examining how students with different experience level use sketches in order describe concepts in geology. Sketching is not an activity limited to science settings, and its analysis can bring interesting knowledge in different learning contexts.

1.4.3.3 Action and gesture analysis

Action and gesture analysis present another example of the use of multimodal techniques. They focus on the analysis of the human body language, which is a rich source of various information that can help understand learning processes, especially inter-personal communication (Raca, Tormey, & Dillenbourg, 2014). Action recognition and analysis within MMLA is usually performed with use of video material. Worsley and Blikstein (2013) conducted a research in which they recorded students who were engaged in a hands-on building activity. Their goal was to understand and identify expertise of students in engineering design. Prior to the study participants were divided into groups based on their expertise levels. Researchers used many different approaches to analyse videos in order to examine the differences in actions taken by participants depending on their assigned expertise levels.

Another research where action analysis was applied in an educational setting was conducted by Raca et al. (2014). Their goal was to use frame-by-frame analyses to measure the level of attention and engagement estimated based on synchronization of student actions. The idea behind the research was that focused students would react faster if important information was given to them. Researchers proposed a method for evaluation of attention where students' motions were analysed in pairs from the video material to check how synchronous their movements were. This was later compared with the attention level that students reported in questionnaires.

Different technologies, such as Microsoft Kinect sensor or Nintendo Wiimote, have been applied to study human gestures. The focus of the research conducted on gesture analysis is quite vast, from examining and providing real-life feedback on students' understanding of proportions (Howison, Trninic, Reinholz, & Abrahamson, 2011, as cited in Blikstein & Worsley, 2016), through comparing gestures used by experts and novices (Worsley, Blikstein, 2013), to analysing different aspects of students learning in dyads through data collected by Kinect sensor data and Tangible User Interface (Schneider & Blikstein, 2015). Schneider & Blikstein managed to extract several predictors of student learning from their datasets. They analysed body posture to identify different states (active, semi-active, and passive), and showed that the transition patterns can be used to predict learning gains. Another predictor was frequency of movement. Schneider & Blikstein also analysed body coordination and gestures in order detect student's leadership within dyads. They argue that hand movements can be used between drivers and passengers (Shaer, Strait, Valdes, Feng, Lintz & Wang, 2011, as cited in Schneider & Blikstein, 2015) in a collaborating group. Researchers hypothesised that body distance between group members can be used as learning predictor - even though this hypothesis was not confirmed, there seems to be a correlation between the familiarity of the topic and the distance that students put between himself and other members (those who feel uncomfortable within certain topic tend to establish bigger body distance). As it can be seen from above research, analysis of bodily movements and gestures can prove to be a big source of data on students' learning.

1.4.3.4 Affective State Analysis

Affective states are, as we stated, beyond the focus of this thesis. This is because we argued that observational data is not enough to infer about the emotional state of the participants to a satisfactory extent (it is not to mean that no information on emotions can be gained through analysis of video data). However, emotional regulation is considered a part of SSRL-related activities and for that reason learning analytics related to it are worth considering. Definitions of emotion and affect differ among researchers, and discussion different ways of defining affect and emotion is not relevant to the research presented, in order to make the topic more understandable, we will shortly define emotion as "the umbrella term for all of the behavioural, expressive, cognitive and physiological changes that occur", affect as "the conscious experience of an emotion" and emotional affect as the “unconscious component of emotion” (Panksepp, 2000, as cited in “Blurred Definitions of Affect and Emotion”, 2006). Affect manifests itself by facial expressions and body language. Application of machine learning to the video data allows for recognition of affective states (Blikstein, Worsley, 2016), such as boredom, stress and confusion (Craig et al., 2008). They also talk about possibility to use posture and speech intonation and combine all those types of data for better recognition accuracy. Tutoring system, able to recognise changes in affective state, could react to this change accordingly, e.g. help the student overcome frustration. Apart from visual data, also conversational cues from spoken dialogue (D’Mello, Craig, Witherspoon, McDaniel, & Graesser, 2008, as cited in Blikstein, Worsley, 2016), and physiological markers such as skin conductance or pupil dilation may be used to identify affective states. Blikstein and Worsley (2016) argue for the importance of affective state analysis: “The various studies of student affect emphasize the potential for empowering educators through student sentiment awareness. Using one, or more, of the modalities of speech, psychophysiological markers, and computer vision, researchers are able to better understand the relationship between affect and learning, and at a much more detailed level” (p. 229).

The question that remains open is whether this data can support students if it is presented directly to them. It seems that current research sees the value in affect recognition mostly when the results of that recognition are presented to educators, or used automatically to improve the experience within automated tutoring systems.

1.4.3.5 Neurophysiological data

There is a growing body of research related to relationship between psychophysiology, and cognition and learning (Blikstein, Worsley, 2016). The work that has been done by different researchers till now uses such techniques as measuring brain activity with electroencephalograms (EEG) and examining cardiovascular physiology (Cowley, Ravaja, & Heikura, 2013, as cited in Blikstein, Worsley, 2016). EEG has been used to measure mental effort undertaken by students, providing data on cognitive load, distraction, engagement, concentration and attention (Blikstein, worsley, 2016). The advancement in technology allows for making the collection of neurophysiological data less invasive (Mills et al., 2017). Such improvement could be seen e.g. in case of QUASAR, a headset with dry electrodes that is similar to a hat. QUASAR allows recording of EEG signals, but in comparison to some earlier EEG systems, it is a wearable technology that does not come with a set of cables and does not require use of gels (“Quasar USA,” n.d.). EEG can be used to measure students’ cognitive load, thus measuring how much of their working memory an individual is using at a particular time (Mills et al., 2017). Mills et al.

(2017) attempt to use data on cognitive load to create a system that would use the real-time measurement of cognitive load to improve instructional strategies. The system would aim to promote intrinsic cognitive load, while making sure that students do not experience cognitive overload, a situation in which the load exceeds memory resources, thus stifling the learning process.

1.4.3.6 Eye gaze analysis

Eye-tracking and gaze-analysis have several applications within the educational context, e.g. analysis of the gaze patterns to see if there is a difference in that regard between high- and low-performing students (Andrade, 2017). However, Blikstein & Worsley argue that when it comes to eye-tracking its most promising area of use in LA is studying small collaborative learning groups. Raca et al. (Raca et al., 2014) claim that analysis of consistency of gaze patterns in a dyad can be used to assess both the quality of collaboration and understanding. Overall, so far the studies on collaboration with use of eye-tracking shared a similar framework that consisted of using dual eye-tracking, which means applying two synchronised eye-trackers to follow the gaze of both students in a dyad and calculating how often the pair achieved so-called joint visual attention (JVA) (Bliksten & Worsley, 2016). JVA is considered to be a good predictor when it comes to quality of a group's collaboration. The research using JVA in educational setting has been conducted both in a remote settings where students were performing their tasks in separate location (Jermann & Nüssli, 2012), but recently it started to be applied also in co-located settings. With introduction of new technologies, such as non-invasive mobile eye-trackers (Schneider et al., 2015), the analysis of eye-gaze is becoming an even more promising source of data on learning practices, as it no longer requires participants to hold a steady position in front of a screen, as it was the case with older eye-trackers. It can then be applied to more natural learning contexts and be less intrusive for participants.

1.4.3.7 Challenges

Even though MMLA bring multiple opportunities, the research in the field is facing many challenges (Ochoa & Worsley, 2016). We will shortly discuss some of them, starting with the issues related to finding a way of extracting value from such a multitude of data. As pointed out by Ochoa & Worsley (2016), the problem with MMLA that

> arises with the availability of large amounts of raw learning traces is how to combine the data to produce useful information to understand and optimize the learning process. Traces extracted from different modes and with different extraction processes are bound to have very different characteristics (p. 217).

What is more, the size and complexity leads to impossibility of analysing all of the available data, which creates the need for applying a top-down or a mixed approach. This in turn requires reflections on how a certain type of data could be, after analysis, used as indicator of certain learning constructs.

Another challenge that MMLA will need to address in the future is related to privacy (Ochoa & Worsley, 2016). While the questions of ethics and privacy have been raised probably from the moment that the concept of learning analytics was born (Ferguson 2012; Siemens 2012), the use of multimodal data makes this issue even more relevant. If the collection of data is to become even more extensive, it may be met with resistance from users. The research conducted so far might have simply used consent forms, but with introduction of MMLA into real world educational settings, the issues of data ownership have to be revisited.

1.4.4 Learning analytics for collaboration

As our main interest in this research is using learning analytics to support collaboration, we will shortly discuss the research that has been done within this part of the LA field. Even if not all of the described studies are directly applicable to our work, we still find it relevant to see what they focused on, and what they aimed to achieve. Discussing what has been done also allows for both gaining inspiration, as well determining as determining possible gaps in the research.

Our literature review seems to suggest that the implementations of learning analytics focused not on individual students, but rather on researching collaborative group practices, is still quite limited. This could be, at least partly, attributed to one of the main factors driving the development of the field, being the needs of institutions. If one of the main application of learning analytics is that of improving retention by identifying and supporting at-risk students, then it seems logical that the majority of learning analytics features examine individual learning. It is not to say that collaborative learning has not been included in the LA fields. It seems to us, based on literature review, that the challenge described by Ferguson related to making stronger connections to learning analytics, has been addressed in recent years. The growing body of research on collaboration, is one of the indicators of a turn, or at least raising interest in more constructivist learning approaches in the field. This has been also seen in case of MMLA, where key researchers explicitly emphasise the opportunities that MMLA bring to research in constructivist settings, such as courses implementing project-based learning (Worsley, 2012). The focus that has been recently given to collaboration can, at least partly, be ascribed to teamwork being one of the 21st century competencies (Koh, Shibani, Tan, & Hong, 2016). The growing interest in the analysis of collaboration in the learning field has been mostly visible during the last two or three years. During the literature review, we searched for the term "learning analytics" within International Journal of Computer-Supported Collaborative Learning - this search returned only 18 results. The conclusion that comes from it is that researchers within CSCL have not yet made the clear connection between their field and LA. This means that while CSCL does include research that could fit within the field of LA, it uses different terminology. The bridge between CSCL and LA has however started to be bridged. During the 10th International Conference on Computer Supported Collaborative Learning (CSCL'13) learning analytics were not mentioned in the program - two years later, the program of CSCL'15 included 9 papers and 3 posters that did use the term LA (Fischer, 2015). We will now shortly discuss the main themes and approaches that have been used within LA implementations related to collaboration, while giving special attention to studies that aimed to combine CSCL and LA.

1.4.4.1 Understanding collaboration

Frequent goal of learning analytics implementations related to collaboration is to create a better understanding of collaborative processes. An example could be study that aimed to both capture and analyse collaborative interactions of groups with use of an interactive tabletop (Martinez-Maldonado, Dimitriadis, Martinez-Monés, Kay, & Yacef, 2013). Tabletops can not only be used to support collaborative learning in f2f settings, but can also track interactions. Martinez-Maldonado et al. argue that this data "can make key aspects of collaboration visible and can highlight possible problems" (p. 455). They aimed to identify patterns of collaborative activity based on both students' speech and actions that students performed on the surface of the tabletop. The researchers attempted to determine whether these types of data may help, when used together or separately, distinguish between low- and high-collaborative groups. While the results were not exactly conclusive, Martinez-Maldonado et al. argued that their study "showed considerable promise for obtaining indicators of collaborative work" (p. 479).

While the above study was a bottom-up approach, where data analysis was used to find patterns, it is also possible to design LA analytics in a more top-down way. An example could be the framework for collaborative problem-solving proposed by Cukurova, Avramides, Spikol, Luckin, & Mavrikis (2016). The creation of framework consisted of three stages, where the first two had theoretical bases - merging of assessment framework for collaborative problem solving competences with theories related to knowledge deficiency. The result was then elaborated using fine-grained actions that were derived from video-data. The authors argued that even though at the point when the article was written the framework they developed could not be used using the current technology, it was the first step in creation of automated analysis of collaborative problem solving.

1.4.4.2 Intervention framework in learning analytics for collaboration

Many of the implementations of learning analytics for collaborations that have been done to date, even though they embrace constructivist principles, still focus more on the perspective of teachers and do not provide students with data on their own learning. They thus mostly fit into the intervention framework, with teachers identifying groups that encountered problems and supporting them.

An example could be research conducted by van Leeuwen, Janssen, Erkens, & Brekelmans (2015) that was done in the context of collaborative writing task. Teachers in the course were given two different learning analytics tools - the Concept Trail and Progress Statistics. First of the two was a timeline that displayed an information on when students used one of predefined set of concepts related to the tasks. Progress Statistics tracked the number of the words that students wrote. While access to analytics did not improve teachers' recognition of problematic groups, it enticed them to offer their support more often.

Identification of groups that encountered problems in collaboration has been done also with use of speech analysis (D'Angelo et al., 2015). The goal of the project of D'Angelo et al. was to investigate whether using speech to evaluate the quality of collaboration in small group of students was feasible and what were the challenges that came with it. The indicators that they used in the time the paper was presented consisted primarily of the analysis of the amount of time that students in the group spent talking throughout the tasks. They also investigated how students in the group took turns speaking. Their future research was to include data on asking questions and encouraging other members to participate. They argue that speech-based analysis may guide teachers' interventions: "rearrange membership of a group when one student is too dominant, adjust roles if all students are not participating, explore further if the groups' rate of progress has slowed, or visit the group to debug frustration among the members" (p. 1).

1.4.4.3 Live learning analytics for collaboration

Stahl (2015) points out that learning analytics, especially live learning analytics as one of the future directions of development of the field of CSCL. He argues that while the concept of presenting LA in a live setting has been often mentioned in literature, "the evidence that the analytics proposed by researchers and programmers are understandable and helpful for classroom teachers and their students is far less common" (p. 341). An example of a live learning analytics project that actually improved learning in practice is AMOEBA system (Berland, Davis, & Smith, 2015), a tool that records student activities and presents them in a form of a real-time log. AMOEBA supports teachers in organisation of collaboration of beginner programmers in middle school and high school. The tool helps to determine which of the students presented similar work patterns - an information that can be later used to create better pairing of students. With support from the tool, teachers matched students in a way that ultimately led to higher complexity of the resulting programs, the positive results of right pairing remained even after pairs were separated and students continued working alone.

1.4.4.4 Learning analytics features directed to students

Apart from learning analytics features directed to teachers or faculty, there have been also implementation of LA for collaboration that present data to students. Koh et al. (2016) specifically address the challenge for learning analytics field to establish stronger connections with learning theories that was stated by Ferguson in 2012. They created an explicit pedagogical model, namely the Team and Self Diagnostic Learning (TSDL) framework, that was to be applied in collaborative inquiry tasks context. The framework was based on experiential learning cycle (Kolb, 1984, as cited in Koh et al., 2016), and thus consisted of four stages. The first stage comprised of the team of 14-year old students performing a collaborative inquiry task, and was followed by an awareness stage, in each the team was presented with some visual analytics. In the next stage team members were to go through activities that aimed to enable self and team reflection and sense making, e.g. answering pre-prepared reflective questions. In the last stage team was meant to change and grow as a result of reflection and goal-setting. During evaluation with students, the framework was met with positive perception. What is interesting, the main focus of this research was not learning analytics presented to students per se, but the surrounding activities that allowed them to reflect on the data and improve based on it. The framework is planned to be used not only by students, but also provide data to teachers.

Another learning analytics implementation that was directed mainly to students, focused on collaborative writing in a project-based, peer-to-peer feedback environment (McNely et al., 2012). Uatu, the system designed as a part of the research, was meant to show the real time edit and contributions history of the documents that the team was working on, so it is an example of live learning analytics. The researchers' goal was to determine how students might apply learning analytics to "foster metacognition and improve final deliverables" (p. 222). The conducted study lasted 15 weeks and although the results indicated that Uatu may provide useful metrics, it also met multiple challenges. One of them was the fact that students preferred f2f meetings, which content, although integral to understanding of the collaborative writing, was not recorded by Uatu. Multimodal analytics would be needed in order to record interaction happening outside of the writing software (in that case Google Docs).

1.4.4.5 Regulation of learning

The field of CSCL has made significant progress in respect to such aspects of collaboration as enhancement of cognitive performance, understanding and simulation construction of knowledge, or examining interaction processes (Järvelä et al., 2016). Some of the key CSCL researchers argue that what is underrepresented in the field, when it comes to supporting collaboration, is facilitation of regulatory processes of groups (Järvelä et al., 2016). They argue that "individual and socially shared regulation plays critical roles in successful collaborative learning. This process can be supported by the SSRL tools, but there is no evidence yet about the contribution of such tools to the quality of collaborative learning" (p. 275).

The collective regulatory activities related to cognition, motivation and emotions can be supported with use of learning analytics. Järvelä et al. (2016) claim that MMLA can provide the data that is needed to build a better understanding of "strategic adaptation of regulation" (p. 276) and they mention electrodermal activity measurement, facial recognition and video observation as some of the multimodal techniques that could be used for that goal. There have not been many studies related to combining SSRL and LA so far, but this line of research has been gaining more focus in the LA community, with symposium on the opportunities of learning analytics to support SRL and SSRL being held in 2015 (Fischer, 2015).

1.5 Networked Learning

In the following section, we account for our review of networked learning, the section is largely based on Christopher Jones' book *Networked Learning: An Educational Paradigm for the Age of Digital Networks* (2015), which gave us an understanding of the history, ontological viewpoints and the criticism related to the field. As we did not decide to use networked learning, and therefore will not provide an extensive description of it, what follows in an overview of some concepts of the field that we decided to include as they aided our ontological understanding of collaboration and its complexity.

1.5.1 Key Concepts

Networked learning is a field of inquiry that concerns itself with analysing and documenting the practice of learning in a networked society. Jones starts by defining it as "…learning in which information and communications technology (ICT) is used to promote connections: between one learner and other learners, between learners and tutors; between a learning community and its learning resources" (2015, p. 5), and states that a focus in this definition should be on connections, meaning that the field itself is heavily focused upon the the aspect of "networked" in networked learning. Throughout the book, Jones relates the field and its ontological stances to those of other fields and theories that shares a similar focus, in order to arrive at what distinguishes it from them. In the conclusion, he arrives at three key concepts that he finds can define the field and the research it concerns. The three concepts are as follows:

- Affordance

Jones (2015) defines affordance with more complexity than, for example, Don Norman, in the sense that he argues that there is value in following the view of affordance that Kaptelinin and Nardi employs. In this viewpoint affordances can be visible, hidden, and even false. Moreover, affordance can have different degrees of affordance, and can be at different levels and of different types. The two latter, according to Jones, are specifically important to the field, as viewing affordances not only as properties mediated by a single mediator, but also acknowledging they are relational to the perceiver, allows the researcher to delve deeper into how affordances are perceived, not only to individuals, but also to a network. Furthermore, Jones argues that technologies, in contrast to physical objects do not have affordances but rather properties. The properties only become affordances at the point that they become set in relation to the user who perceives them. As a last point, Jones states that technologies should not, when looked at through the lens of networked learning, be regarded as separate from the users, but rather as complex systems of humans and computers.

- Agency

As one should not view technology as entities separate from the social relations that they are incorporated into, Jones argues that agency becomes an important aspect to consider. For this concept, Jones again draws his main inspiration from Kaptelinin & Nardi, who argue that the original thought of agency of the door groom (as proposed by Bruno Latour) is flawed is it does not consider intentionality. They argue that one intentionality or lack of thereof is what differentiates between objects and living things, as a door can never have intentions and therefore acts differently (predictably) when compared to living entities (as cited in Jones, 2015). Jones differentiates himself from Kaptelinin & Nardi by introducing a third entity, rather than just the non-living and living entities. The third entity is the sociomaterial entity, which is understood as pre-existing entities such as organisations, governmental institutions and other complex entities that are not strictly living but not without intention. The sociomaterial entities become valuable points of analysis as they are dynamic and intentional entities that can have agency both over living beings, but also over objects.

- Assemblage

The third and last key term that Jones mentions in his book is that of assemblage, a term most notably, at least in relation to this field, brought forward by Latour. Jones, although he agrees with Latour on the matter that assemblages are inherently unstable and subject to change, argues that some form of stability should be allowed. To allow for stability Jones makes use of black-boxes from actor-network theory, levels and phase changes. Most interesting of these we believe is the notion of levels in assemblages. This means that rather than viewing the assemblage the way Latour does, as having a possibly infinite number of dimensions that are constantly connecting and changing, Jones argues that the introduction of levels allows the researcher to assume stability at a certain level, in turn allowing the researcher to investigate the level in relation to others. The arguments stated on levels coincide quite notably with those of black-boxes and phase changes when one puts the terms into effect, as Jones' does with an example of a university:

> A university is not reducible to its external relations because it does have a degree of dependence on its internal components. The university has a stability that allows it to persist despite changes to its internal composition and to its external relations, but there are times at which a change in either the internal or external relations can lead to a significant overall change—something I have argued is similar to a phase change of the kind that takes place between different phases of matter (Jones, 2015).

1.6 Narrowing the problem statement

One of the challenges of the study conducted during our internship was the fact that we did not utilise any theory that would allow us to frame the concept of collaboration. Through reflection we can to the conclusion that the complexity of the different processes that constitute collaboration might have been one of the reasons why the insights we gained during our internship research were of quite a general nature. The literature review that we conducted while planning our research allowed us to rectify this issue by narrowing our problem statement. At this point, instead of attempting to answer the question of how learning analytics could support collaboration as a whole,we focused at examining how data could be used to facilitate only a certain aspect of collaboration, namely socially shared regulatory processes of a group. This choice was dictated by key researches in the field of LA discussing the potential of combining SSRL and LA to investigate collaboration. SSRL consists of different types of activities: cognitive and metacognitive regulatory strategies, and efforts related to motivation and emotion regulations. We decided to further eliminate complexity and gain insights particularly into socially shared metacognitive regulation, as this aspect of regulation is the easiest one to be inferred on through video observation, which is the most common method applied in SSRL research (Panadero & Järvelä, 2015). What follows is the problem statement that we arrived at after concluding the literature review:

How can learning analytics be employed to improve metacognitive regulatory processes within collaborative group work, in a PBL setting?

- How do groups regulate their collective activities when working on a problem?
- What are the ICT solutions that students use in their work and what is their role in socially shared regulation of learning?
- What data collected on collaborative learning activities could support collective regulation of learning when presented back to students?

Chapter 2

Results & analysis

In this section of the report we will present our data and analysis. First and foremost we will describe the theory that we decided to base our analysis process upon. This will be done whilst discussing how we decided to use the theory, and which data we used for the analysis. At the end of the chapter, the results of our analysis will be presented. The following is primarily based on the article by Derry et al. (2010), which we find to quite extensively explain and account for the process of designing video analysis.

Derry et al. (2010) separate video analysis design into four different phases, which are: selection, analysis, technology and ethics, of which, selection and analysis will be explained after a short general description of video analysis, its merits and why it has been gaining popularity in the recent years. The reason that technology is not presented separately and in depth in this project, is that it refers primarily to the tools that can be used to analyse, codify and store video data. The different tools and considerations of use of technology will be presented alongside the accounts of our inquiry. The ethics of the analysis will be covered as we find it relevant to our research.

2.1 Video analysis

In the past, using video in social studies was less popular than, for example, fieldnotes and photographs (Cowan, 2014), and there are several reasons for why that is not necessarily the case anymore. First and foremost, the technological strides in the field of video recording devices have made video data a much more useful tool for researchers. Where, before, cameras were huge, chunky and very heavy, the video cameras of today are small, can record large quantities of video at a time and weigh next to nothing. This means that the mere act of using cameras for recording phenomena have now been made possible due to the facts that the cameras are less invasive, can be mounted onto almost anything or anyone, and can be left to record for long periods of time without the researcher needing to interfere with the situation being observed. For social research this has been a huge change, as the data gathered can now be relied much more upon and in turn the field of social research has increasingly focused on developing methods for recording and transcribing such data (Derry et al., 2010). Video analysis offers opportunities that the conventional methods for observational studies do not. Firstly, video data is rewatchable, meaning that, if compared to, e.g. field notes in which a researcher only observes the situated interaction once, video data makes it possible for the researcher to go much more in depth into the interaction being observed. Secondly, the re-watchability of video materials allows for increased development and refinement of transcripts, whereby representation and readability of the data is improved (Derry et al., 2010).

To properly use and represent video data, the researcher utilising it must do the work, and put in the effort necessary to design the video analysis in such a manner that neither the selection, analysis, nor technology affect the results in a manner that skews the insights towards a predefined goal, but rather keeps the data objective, ethically and scientifically sound.

2.2 Selection

Selection is the first phase that a researcher endeavouring video based research must go through and it is a very important process that shapes all other aspects of the analysis (Derry et al., 2010). This said, selection takes place not only during the beginning of video analysis, but is a practice that occurs continuously throughout a project. For a researcher to properly select clips for his research it is important to understand the nature of the clips that are to be recorded or selected. This means that the researcher must know which event he wishes to observe, and this wish should be guided by his research question, stating the intent of the research and analysis to be done. It also means that the researcher must be very conscious of his own biases and choices, both when selecting some clips and similarly when discarding others (Derry et al., 2010).

As an overall rule, there are two ways of viewing video data for social research, one is data as analytical tool, and the other is as support for a narrative (Derry et al., 2010). If a researcher decides to use his data analytically he will most often code the data, transcribe it in a manner that allows for deduction of insights and quite often use quantitative techniques amidst the qualitative analysis. These quantitative techniques can be coding and counting special instances of an event, such as a specific gesture or verbal utterance. If, on the other hand, a researcher makes the decision of using the data to narrate his research, the result will most likely be more subjective, and in this case the researcher must rely on his own professional abilities in order to represent the observed event in a scientifically valid manner. Both ways of viewing data are equally valid and have their own strengths and weaknesses, and can be used together in research. An easy definition that allows for understanding the difference between two views, is that the analytical path will take a complex situation and try to simplify it by coding and cutting it up into more manageable representations of the event, whereas the narrative one will not simplify but rather make the complexity understandable by describing it in detail (Derry et al., 2010). Besides the two different manners of viewing the objective of the data, there are also two different approaches for the analysis. Those two approaches can be applied to both analytical and narrative analysis.

Of the two approaches for doing analysis, one works inductively which is when a relatively big corpus of video is used in its entirety, without preselecting beforehand, meaning that one has a wide array of filmed events to begin with and then narrows it down continuously (Derry et al., 2010). A deductive approach is used when the aim of the study is very clear and the researcher has research statements describing what specifically is to be gathered from the data material. In this case, the researcher creates a catalogue of events to be sampled in order to answer the questions posed beforehand. Often a research design will be somewhat in between the two approaches as research is rarely entirely one sided (Derry et al., 2010). This is also the case with the analysis that was conducted during this project. Overall, we argue that an inductive approach was utilised, meaning that we watched our entire corpus of material through and then started to code and systematically narrow down our amount of data based on its entirety. Though it can be claimed that deductive work was also done, due to the fact that we coded the events that we observed and relied on that catalogue of events with specific properties, when going from our first to our second phase of analysis, which will be elaborated upon in section 2.5.1.

2.3 The video material

Before we can describe our coding and selection of specific events to be used for further analysis, we will elaborate upon the video data used during the inquiry, and explain why video analysis was chosen as our primary empirical source. The purpose of the inquiry was to gain deep insights into the practice of collaboration, or, stated differently, to define collaboration to a point at which aspects of it, or the collaboration as a whole could be quantified. Different approaches to gaining these insight were discussed before video data was chosen, some if these including; group and individual interviews, cultural probes, observation studies and participatory workshops. As during our previous research we realised that students themselves do not possess sufficient insights into their own collaboration, we wanted to utilise methods that would allow us to investigate collaborative processes without consulting them. This requirement left us with the possibility of using observational data or video data, of which video data was chosen as it allows us to observe collaboration in a natural setting, and furthermore brings an opportunity of rewatching the clips to gain a deeper understanding.

During our literature review for methods on video analysis we were made aware of video data recorded at AAU with an international group which we could possibly to gain access to, and quickly hereafter we had been granted access and started to edit the data for analysis. The video data was made available to us is video recordings from the year 2016, consisting of a single group doing collaborative group work during a project. The data spans over three days, with recorded material from each day comprising of two recording sessions, one from before lunch and one made after lunch. Each of the sessions were recorded with use of five cameras that were placed at different angles circling the table at which the group works. Furthermore, two directional microphones were set up in order to ensure usable audio for the videoclips. The three days of recordings that were made available to us consisted of a group working on different parts of their project, with members mostly working separately and then briefing the rest of the group on their progress. As the data met our main requirements – it was a recording of collaborative group practices, within the PBL setting, where the students spoke the English language (one of the authors of this thesis does not speak fluent Danish), we decided to utilise the material given to us to save time that we could later use to conduct the workshops, that at this point we were still planning to organise. As the video material granted to us was not collected by ourselves, and we therefore did not plan and design the setting ourselves, this of course calls for some contemplation as to whether the data is ideal, and whether it truly fits the research design that we made. As the goal of the research was to observe and gather insights on groups during collaborative processes, and specifically with a focus on students at higher learning institutions utilising a social constructivist approach to learning, we argue that the data, although not collected by our own designs, still suits the project. This is especially the case, as the video material is gathered with the intent of creating a “natural” setting which does not impose meaning and alter the processes.

2.3.1 Environmental factors

During the recordings three main issues arose that could potentially influence the manner that the group collaborate. First and foremost, the group work was taking place in a large room with several other groups working at the same time with limited separation between them. This means that the room had a high noise-level a lot of the time - we can know that the group was bothered by this, as the members commented on the noise on multiple occasions during their work process. The second factor that seems to be important to mention is the fact that the room in which the recordings take place was very cold at least on one of the days of recording. Several times members of the group mentioned this, and a few times individuals stopped working in order to try to warm themselves. The last factor that we want to mention is the fact that the very act of recording (with use of five cameras) influenced the behaviour of participants, although it is difficult to determine the extent of this influence. A few times during the recording the members mentioned the cameras, and although they did not seem to alter behaviour, nor hardly ever looked at the camera, they did comment on them and repositioned themselves in order to give the cameras a better view of the interaction that they were having, meaning that they must have been, at the very least, be partially aware of the cameras. The discussion of how the act of observing influences what is observed is the main question that all research has to face. Compromises have to be made in that regard. As in our case the participants seemed to barely pay attention to the cameras, we argue that they behaviour was not influenced by them to the extent that would make the data unusable.

2.4 Analysis

When embarking on video data analysis there are several aspects that a researcher must be very aware of. First and foremost, the nature of video data itself is important to consider due to its rich nature compared to real time observations. When watching and analysing video, a researcher will have access to, and the possibility to analyse a range of different aspects of interaction. Some of these can be: posture, gestures, eye gaze, facial expressions, use of artefacts, speech, tone- and volume of voice and the environment in which the interaction takes place (Derry et al., 2010). As video data contains such a vast number of analysable components, it becomes very important for the researcher who is using the data, to be completely aware of the purpose of the inquiry, in order to not get lost in the complexity of the material. This means that a researcher needs to keep a stern focus on the research question made to guide the analysis, but simultaneously, the researcher must also be open to the possibility of emerging phenomena from the material, and consider how the material that is being analysed is to be reported (Derry et al., 2010). Analysis of video data is not normally something that is just done in one go, usually it becomes a time-consuming process of selecting, watching, transcribing and discussing clips over and over again in order to understand the context and interaction of the video material. This means that the following account for what was decided during this process might be slightly misleading, not in terms of results and deductions, but rather because the process itself was hardly a road from a to b to c, but rather a winding road leading forth and back between positions several times. Though in order to give an understandable account of the inquiry leading to the results presented at the end of this section, the accounts will follow a straight path.

During the process of analysis, a total of four different analysis tools were used, namely macrolevel coding, transcription, graphical transcription and a data session with peers. Before delving into the description of these, it is important to have an understanding of our first encounter with the data and the preparations that were needed before analysis was feasible.

2.4.1 Preparation of data for analysis

As explained earlier, the data that we had received was recorded at different angles and with different sources of sound, meaning that preparation of the data was necessary in order for the data to be usable. First, the sound of the individual recordings was not at a level at which we could properly hear what was said and decipher which sounds were made by the group, and which sound came from the surrounding environment. Therefore, the first thing that was to be done was to merge the video material with the sound recordings made by the directional microphones. To prepare the data, a range of different solutions were considered. The first one was to cut and add the sound recordings on top of the videos in the media player or transcription software chosen for the task of viewing the data. This solution was discarded as that, to our knowledge, not only would become a time-consuming process but also limit us in regard to the use of multiple sound sources at the same time. The second solution that was considered was to use software and computational power available to us at the university. We were informed that we would be able to insert the data and sound, which would then automatically be joined and synchronised by the software, making it ready for analysis. Unfortunately, it quickly became evident that this solution would not be possible as we would have to wait for a period of time for the software to be available, which would push our deadlines and result in less time for analysis. Therefore, a third solution was chosen. Rather than having the synchronisation of the data done automatically we would do it manually with video editing software. This meant that we were to watch through the data, find points of sound that could be recognised easily in both the video and sound recording and thereafter join them, a process that was very time consuming.

2.5 Macrolevel coding

As the video data that we received was wide in its scope and encompassed not just hours of material but also several different stages of project work, it was decided that we would code the data and reduce it to a manageable size for transcribing as our next step. To code the data in a systematic manner that would support not only our problem statement itself, but also the further analysis of the data, we decided to start by watching the corpus of data in its entirety. This was done to get a clear picture of what was available to us and which events occurred during the videos. This process of viewing our footage concluded in our first phase of selection as two of the six recordings were discarded. The recordings were removed from analysis based on the contents - the members of the group did not occupy the table being filmed, which in turn rendered the data useless. After having discarded one third of the video material, the rest was coded using a coding framework build from our knowledge of SSMR and the problem statement. The following is the coding framework that was created and utilised.

2.5.1 The coding framework

When finding a framework through which to understand cognitive and metacognitive regulation, we did (following the example of Rogat & Linnenbrick-Garcia, 2011) draw from research on individual self-regulated learning and saw cognitive regulation as consisting of processes of planning, monitoring and evaluation, that are described in more detail in section 1.3.3.1. We specified that in order for SSMR to occur, the abovementioned cognitive regulations processes of planning, monitoring and evaluating needed to involve at least two of the group members (Iiskala, 2015). When analysing, we were therefore be interested in regulation performed on an individual level, even if it affected the whole group (e.g. one group member assigning tasks to other members without shared discussion/decision making was not seen as an instance of SSMR).

Apart from the regulatory processes themselves, coding also included identification of tools (both ICT and non-ICT) that the group used to facilitate metacognitive regulation processes. Finding what tools were used and how they were applied was meant to help assess what data on group activities was already being collected or could be collected if multimodal learning analytics were applied or if non-ICT tools were replaced with ICT ones. The whole coding framework can be seen in Table 2.

Table 2.

Coding framework

Codes	**Subcodes**	**Description**
Cognitive regulation	Planning	"Identification and selection of appropriate strategies and allocation of resources" (Lei, 2011, p. 7)
	Monitoring	Assessing progress
	Evaluation	Assessing the products of learning Revision of learning goals
ICT tools	ICT for planning	Group using ICT to facilitate planning

Codes	Subcodes	Description
	ICT for monitoring	Group using ICT to support their monitoring efforts
	ICT for evaluation	Groups using ICT for evaluation purposes
Non-ICT tools	Tools for planning	Group using non-ICT tools to facilitate planning
	Tools for monitoring	Group using non-ICT tools to support their monitoring efforts
	Tools for evaluation	Groups using non-ICT tools for evaluation purposes

2.5.2 The result of coding

Having looked through the video material, we used our coding framework to identify instances of SSMR based on the interactions observed. The process of coding was done separately by both of us, as this meant that we would not influence each other in the judgement of which events should be classified as which processes of SSMR. The result of the coding was a list of events, each described with a timestamp, a code and a description. Each event was reviewed and discussed to make sure that we agreed on the classification of it and our lists were compiled into a single list consisting of the different events that we had identified. What follows (see Table 3) is the list created for the first recording from the first day, which was ultimately the one that was deduced insights from, the rest is found in Appendix 2.

Table 3.

List of SSMR instances that emerged through macrolevel coding

Timestamp	Code (Frederik)	Description (Frederik)	Code (Daria)	Description (Daria)
00:13	Planning/tools for planning	The group collaborates on planning the day, using the whiteboard is to keep a list of tasks to be done. One members writes on the board whilst the other discusses whom should do what, and when.	planning tools for planning	one of the team members is writing a list of topics to be researched while discussing the points to be included with others
06:35			planning	one of the team members asking if anyone knows website with some specific information
07:40			planning	deciding on how to assign topics from the list - one of the member suggest for people to research topics they have most knowledge about, others agree
09:18			planning	members discuss preparing question list and sending it to supervisor
11:20	Planning	Whilst distributing tasks, the receiver of a task comments on her competencies regarding that specific task		
15:15	Planning/tools for planning	Tasks generally gets distributed based on whom is most capable of completing said task, though it seems that the member operating the white board takes on a leadership role and therefor asumes higher athority in the distribution		
13:00-15:20			planning/tools for planning	assigning topic to specific people, using whiteboard to point to

				topics and writing down the names of responsible group members
15:40			monitoring	one of the members asking if anyone else checked some website
30:00	Monitoring	During the work, members utilise each other's understanding of the tasks to complete them sufficiently.		
34:38			planning	one of the Finnish members asking for information related to Danish history, one of the Danish people offers to search for it
60:00	Monitoring/tools for monitoring	During one discussion, the members seems unable to find the needed information on the laptops and a members refers to some documents hanging on the wall in order to retrieve the information		

2.6 Transcription

Having coded our data and created a repository of clips that potentially could support the analysis and our understanding of the elements contained in SSMR, a further narrowing of the video material and scope was to be made before starting the transcription process. Firstly, a choice was made to discard the recordings made during the third day. This was done as it was deemed that collaboration was most apparent and watchable during the second day. The recordings of the third day mainly consisted of the group collaborating around a model which they were sat around, which meant that it was hard to decipher facial expressions, what was being said and what the conversation revolved around.

From the second day of recordings two separate events were chosen for transcription and analysis. The first being was an event of planning in which the group discusses how to proceed with their tasks, and planned their further progress. The second event chosen was one of evaluation in which the group discussed and evaluated a completed task. In the clip, one of the students presented the result of her work whilst the other engaged in a discussion on the product.

In the following section, we will present the theory based on which we conducted our initial transcription, followed by an excerpt from the first iteration of transcripts.

2.6.1 Theory

Making transcripts is the act of turning one medium into another, mostly with the purpose of documenting and working with the data to be analysed in order to induce meaning from such (Derry et al., 2010). Transcribing has a long history within the social sciences and therefore has a strong theoretical grounding with many accounts of use and best practices already discovered. Although transcripts can be thought of as relatively simple representations of complex data, more focus has over the years been given to the fact that transcripts can rarely be used as general representations of a phenomena. Rather transcripts should be viewed as a product of the material that it is describing, the context of which it is made and of the researcher that created the transcript (Cowan, 2014). This does not remove value from the transcript itself, but it does mean that the researcher using transcription as a means of representing and analysing data, needs be explicit about the intent of his inquiry as to not cloud from which perspective and with which research questions the transcript was made (Cowan, 2014). During this project we decided to direct our attention to the practice of making multi-modal transcripts, as these focus not only on the speech in the interaction but also the embodied interaction (Cowan, 2014). This means that the transcript itself inevitably becomes more complex as more dimensions are added to the representation of interaction. Further, this entails that the researcher creating the transcript must be very aware that it is hardly possible to represent every interaction and aspect hereof in the transcription, and that the researcher must choose and discard aspects to focus on (Cowan, 2014). Typically research, which is also the case within this project, will adapt the transcription techniques used for a given project to the time, funds and manpower available, and also to the purpose of the transcriptions itself. During this project two different styles of transcription were used. Firstly, the classical approach of a textual transcription was performed with the intent of capturing speech patterns and connecting these to the bodily interaction of the group being observed. Secondly, a graphical transcript was used in order to visualize and represent the event being observed. Both of the techniques will be further elaborated, following is an account of the technique used for the initial textual transcript.

The initial round of transcription was an iterative process of transcribing what at first seemed to be a relatively simple sequence of interactions, but which turned out to be much more, as the mere act of transcribing brought us deeper into the material and forced us to make choices that were not anticipated. To understand the method and process of the initial transcription, first it is important to understand the intention that it was based on. Qua our problem statement, the insights we wanted to extract from our video data were of the interactions. We aimed to extract observations that could be quantified in order to bridge the gap between a mostly qualitatively guided idea of understanding the mechanisms of collaboration and the mostly quantitatively based field of learning analytics. Therefore, it was decided early on that the transcription to be made would be multimodal. We wanted to observe not just what was said, and how it was said, amongst the members of the group, but also the embodied interaction of the group.

To transcribe the interaction within the selected clips, a template was created consisting of 4 columns. The first column merely held a number indicating which entry was to be described. The second column had the heading of timestamp, indicating that whatever observation was made should be timestamped so it could be referred to, and further, to ensure a sense of progression and time in the transcript. The third column was to include information on the embodied interaction and the fourth column was for spoken language. The reason why the columns were placed in this order was to ensure that we were forced to consider embodied interaction before actually listening to the participants, in an attempt to ensure the correlation of the two rather than seeing speech and embodied interaction as separate entities, an attempt supported by the experience of previous researchers (Davidsen, 2014). In the column containing embodied interaction we were to write down: shifts in gaze, posturing and gesturing, all things that would theoretically be measurable but still accounted for a large part of the bodily interaction. In the column for spoken language, we were to transcribe any verbal communication made, a choice that was expanded after a data session to include breaks, volume and overlaps, which was done by appropriating the Jefferson notation system (Jefferson, 2004) to the format of the transcript.

2.7 Data session

Using video data has several advantages, one of these being that clips can be re-watched repeatedly to gain further insight. A second advantage that this has is further that clips can be watched with other researchers and peers, allowing for second opinions on the content and transcriptions that are created, which in turn can afford improvements, both in regards to readability of the transcripts and to the understanding of the events themselves (Derry et al., 2010).

During our initial round of transcription, we decided that the best way of gaining as much insight as possible and getting the best representation of the data that was analysed, was to view and transcribe the video material separately and then discussing the resulting transcriptions based on differences. As it turned out, our transcriptions were similar, leading us to believe that a data session with external researchers would be a good idea. The purpose of the data session was to verify that our method of transcription was understandable to peers and to discuss specific points of interaction. The data session was held with two researchers from e-Learning Lab, and during the session we gained useful insights which led us to reiterate the transcriptions with added complexity to the speech, adding the appropriated Jeffersonian notation. Furthermore, during the session we presented our ideas for the next step of the transcription, which further inspired the method of graphical transcription that was used.

2.8 Transcription excerpt

In the transcript excerpt that we decided to include in the report, as mentioned earlier, the Jeffersonian notation system inspired the notations made in the column representing spoken language. As some of the original notations that Jefferson presented enlarges the amount of space needed for the text to be represented, a few alterations were made to improve the readability of the transcripts. The following are the notations that were used.

Rather than representing overlaps as shown here: ***Lord Wader: Luke, I am your Fath[er]***
Skywalker: [NOOO]

We decided to just start the part that was overlapping with a bracket, and ending the bracket at the end of the overlap. That was possible as only short parts were ever overlapping.

The second appropriation that was done was to the notation of lower and higher volume, and pressure on words. We decided to simply write words that were said in low volume with *cursive* text, while normal words were written normally, and high volume words were written with **bold** text. Break symbols were used similarly to Jefferson with (.) meaning a short break and then adding numbers behind the "." to indicate longer pauses (Jefferson, 2004).

In the transcription, the participants have been labelled A, B, C, D, E in order to ensure their anonymity. A, B and C is position at the left side of the table being observed and D and E are positioned opposite on the right side (see picture 1). The participants have been anonymised in order to comply with the standard ethical conduct of not revealing their identities without them having given explicit permission to do so.

The following is the excerpt that was decided upon, this transcript is the same that will later be represented in a graphical transcript. The full transcripts from our initial phase can be found in Appendix 3.

Table 4.

Excerpt of textual transcript

N.	Timestamp	Embodied interaction	Spoken language
1	8:08		E: eeeehm(.3)
2	8:09	C: moves gaze onto E B: moves gaze onto E	
3	8:10	E: Crosses arms and moves gaze away from the group unto a person entering the room C: follows gaze and looks into the room	E: should this(.1)
4	8:11	B: moves gaze unto room to see was is being looked at then moves gaze back at E C: moves gaze to E and then onto the whiteboard	E: material(.1)
5	8:12	E: looks upwards into the yonder C: moves gaze back onto E D: removes hands from keyboard, folds them and moves gaze from screen onto E	E: that weee(.2)
6	8:15	E: Moves both and in forward circles in front of her B: moves her mouth and exclaims an inaudible "yeah"	E: produce today(.1)
7	8:16	C: moves right hand to his mouth and leans onto the table E: the gesture continues	E: should it be in the report?
8	8:19	E: the gesture continues	E: or should we just(.1)
9	8:20	E: the gesture continues B: looks upwards and seems to be wondering	E: make some(.1) quick(.2)
10	8:22	E: the gesture continues	E: illustrations(.1)
11	8:23	E: right hand continues gesture, left hand moves out to the left	E: to shooow(.1)
12	8:25	B: nods heavily D: nods	E: to Anne- B: [**yeah,** that would be right
13	8:26	E: the gesture continues B: keeps nodding, though less heavily	E: *oooor]*(.1) in order to [decide(.1) B: *yeeah*]
14	8:27	E: the gesture continues B: keeps nodding	E: what they should [look like B: yeah
15	8:29	E: moves hands from one side to the other D: nods	E: When] we place them in the report D: *yeah*
16	8:31	B: moves her hands across the desk in a gesture C: moves gaze to B D: moves gaze to B	B: Maybee(.1) we just(.1) eeeeh(.1)

17	8:34	E: nods	B: Have all the material that we can(.1) do(.1) today(.1)
18	8:36	E: nods	B: And then we can show and discuss
19	8:38	B: moves hands up and down whilst imitating typing	B: and then we can(.1) make those(.1)
20	8:40	B: moves hands to table E: nods D: nods	B: Findings E: **yeah**
21	8:41	E: continues nodding B: nods D: nods	E: [that would B: that would be really(.1)
22	8:42	E: nods B: nods	E: be great B: effective]

2.9 The graphical transcript

When making textual transcripts of video materials, the visual aspect of the recording being watched is removed and rather the interaction that once was visual- and audio based is now reduced to being represented by textual means. With graphical transcripts, a researcher has the ability to give the reader a view of the actual recordings that fostered the transcripts being read. This can be done in different ways, ranging from drawings to cartoon style storyboards and to screenshots of the actual recording being represented (Laurier, 2014). During the transcription process that was conducted during this project, we decided to do a second iteration of transcribing that would further represent the visual side of the recordings that was analysed. This was chosen in order to represent better the embodied interaction that happens between multiple people at any one time. As the video material we employ has five individuals, meaning that hardly ever is any dialog happening between only two people at a time, this we find is better represented whilst being able to see the positioning of the individuals in relation to each other.

In the transcript, a screenshot has been taken and added any time an action requiring documentation occurs. This means that the graphical transcript follows the first transcript made, and one can therefore return to the textual transcription if a deeper understanding of the verbal communication is needed. In this transcript the verbal communication has been added as talk bubbles emerging from the person speaking. A few times the bubbles overlap, which represents overlaps in speech, for elaboration on these overlaps please see Appendix 3. All pictures in the transcript have been altered with a filter in order to ensure anonymity for the participants, the filtering has been done in such a manner that facial expressions and body language is preserved to the degree possible, whilst still keeping the necessary amount of anonymity to not overstep any ethical boundaries. Lastly an overview of the interaction happening in the screenshots in made to ease the readability of the transcript. The graphical transcript follows:

2.9.1 The transcript

We enter the scene right after a subject has been discussed and agreed upon. The group has just had a five second though-break and now embark on a new discussion. The clip chosen was during the coding phase marked as planning, given that the group is planning whom should do which tasks, and how the tasks should be done.

Picture 1:

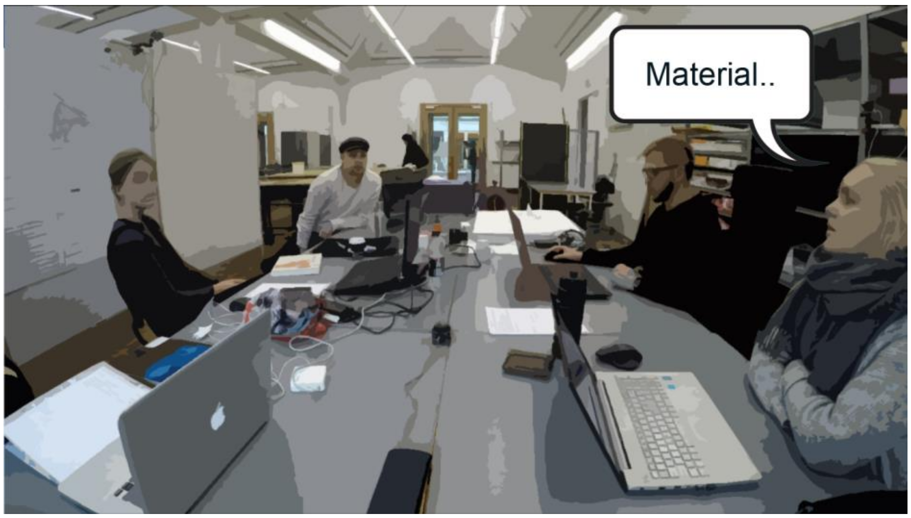
The group is sitting at the table. B, C, D and E can be seen in the frame, A has moved backwards and is during the clip not in the used camera view. B, C and E are all looking at the assignments that are written onto the whiteboard and D is looking at his monitor whilst using his computer mouse. E is fiddling with her fingers

Picture 2:

As E starts talking she crosses her arms and sits upright whilst moving her gaze onto a person entering the room in the background. B and C both moves their gaze onto E whom and C moves his body towards E. D is still looking at his monitor.

Picture 3:

B and C turn to look at the person that E was looking at. Meanwhile, D is still looking at his monitor and does not follow the gaze of the other members.



Picture 4:

B and C turns their gaze back onto E whilst she repositions herself which speaking with breaks in between the words.

Picture 5:

C turns towards the whiteboad and looks at what is written on there. D looks ip from his monitor, folds his hands and turns his gaze onto E. E looks upwards at the ceiling as she continues to speak with breaks.

Picture 6:

C moves his gaze back onto E and leans slightly forward. E start gesturing with her hands in rhythm to the words that she is saying.

Picture 7.

C picks up a pen, moves his hand to his mouth and leans onto the table. E continues her gesturing whilst asking her question. She shifts her gaze direction from B to A.

Picture 8.

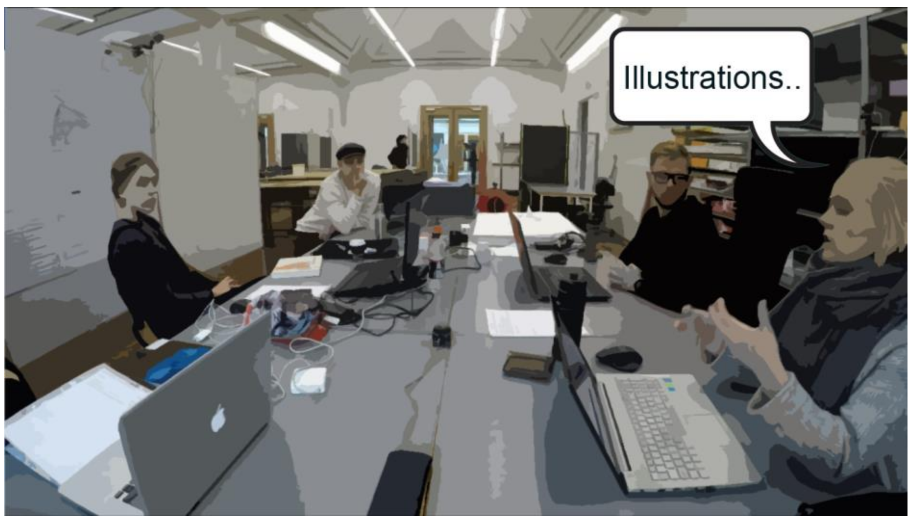
E keeps gesturing whilst talking

Picture 9:

E makes circular gesturing with her hands as she continues to speak, she has more breaks in her line of speech. She shifts her gaze direction from A to B.

Picture 10:

E has a short pause in her gesturing whilst finding her words and then continues. B turns her gaze upwards and D turns his gaze onto the table.



Picture 11:

E moves her hands to the left whilst asking her question. B nods while answering.

Picture 12:

B keeps nodding and speaks over E. E continues her line of speech.

Picture 13:

E shifts her hand to the right whilst speaking, B keeps nodding and her speech overlaps E. D nods. E shifts her gaze from B to A.

Picture 14:

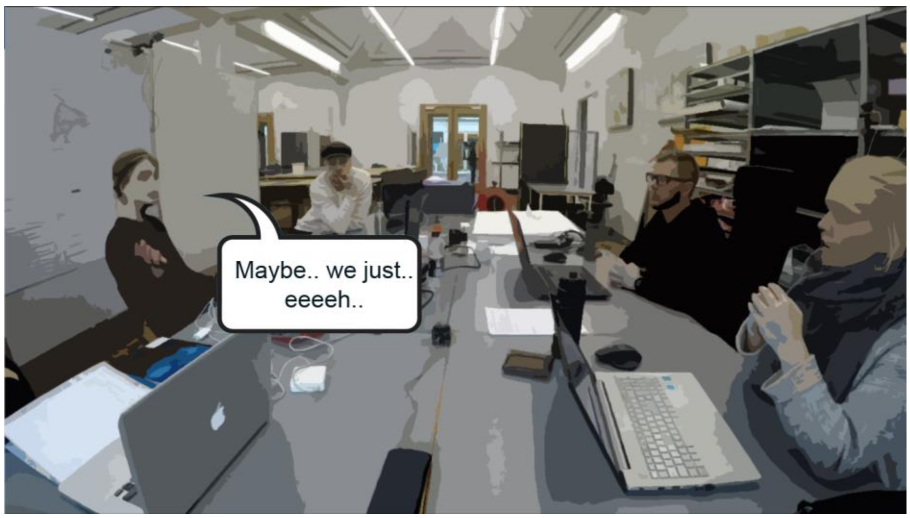
E is gesturing in front of her body. B keeps nodding. C repositions himself slightly closer to the group.

Picture 15.

E shifts her hands to the left again. D nods.

Picture 16:

E stops gesturing and folds her hands. B shifts her right hand outwards to her right. C and D moves their gaze onto B.

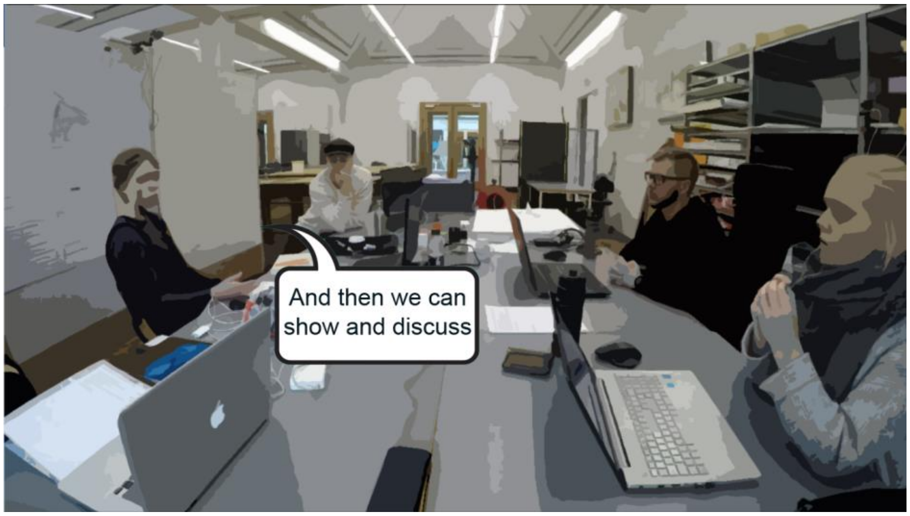


Picture 17:

B moved her hand across the table and shifts her gaze from E to D. E nods.

Picture 18:

B makes gestures with her hands in front of her and switches her gaze from D to E. E nods.

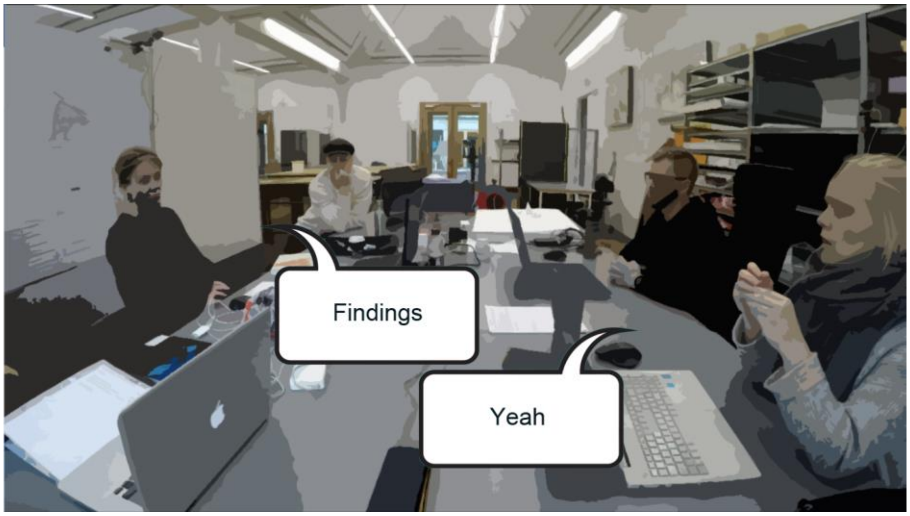


Picture 19:

B pulls her hand of and makes a gesture in the air.

Picture 20:

B stops gesturing. D and E nods.



Picture 21:

B and E both nods while speaking on top of each other. D also nods.

2.10 Arriving at the final problem statement

As we were conducting the analysis of our video data, we started to realise that the complexity of the phenomena that we were observing was much greater than we had initially expected. Furthermore, it became increasingly evident that, although the observations we were making were showing clear indications of the mechanisms that we had wanted to find, and that the mechanisms could be studied in depth. Because of this, we would have to choose either one of two ways in which to continue. One way would be to spend more time on the recordings, transcribing them further in depth in order to further understand the complexity of the phenomena that we were to quantify. The other path that could be taken, was to gather the insights already collected and build a workshop upon them. After some deliberation, we decided that we would not attempt to make a workshop and rather keep analysing the data. We based this decision of continuing with the analysis on a couple of simple arguments. The first and most important argument was based on our initial goal. As we had during our internship failed to achieve the level of insight that we wanted, and had based this partly on the idea that we did not understand the phenomena that we dealt with to a necessary extend. Cutting this part of our research short seemed less than ideal. The second argumentation for further video analysis was the amount of insights that we had gained through the coding and transcription of the data thus far. It seemed evident that further research would be necessary before conclusions could be drawn. The following problem statement is the last one that was made, and we want to emphasise that the decision was not based on a wrong choice of method, but rather an underestimation of the complexity of the insights and time that was to be used in order for them to be extracted from the video material, which prompted us to make the change. First and foremost, the act of finding out how to show the data to students was taken out of the problem statement. This choice was based on the fact that we would no longer involve students directly into our work, and therefore would not be able to test our solutions, even if we decided to attempt the design of such. The second large change that was made was the exclusion of ICT from the problem statement. This was a change that took some discussion in order to agree on, but the final argumentation, was that the data we had available really did not show any interaction with ICT. Furthermore, we still believed to be in line with our study regulation, given that we were still dealing with data, as the main premise of the study would still remain learning analytics. Lastly the problem statement was situated to the new reality that we faced. As we were no longer doing a workshop and were relying on the video data available, we could now define the problem statement to be looking at face-to-face collaborative group work.

How can metacognitive regulatory processes within face-to-face collaborative group work be measured and quantified, allowing for learning analytics to be employed to facilitate collaboration?

- How can assessment of collaboration be supported by observing socially shared metacognitive regulation?
- What data collected on socially shared metacognitive regulation of learning could support collective regulation of learning?

2.11 Results

2.11.1 Different modalities of interaction

In the previous sections we described in detail the transcription process and presented the resulting transcripts of a 36 seconds long sequence. Our aim throughout the analysis was focusing on interaction of the participants, including different modalities, such as language (both verbal and nonverbal), bodily movements, gesture, and gaze direction, and use of ICT or artefacts. Those modalities are used to organise the following section, which describes what happened in the analysed clip, while pointing to interesting phenomena and interaction patterns that emerged at this stage of the transcription process. We will not however restrict this analysis to only elements of interactions that are, in our opinion, related to SSMR. This is because in this work we try to reflect on the possibility of automated data collection and analysis, so we find it important to present to the reader the whole complexity of different actions that happen simultaneously with group's collective metacognitive regulation. We discuss actions of four of the group member - B, C, D, and E, as A is not visible in the video recording. Based on the audio, we can however know that A does not say or utter anything in this particular sequence. The sequence that we decided to look further into does not include use of ICT and any artefacts, therefore the ICT aspect of collaboration will not be further discussed.

The analysed sequence started just after the group agreed upon the division of topics that each member was to investigate further during that day of group work. Once the division was concluded, the group proceeded to discuss what they should do with their findings. One of the members, E, asks whether the materials that the group agreed to prepare on that day should be included in the report or perhaps a better idea would be to first prepare some illustrations that could be shown to their supervisor. The other student, A, approved of the suggestion of showing all the material from that day to the supervisor in order to discuss it and proceed with work. We coded this sequence as planning, because the group was making decisions about their future actions, strategizing what should be their next step leading to accomplishment of the goal of delivering a good semester project.

2.11.1.1 Verbal and nonverbal language

While it was a combination of different elements of interaction that allowed us to identify SSMR processes and differentiate between planning, monitoring, and evaluation, verbal cues were the most important factor used for coding. For that reason we will start this description of the interaction from discussing verbal and nonverbal language elements of the interaction. This short planning session was initiated by E, who started the group's metacognitive regulation by uttering an *eeehm* sound (line 1) aimed to draw attention of the other group members. She then continued asking for the group's opinion on what should be done with the materials that they were preparing on that day. As she described different options, she used the word *should* several times - "*should* this material that weee(.2) produce today (.1) *should* it be in the report or *should* we just" (lines 3-8). The use of the word *should* together with the question format suggests that E wanted the group to decide what to do next, so she started metacognitive planning process, whereby the group was to pick the best strategy. While she was talking, A agreed with her that they should show the materials to the supervisor, and indicated that by saying *yeah* three times (lines 12-14). It was one of the instances of B and E, the primary speakers of this planning sequence, talking at the same time (also 20-21). B, D, and E all used *yeah* during this short clip, informing other members that they agree with the suggested course of action (e.g. lines 15,20). *Yeah* was the loudest utterance of the clip, which further shows the importance of the group members showing that the group as a whole supported the plan (lines 12, 20).

2.11.1.2 Gaze direction

After E started the session uttering *eeehm,* even though D did not react to this nonverbal cue, the other two members, B and C, shifted their gaze to E while she continued to speak (line 2, pic 2). Throughout the planning session the gaze of other students was almost at all times directed at the person who was taking the turn talking. There were however a few situations, when the gaze of some group members was not directed at any of the other students within the group. When E was speaking and she started looking at a person who entered the room (not a member of the group), B and C followed her gaze (picture 3), which is a sign of a joint attention. At this point D did not achieve joint attention with E, as he was still looking at his laptop, though a few seconds later he also shifted his gaze to still speaking E (picture 5). After C stopped looking at the newcomer, he shortly glanced at the whiteboard behind his back (picture 5), though there was no apparent reason for doing so. Those examples of students (D and C) not looking at other members of the group may be attributed to temporary distraction, but while C seemed to be nonetheless constantly following the planning session, it is difficult to say if D was paying attention to the discussion happening in the group while he was looking at the laptop screen. Another situation when the gaze of some of the students was not directed at the group can be attributed to thinking - at separate times both E and B directed their respective gaze up for several seconds - E did this while talking (line 5, picture 5), and B shortly glanced upwards when listening to E (line 9, picture 10). While following the gaze of speakers, it becomes clear that they kept shifting their gaze between other members of the group while talking, in order to make sure that they have their attention, or to receive nonverbal feedback. Both E and B kept looking at people who sat in front of them, with E shifting her gaze between A and B (e.g. pictures 7, 9, 13), and B shifting her gaze direction between E and D (e.g. pictures 17, 18).

2.11.1.3 Bodily gestures

The group members used different gestures throughout the planning session. It can be noticed through the transcriptions that students tended to perform more hand gestures while they were talking. While some of the hand gestures were hard to interpret, the other ones were clearly used to better visualise what the group member was saying. Though their meaning is difficult to be inferred based on the gesture alone, they supported the ideas conveyed in the speech. An example of this can be seen when E talked about the materials prepared by the group and suggested sending them to the supervisor. When she mentioned *production* of quick illustrations, she kept making circular movements with her hands, as if representing a continuous process of doing something (picture 9). Later, while E talked about showing the material to the supervisor, she waved both of her hands to the side, thus visualising that the product was to be passed to the absent supervisor (picture 11). She then said that this would help them decide *what the materials should look like*, at the same time making a weighing gesture with her hands, like she was trying to weigh two options in order to pick the best one (picture 14). Similarly to E, A also gestured when it was her turn to talk. She as well used her hands movements to help her convey meaning, an example of this can be seen when she talked about producing materials *today,* emphasising the word *today* by putting her palm on the table, thus visualising that the production was to be happen at this specific time and place (picture 17). She later mentioned *making* findings based on the discussion of the material, and she represented making of findings by moving her fingers as if she was typing (picture 19).

In the analysed sequence the group members generally performed much less hand gestures while listening. Shortly after E started the planning session, D stopped looking at the laptop, turned to her, and put his hands together, thus signalising that he is focused on the discussion (picture 6). Similarly, C leaned towards E (picture 6) to indicate that he was paying attention to what she was saying. Just afterwards, C picked up a pen, and leaned his chin on his feast - his whole posture showing that he was engaged in the planning session. The most common bodily gesture used by the group members included nodding. B, D and E nodded on several occasions throughout the sequence, thus showing that they agreed with what was being said by other group members. An example of this can be seen when E starts the session and explains what is the decision that she is unsure about, and B indicates her agreement and support by nodding for 5 seconds while E is talking (lines 12-15, pictures 11-14). B not only nodded, but she also said *yeah* three times during those 5 seconds - she used nodding as support for her speech, just as she did with her hand gestures later. However, nodding is a gesture transparent enough that it was also used without verbal communication (e.g. lines 17-18, 20-22).

Chapter

3

Discussion & conclusion

3.1 Discussion

During this section we will discuss the results and knowledge that have been obtained through the analysis of our data. We will start by answering the first sub-question of our problem statement, namely how our observations of SSMR within the video clip that was analysed can be used to support the assessment of collaboration. After this we will proceed to discuss how the insights that we extracted through the process of transcription, could be quantified and how these data could further be used to support the students with their collective regulation of learning.

3.1.1 How can assessment of collaboration be supported by observing socially shared metacognitive regulation?

We argue that through the stages of the analysis of our video materials we were able to identify SSMR at different levels of abstractions. At a macro-level we found instances of the three processes associated with collective metacognitive learning- planning, monitoring and evaluation. After that we proceeded to the analysis of a single clip that included a sequence coded as planning. At this meso-level level of analysis, we were able to detect different mechanisms embedded within the abovementioned planning session, such negotiating the best course of action, and agreeing on a specific plan. At a micro-level we observed different bodily interactions, which combined with verbal and nonverbal language created the meso-level mechanisms that together become planning, evaluation and monitoring.

From the graphical transcripts we interpreted the different verbal and nonverbal interactions that collectively became the act of negotiating the purpose and nature of a task that was to be carried out. Through the understanding of this process and the elements it contains, it has become quite evident that even the assessment of this single aspect of collaboration becomes quite complex. What one should start with is to question whether the identification and assessment of SSMR is enough to constitute a full assessment of collaboration. We argue that even though we cannot state the collaboration that we witnessed was generally successful based solely on SSMR, the observations that we made could to some extent be supportive in the assessment of collaboration. At a meso-level we have been able to identify and examine the act of negotiation and define it as successful given that the group agrees upon the nature and purpose of the task in a relatively short amount of time. Likewise, we can argue that the observations made at a microlevel further supports this. At this level we have been able to see that the entire observable part of the group was indeed participating in the planning. All of the members actively engaged in the reciprocal process of regulation, whether with use of hand gestures, gaze direction, change in posture or verbal interaction, meaning that the agreement that the group came to was not just an agreement between two members of the group, but rather the group as a whole. We find that all the abovementioned elements could be indicative of the quality of collaboration in the instance of group work that we investigated.

However, we do want to emphasise the complexity of the collaborative process. What we observed, was merely a single planning instance in a large pool of different elements that together constitute regulation. We thus cannot infer whether the interactions patterns that we observed and described are the typical elements of planning. Some of the regulation aspects may be distinctive of this specific group, as collaborative practices of groups can differ significantly. By having only analysed a short clip such as the one we chose, we also cannot state that the actions that we observe are not somewhat influenced by previous events in the group work. During our work we have been increasingly aware of the complexity of the collaborative practice that we investigated. We do believe that the mechanisms and processes that we were able to observe would be supportive in the assessment of collaboration. It does however need to be kept in mind that we only focused on a short planning session, more data should be collected analysed in order to further discuss how observable elements of different SSMR processes can be used to assessment of collaboration.

3.1.2 What data collected on socially shared metacognitive regulation of learning could support collective regulation of learning?

When we have to answer the question of how metacognitive regulation can be measured and quantified in order to facilitate collaboration, the abovementioned insights become valuable. Next we will discuss how learning analytics could be utilised to measure the insights that we made, and what are the difficulties and opportunities that lie therein. To answer the question we will, as before, look at our data and results from a macro, meso- and micro level in order to illustrate the difference that abstraction in this regard makes. When considering the micro-level, the different modalities of interactions that we described in section 2.11.1 are measurable individually through the use of the multimodal technologies presented in section 1.4.3.

3.1.2.1 Verbal and nonverbal language

Starting from verbal and nonverbal language, speech analysis techniques could be employed in order to measure different aspects of verbal communication. We know that text and speech analysis have already been employed in the field of learning analytics (Blikstein & Worsley, 2016), used to analysed quite complex matters, such as progression of ideas (Sherin, 2013, as cited in

Blikstein & Worsley, 2016). Techniques such as text mining and machine learning allow for using textual data for different and complex types of analysis (e.g. Sebastiani, 2002). In the sequence that we analysed a group member asked questions containing the word *should* several times. As we mentioned in section 2.11.1.1, in our example we found utilising of *should* questions indicative of the group being engaged in a planning process. Analysis of more instances of planning, monitoring, and evaluation, performed by different groups could result in finding more phrases that would then be used to identify and categorize the metacognitive processes that the group was performing both at a macro-level, and meso-level. Speech analysis could also be employed in order to examine further how exactly the peer members are reciprocally operating based on the regulative acts of others (Backer et al., 2015). This could be investigated by analysing the order in which the members took turns speaking, and show the progression of the ideas or negotiation of meaning. In our example some of the group members (B and E) spoke significantly more than others. It could be interesting to measure the number of utterances made by each of the members (preferably pre-analysed utterances that were categorised as relevant to the regulatory processes) and thus investigating who participated more or less actively in the shared regulation.

As it can be seen, there are many aspects of verbal communication that could be further measured and analysed, and used to infer information or SSRM that could be later utilised to support the regulatory processes. The identification and categorisation of different types of the shared metacognitive regulation could allow to investigate whether and how often the group engages in shared regulation. This data, if showed back to students or the teacher, could, for example, allow the group to reflect upon whether the monitor their activities as frequently as it is needed. The number of words uttered by each member during the regulatory activities might be used to investigate whether the group is not dominated by one or some of the members. The possibilities of using speech data to analyse and support SSRM seem endless. It is however important to remember that each of the presented ideas shows only a limited picture of the regulative processes. To better visualise it, let us take a closer look at the planning sequence we analysed. In the clip some students said *yeah* when they agreed with their colleague, while others only nodded. In this situation the calculation of the number of utterances might suggest that the members who said *yeah* actively participated in the regulation, while their nodding group mates did not. This conclusion would however be misleading, as all of the members did indeed provide their feedback to the proposed idea, though they delivered it through different modalities.

3.1.2.2 Gaze direction

The application of eye-tracking is argued to be very promising for using analytics to study collaboration in small groups (Blikstein & Worsley, 2016). Our data confirms that eye gaze direction is an important element of group's collective regulatory activities. The eye gaze related research so far focused on using joint visual attention (Blikstein, Worsley, 2016) as a predictor of a quality of collaboration. As we mentioned, in the planning sequence that we analysed, the listening members of the group tended to look mainly at the speaker, who in turn shifted gaze direction to look at the opposite members of the group, as if ensuring their attention. We could then say that the students who looked at the speaker did achieve the JVA. This could be measured and presented to teachers and students, thus informing them of the quality of the collaboration as a whole. However, if we take into consideration only the gaze direction, while we can say that students do actively engage with one another, we can in no way no if they regulate their activities, or even work on their assignment. At the beginning of the planning sequence a person walked into the room, and after the speaker looked at the newcomer, two of the other students did too. While they did manage to achieve joint visual attention, the action of shifting their gaze was not related to neither regulatory activities, nor collaboration. It would then mean that while lack of JVA can be used as a warning signal, high JVA still does not mean that the group is regulating their activities, and working towards a high-quality product. In our data there were also a few instances of students looking up instead of directing their gaze at fellow team members. We interpreted gazing up as an indicator of thinking - while those students may have scored lower on the scale of having joint attention with their colleagues, it cannot be said that they did not actively participate in the regulation, if that was the topic of their thoughts.

3.1.2.3 Bodily gestures

Through the analysis of video material, we managed to describe several ways in which different gestures were used by the group members during their short planning sequence. We found that those gestures paid a very big role in the understanding of the interaction that was happening within the group. The speakers in the clip used hand gestures extensively to help them support their speech by additionally visualising and conveying the meaning. The examples of this were circular hand movements made by E that accompanied the spoken idea of *production* of quick illustration, or B putting her palm on the table to emphasise the production of the materials *today.* While those communication subtleties are important to us, humans, it is not difficult to imagine that recognition of these and similar, gestures of high complexity may be too challenging of a task for a machine. Even if machines could identify a wide rage of popular gestures, the meaning of which was more culturally agreed upon, the examples that occurred in the analysed sequence seem to be situated gestures, ones that could possibly convey a different message if put in a different context. At some point B made typing gestures with her hands, if the automated system could indeed recognise that the gesture was related to typing, it could still make a mistake of interpreting it as B actually performing a writing task. So far the research related to gesture analysis in the learning analytics field was far less complex than the task we described above, focusing on goals such as differentiating between hand gestures of novices and experts (Worsley & Blikstein, 2013) or evaluating the attention level by measuring the synchronicity level of the group (Raca et al., 2014). The group members in the planning sequence acted in a synchronised way through the majority of the time, reacting fast to the statements and actions of others, e.g. by nodding or adjusting posture. While synchronicity could then be an interesting indicator of the quality of regulation, the problem encountered is the one of the similar nature as it was the case with eye gaze, namely even though we could measure that they are synchronised, bodily gestures alone cannot tell us if their attention is directed at the task at hand.

In the analysed sequence, B and E talked and gestured much more than the other members of the group. While the clip was not long enough to infer anything in terms of leadership in the group, the hand gesturing and other bodily movements could be measured to understand better the power balance within the group if applied to a bigger dataset (Schneider & Blikstein, 2015) or the level of engagement. This type of information, if presented to students or teachers, could be used for reflection or intervention, e.g. reorganisation of groups.

3.1.2.4 Combining modalities

There are many insights that can be gathered through measurement and analysis of data from different modalities, e.g. eye gaze can be measured to show where students direct their attention, posture and gesturing can be measured to evaluate engagement and attention, and the conversation can be analysed through its contents to categorise regulatory processes. While looking at individual modalities may provide interesting indicators, it is far from providing a full picture of SSMR. In previous sections we discussed some of the issues that might arise when looking at data from a single modality, such as being able to evaluate engagement based one eye gaze patterns, but not being able to tell if that engagement is directed at working on the assigned task. The problem of limited picture of shared regulation that can be painted through use of data from a single modality can be addressed through simultaneous measurement and correlation of data from different modalities. Let us go back to the example given in the section 3.1.2.1. We mentioned that using a number of utterances as an indicator of engagement in the interaction could be misleading, as some people use bodily gestures as feedback instead of verbal language. This issue could be solved by combining the analysis of speech with that on bodily gestures. Similarly, if data on speech and gaze direction was put together, it might help address the problem of evaluation of engagement using gaze patterns as indicators, without really knowing if what the group is engaged in is related to the task.

3.1.2.4.1 Challenges of combining modalities

The more modalities we combine, the more indicators are used, the fuller is the picture of collaboration that emerges. However, the more modalities we include, the more complex becomes the analysis. Even though detailed discussion on the technological aspects of multimodal learning analytics is beyond the scope of this thesis, we would like to still acknowledge the difficulties that arise when multimodal data of vastly different characteristics is put together to produce useful information (Ochoa & Worsley, 2016). This is not a problem that is easily fixed, and much more work in the field is needed before the modalities are successfully combined and inferred meaning from. Moreover, it is important to keep in mind that even when more modalities are included, the analysis still will not reveal a complete picture of SSMR, but only aspects of it. This is particularly crucial when the learning analytics are to be introduced into real learning settings and given to teachers and students. Even complex data analysis may misrepresent the actual learning process, as it is just a simplification of it. In previous sections we gave many examples of such misinterpretations, related e.g. to external factors, such as distractions in a form of a person walking into the room. While in a laboratory setting it is possible to control the environment, a real classroom setting does not afford this. Both teachers and students need to be aware of the limitations that come with learning analytics, when they use it for reflections, intervention or support. While possible problems with use of data for evaluation and support of regulation need to be kept in mind, it does not mean that learning analytics could not and should not be used to facilitate collective regulatory processes. We described several data analytics features, that, based on our analysis of video material of collaboration, pose interesting opportunities when it comes to support of SSMR. It is however just the first step on the long road that the field of learning analytics still has in front of it.

3.2 Conclusion

When we began our work in the field of learning analytics, our aim was to design learning analytics features to support collaborative work of student groups. At this point little did we realise how ambitious of a task this was. The problems that we encountered during our first learning analytics research inspired the study that we conducted as a part of our thesis. We started from taking a step back from the learning analytics field and set to begin our new study by investigating the collaborative practices of small groups of students, in order to later examine how data on those practices could be used to facilitate collaboration. We anchored our research in the field of CSCL, and decided to combine it with the concept of socially shared regulation of learning, thus framing our understanding of collaborative learning, role of technology in learning processes, and narrowing down our focus from that of facilitating collaboration as a whole, to supporting collective metacognitive regulation of learning, one of the crucial aspects of successful collaboration.

Those theoretical choices allowed us to hone our problem statement to that of investigating how metacognitive regulatory processes within face-to-face collaborative group work could be measured and quantified, thus allowing for employment of learning analytics to support collaboration. Through analysis of video recordings of a collaborating group, we managed to identify instances of metacognitive processes of planning, monitoring, and evaluation, and later extracted insights and patterns of interaction happening at different modalities during a short planning sequence. We looked at those interactions from three levels of abstraction, and showed that each level provided a different perspective on collective regulation, and with this also different criteria for successful regulation of collaboration. The gathered insights were used to argue that observations made on socially shared metacognitive regulation can indeed be used to support assessment of the quality of the group's collaboration, even if the complexity of such assessment would be extensive.

We further used the description of interactions happening within different modalities to identify potential indicators of the quality of SSMR. The main contribution of this work lies within reflections related to how multimodal learning analytics techniques could be used to provide measurements of the aspects of interactions happening during socially shared metacognitive regulation. Our research contributes to the growing new trend in the field of learning analytics related to application of LA to support and understand SRL and SSRL. While there are many interesting ways in which data on interaction from different modalities could be used for evaluating SSMR in order to provide information on it to students or teachers, most of them paint a very incomplete picture of regulation. The risks of misrepresentation of actual regulatory processes through the use of data becomes smaller when datasets from different modalities are combined, but the merger of multimodal data poses a big technological challenge that is yet to be addressed by the LA field.

The message that we would like the readers to take from our study is that the line of research that aims to employ MMLA to support socially shared metacognitive regulation is promising and worth pursuing. In our work we described some ideas of how analytics could facilitate regulation, and even if those ideas are preliminary and need further validation, they show that the opportunities are there, they just need to be further investigated. We do not however remain uncritical towards the capabilities of learning analytics and want to emphasise that any picture of regulation or collaboration that will arise from the analysis of data, even multimodal data, will be representative only of some aspects of collaboration. The need for remaining critical and reflective towards the data should not be forgotten especially when MMLA enters the real learning environments.

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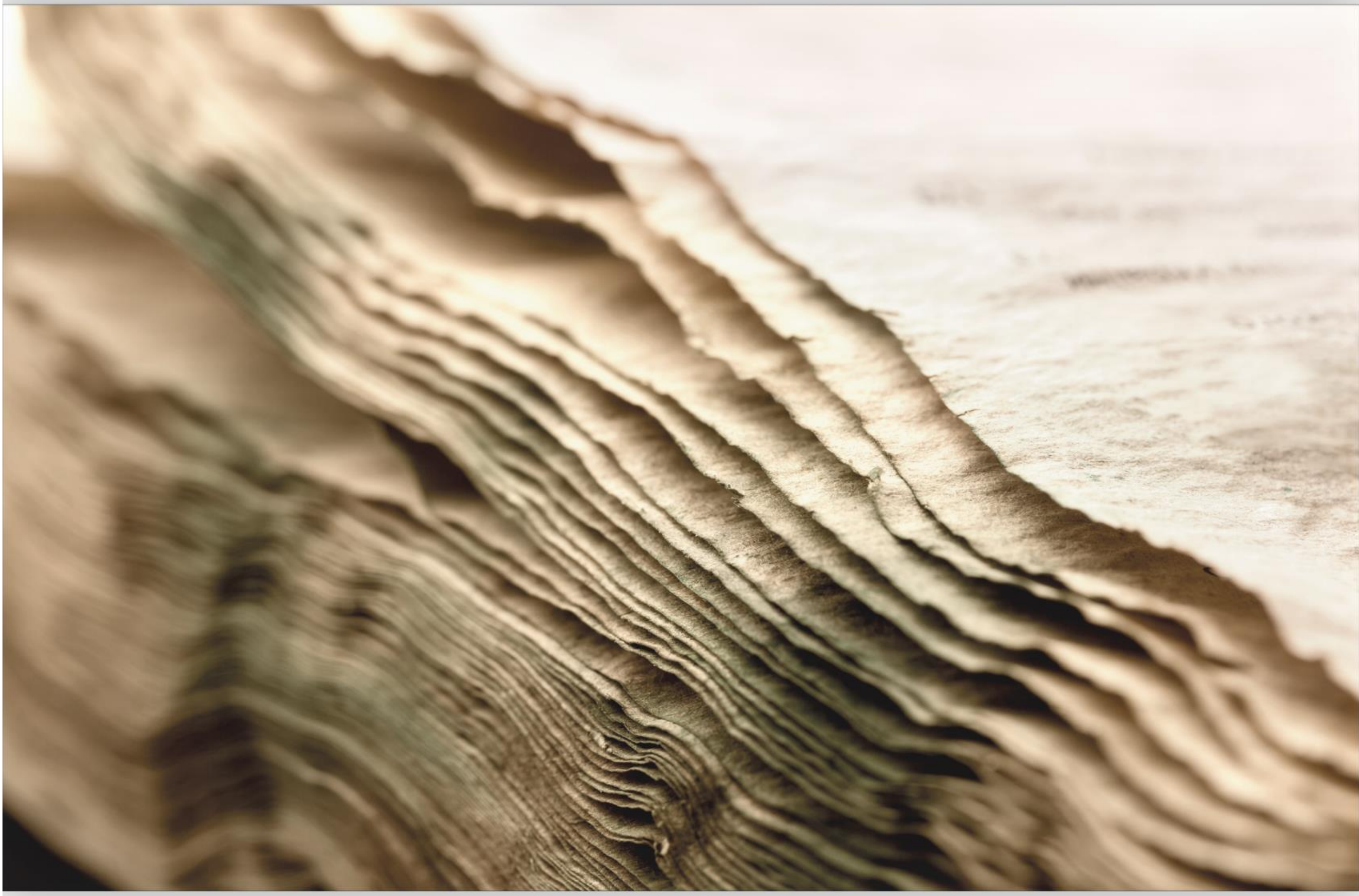

Appendices

5.1 Appendix one – Article

The article can be found using the following link:

https://drive.google.com/file/d/0B64aTjQ1g_-_YnNBWUpKS1MyV0k/view?usp=sharing

5.2 Appendix two – Macro coding

Day two – morning

Timestamp	Code (Frederik)	Description (Frederik)	Code (Daria)	Description (Daria)	
00:13	Planning/tools for planning	The group collaborates on planning the day, using the whiteboard is to keep a list of tasks to be done. One members writes on the board whilst the other discusses whom should do what, and when.	planning tools for planning	one of the team members is writing a list of topics to be researched while discussing the points to be included with others	
06:35			planning	one of the team members asking if anyone knows website with some specific information	?
07:40			planning	deciding on how to assign topics from the list - one of the member suggest for people to research topics they have most knowledge about, others agree	
09:18			planning	members discuss preparing question list and sending it to supervisor	
11:20	Planning	Whilst distributing tasks, the receiver of a task comments on her competencies regarding that specific task			
15:15	Planning/tools for planning	Tasks generally gets distributed based on whom is most capable of completing said task, though it seems that the member operating the white board takes on a leadership role and therefor asumes higher athority in the distribution			
13:00-15:20			planning/tools for planning	assigning topic to specific people, using whiteboard to point	

				to topics and writing down the names of reponsible group members	
15:40			monitoring	one of the members asking if anyone else checked some website	
30:00	Monitoring	During the work, members utilize each others understanding of the tasks to complete them sufficiently.			
34:38			planning	one of the Finnish members asking for information related to Danish history, one of the Danish people offers to search for it	
60:00	Monitoring/tools for monitoring	During one discussion, the members seems unable to find the needed information on the laptops and a members refers to some documents hanging on the wall in order to retrieve the information			

Day two - Afternoon

Timestamp	Code (Frederik)	Description (Frederik)	Code (Daria)	Description (Daria)
05:00			planning	longer planning discussion, among other things deciding to look at existing projects for inspiration
17:20			monitoring (?)	one of the members adds material to the board
18:00!!			evaluation/ monitoring	members discussing procudt done by one of them, someone saying that they expected it to be done differently
19:20	Evaluation	A group member shows of her completed task and comments on it herself,	evaluation/monitoring	everyone looking at the laptop screen of one of the group members, she explains what she has done and what problems she encountered

		she calls it rather basic		
20:45	Evaluation/tools for evaluation	the group uses the available documentation to understand the completion of the task		
22:00			monitoring	one of the members keeps walking around to see what others members have done so far
31:40			planning (?)	discussing which printoouts on the whiteboard are most important and removing some
33:50			monitoring	one of the members looking at a girl's screen while she talks about what problems she encountered and what she's going to do next (see 22:00)
42:35			planning	two members discussing what calculations need to be done and making plans to talk to the supervisor
56:30!!			planning	two members discussing what one of them could do next
1:07:00	Monitoring/evaluation	they evaluate each others understanding of the area in which they are to build the church	monitoring/ evaluation	members take turns talking about what they've done so far and getting feedback (only one presentation actually recorded)

Day three – Morning

Timestamp	Code (Frederik)	Description (Frederik)	Code (Daria)	Description (Daria)
6:00			planning	discussing the final goal, how to create design that can actually be put into life
25:00			planning	one of the members suggests working on concept instead of illustrations in order to have something to do over weekend
26:07			planning	group decides to make concepts individually and later put them together
26:30			planning	one of the group members will be busy over weekend, so the groups

				discusses how to deal with it - she should do as much as she can
27:36	Planning	The group plans sketching	planning	members agree that everone can decide to either sketch or describe (whatever is more comfortable)
28:40			monitoring	one of the members asks what else is to be done
29:00			monitoring/ tool for monitoring (?)	one of the members elaborates on what he is working on now with another member, points to what he has done so far on the whiteboard
29:40			monitoring	one of the members explains what she's done so far and why she's not done
35:00			monitoring	another members talks about what she's been doing so far; she's waiting for response from supervisor

Day three – Afternoon

Timestamp	Code (Frederik)	Description (Frederik)	Code (Daria)	Description (Daria)
04:00			planning	discussing how to continue with the projects - what kind of sketches
05:40			planning	group agreeing to sketch separately to get more ideas
07:40!!, 14:45			planning	group reading requirements out loud and trying to understand them
11:00			planning	group discussing how to deal with one of the member's dyslexia - what tools she can use to deal with this problem
18:15			planning	discussing what needs to be done next, which diagrams need to be done first as they're needed for other tasks
20:05	Monitoring	a group member helps another in finding the right documentation for her task		

5.3 Appendix three – Textual transcript

Day two – Morning

Context:

The group is distributing tasks to the different members, at the point of transcription the group is deciding on how to distribute the tasks in the most meaningful manner.

Timestamp	Embodied interaction	Spoken language
7:02	C: Scratches his neck whilst whilst looking at D and E and changing his posture from slumpy to upright. E acknowledges his gaze and statement with a swift nod	C: Eeh(.1) i saw yesterday that people were using some
7:04	C: puts emphasis on “sites” by putting out his hands	C: sites D: -yeah
7:06	C: changes his gaze to A and B whilst fiddling with his pen E: Supports C’s statement with an audible “heeh” and by redrawing slightly from pc.	C: I haven’t had any clue(.2) like(.3) before(.2) E: *heeh..*
7:11	C: looks at whiteboard and then back at B	C: Sooo(.1) I guess(.3)
7:14	C: changes his gaze to D and E E: smiles back at C D: nods his head	C: at least(.1) if we can use your knowledge about that *something inaudible* D: *yeah, of course*
7:17	C: changes his gaze back to B B: Smiles at C	B: *yeah*
7:19	C: looks back at whiteboard and points pen at it	C: *Eeehm.*
7:22	C: waves pen slightly around pointing at different topics on whiteboard D: scratches his forehead and lowers head whilst keeping gaze at whiteboard	C: These other kind of stuff that(.1) that we ha’(.1)
7:24	C: throws out hands D: repositions glasses	C:like we aaaall(.1)
7:26	C: points back at whiteboards and moves pen up and down	C: do- don’t have any(.2) any idea(.1)
7:28	C: Points pen back at forth from himself to B B: does not visibly react E: moves her gaze from screen to B	C: maybe we could take those(.1)
7:31	C: puts put hands and moves them up and down close to the table, tilts his head slightly to the left	C: and(.1) and like(.2)
7:34	C: Quickly changes gaze to E and then back to be. Changes movement of hands from up and down to left	Iiiifff(.1) any of you

	and right, whilst slightly shaking his head from left to right	
7:36	C: points back at whiteboard and moves hand up and down	C: Have any(.1) idea(.1)
7:37	C: Stops hand a specific point on the whiteboard and moves hand from left to right E: Nods ever so slightly B: looks at C	C: About these other things(.2) B: yeah
7:40	C: Changes gaze to E and nods a single time	C: like(.2)
7:41	C: Claps thigh and moves gaze from b onto the table and fiddles with object on the table E: nods again B: moves gaze onto E	C: use your special kiii.. skills(.8)
7:43	E: nods D: nods C: moves gaze to A and B	
7:45	B: looks at C, then turns neck backwards, and looks at A with her back turned to her, then looks back at C E: looks down at nails C: Smiles at A and B, stops smile once B looks back at him (at this point it seems like A is saying something but there is no auditory evidence of this)	A: *yeah*
7:49	B: changes her gaze from C into nothing	B: ii know some(.1) you(.2)
7:50	B: casually throws right hand and changes gaze onto A	B: for example that..(.1) C: *eeh(.2)-*
7:51	C: point at whiteboard	[C: Just say it out loud B: *Inaudible finish to sentence*]
7:52	C: moves hand to a chest-high position with palms facing down	C: -aaand weee(.2)
7:53	C: looks and down and then up again	C: ooor i(.1)
7:53	C: looks onto whiteboard	C: wont "reshow (slighty inaudible" that
7:54	C: Points to whiteboard and moves gaze from white to A and back again	C: And I will let something(.1)
7:56	C: moves hands from white board and changes gaze onto A and B	C: Which is(.1) already(.2)
7:58	C: moves gaze around the group and looks at everyone	C: eh(.1) unknown to everybody
8:01	B: smiles at C C: moves hands to table	B: *yeaaah, that would be okay*
8:04 – 8:08	C: looks around at the group and then at whiteboard B: looks onto whiteboard	(There is a break in the conversation)

8:08		E: eeeehm(.3)
8:09	C: moves gaze onto E B: moves gaze onto E	
8:10	E: Crosses arms and moves gaze away from the group unto a person entering the room C: follows gaze and looks into the room	E: should this(.1)
8:11	B: moves gaze unto room to see was is being looked at then moves gaze back at E C: moves gaze to E and then onto the whiteboard	E: material(.1)
8:12	E: looks upwards into the yonder C: moves gaze back onto E D: removes hands from keyboard, folds them and moves gaze from screen onto E	E: that weee(.2)
8:15	E: Moves both and in forward circles in front of her B: moves her mouth and exclaims an inaudible "yeah"	E: produce today(.1)
8:16	C: moves right hand to his mouth and leans onto the table E: the gesture continues	E: should it be in the report?
8:19	E: the gesture continues	E: or should we just(.1)
8:20	E: the gesture continues B: looks upwards and seems to be wondering	E: make some(.1) quick(.2)
8:22	E: the gesture continues	E: illustrations(.1)
8:23	E: right hand continues gesture, left hand moves out to the left	E: to shooow(.1)
8:25	B: nods heavily D: nods	E: to Anne- B: [**yeah,** that would be right
8:26	E: the gesture continues B: keeps nodding, though less heavily	E: *oooor]*(.1) in order to [decide(.1) B: *yeeah*]
8:27	E: the gesture continues B: keeps nodding	E: what they should [look like B: yeah
8:29	E: moves hands from one side to the other D: nods	E: When] we place them in the report D: *yeah*
8:31	B: moves her hands across the desk in a gesture C: moves gaze to B D: moves gaze to B	B: Maybee(.1) we just(.1) eeeeh(.1)
8:34	E: nods	B: Have all the material that we can(.1) do(.1) today(.1)
8:36	E: nods	B: And then we can show and discuss
8:38	B: moves hands up and down whilst imitating typing	B: and then we can(.1) make those(.1)
8:40	B: moves hands to table E: nods D: nods	B: Findings E: **yeah**

8:41	E: continues nodding B: nods D: nods	E: [that would B: that would be really(.1)
8:42	E: nods B: nods	E: be great B: effective]
8:45	B: looks from D to C	C: yeah (.1) [But (.2) B: we should really] focus on materials
8:47		B: yeah(.2)
8:48	C: looks onto the table and points pen at the table	C: End(.1) end of the daaaay(.2)
8:49	C: moves to a more upright position	C: Should we have(.1) still(.1)
8:51	C: moves his hand to gesture a virtual object on the table	C: some kind of list(.1) of questions
8:53	B: nods E: nods C: smiles at E and then at B	E: [yeah B: yep…
8:54	B: moves her hand towards C with the palm facing upwards	B: yeah. but]
8:56	B: looks at C C: picks up cantina	B: the end of the daaay(.1) we have(.1)
8:57	C: stair lowers suddenly and he hits cantina unto table	B: to do a summary(.4)
8:58	Everyone moves gaze onto C B: laughs E: laughs D: laughs	
9:02	Everyone moves gaze back unto B C: smiles at B B: gestures with her hands	B: End of the day we have done the research(.1)
9:04	C: drinks from cantina whilst holding eye contact with B E: fiddles with her face	B: like(.1) as far(.1) as we can(.1)
9:06	E: looks onto her hands C: finishes drinking and nods slightly	B: sooo(.1) I think theres(.1) going to be questions(.1)
9:09	C: looks back onto B	B: *alot of questions*(.1) *after that*(.2)
9:13	B: looks onto E E: looks away and nods	B: I guess(.3)
9:16	C: puts down cantina and picks up pen B: moves gaze onto C E: looks at her nails	C: Yeah yeah but(.1) like at(.1) at the end day
9:18	C: Points to the whiteboard with pen and moves it up and downwards in large strokes	C: we will(.1) do something similar(.1)
9:21	C: makes a throwing gesture with the pen E: moves gaze in the direction of the whiteboard	C: and we will send it(.1) to Anne
	D: looks away from the group into the rooms	

9:22	E: nods slightly B:nods	E: [yeah B: mmmmmhh
9:24	C: moves gaze to E	C: and(.3)]
9:25	C: looks backwards into the room to see what D is looking at, then looks back at the group E: looks at nails then back at C	
9:26		C: then she won't be mad
9:28	B: smiles at C C: smiles at E D: smiles and nods at B and laughs slightly E: smiles and laughs at C	A: yehesh
9:30	C: smiles and B and then moves gaze onto E	C: it's a good start!

After this, the groups start talking about the supervisor and how to approach her.

Day two – afternoon

Context:

Group members decide to talk about what they have been working on throughout the day
(My take: The group has been sitting and working, we come in as the is loosing concentration and several members have stopped doing what they should be doing. C is looking at the whiteboard, A is standing and stretching and D is sitting with his arms crossed looking into the yonder.)

Timestamp	**Embodied interaction**	**Spoken language**
1:06:45		D: Should we talk about
1:06:46	B: moves her gaze from the computer onto D and moves from a slumped posistion to an upright position C: moves his gaze onto D	D: what *becomes slighty inaudible* (sounds like: "Or analyse some more")(.5)
1:06:48	E: moves her gaze onto D and then onto A C: looks around at the other members B: moves her gaze from D onto the whiteboard	
1:06:50	C: makes a throwing gesture with his right hand and smiles	C: naaaaaaah(.2)
1:06:52	D: imitates the throwing gesture made by C A, B and E: smiles and laughs	

1:06:54	D: picks a piece of fruit out of a plastic bag A, B and E: looks around whilsts still laughing. C: looks around at the other members and makes a gesture towards the whiteboard	C: I think everybody did it (.2) yeah propably (.2)
1:06:58	C: takes off his headphones A: sits does E: sniffs	
1:07:00	B: sits down and positions herself in a way that will allow her to C: looks onto the whiteboard and then back at the other members	C: Who wants to start?(.1) D: *eeehmm* (.3)
1:07:03	A and B: turn towards the whiteboard B and C: moves their gaze onto E D: Makes a facial gesture, seems like he cannot see the whiteboard	E: I can start (.1) Mine is (.) very short.
1:07:06	C: tries to look at the whiteboard over B's shoulder A: turns towards the whiteboard B: turns her gaze towards the whiteboard D: puts on glasses	E: Eeem (.1) The site is placed in aaaa (.2) in the middle of (.1)
1:07:14	C: moves gaze onto E	D: nowhere
1:07:16	B, C and D: look at E and smile	E: Nooo (.1) there is housing (.2) eeeeh
1:07:20	B and C: turn back to the whiteboard D: starts picking an orange	E: on (.1) every (.1)
1:07:22	C: yawns and crosses arms B: turns gaze to E and smiles D: still picking the orange and looking at a little stack of peels that has formed on the table	E: sssside (.) of the (.1) site (laughs)
1:07:24	C: turn to look at E D: looks back up onto the whiteboards	E: Sooo (.2) it's a place
1:07:27	B, C: turn to look at the whiteboard	E: wheeere (.2)

1:07:30	B: turns gaze onto E and then back to the whiteboard D: continues stacking peels and looks back at them	E: people **could** meet (.1) yeah (.2)
1:07:34	C: turns to look at E	E: and it (.1) lies next to a (.)
1:07:36	B: turns her gaze onto E	E: stadium (.) and... two schools and some
1:07:40	B: turns to look at whiteboard C: turns to also look at whiteboard	E: industries, so (.1)
1:07:43	B: turns to look at E C: also turns	E: it could (.1) beeee (.) a place where (.2) there are different people (.2)
1:07:50	B: nods B: points at E	B: yeah (.1) and also it's came to mind
1:07:52	B: points to specific picture on the whiteboard	B: because theres a school, so maybe it should be
1:07:53	B: stops pointing and turns towards E	B: some (.1) when (.1) parents are still where (.) they could go there [E: yeah B: after E: yeah]
1:08:03		B: and meet (.) friends from other schools also (.1)
1:08:05	B: turns to the whiteboard and points	B: and also (.1) or was it this guy (.) eeehm (.1) for young people, and this for (.) old people (.1) or was it there (.1) [was there similar (inaudible) E: eeehm]
1:08:16	E: looks at her laptop to check information B: keeps looking at E	E: I think (.1) it'sss (.1) this iiiiis (.1) eeehm
1:08:37	E: keeps looking at her screen D: moves closer to look at E's screen A, B, C: looking at D and E	E: Ungdomsskole (borderschool)

Group starts discussing school system in Denmark to help international members of the group understand some aspects.