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Investigating self-regulation in Finnish junior high school mathematics classes: a learning analytics case study

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Abstract: Self-regulation refers to a student's ability to approach tasks actively, strategically and in a goal-oriented manner. This study investigates the ways Finnish junior high school students self-regulate their learning in mathematics and proposes ways to support self-regulated learning. The study is a case study mixed-methods research that uses learning analytics to consolidate and analyse data. Twenty 8th grade students were taught the concept of per cent for three lessons using the digital materials developed for this study. Students' perceptions were collected with a questionnaire, and their interactions with the materials were captured into trace logs. Cluster analysis revealed students used five learning tactics and three different learning strategies to learn about per cent. The results show that students enjoyed the freedom to regulate their learning, but some lacked the necessary skills to use the available learning resources effectively. For this issue, teachers could use specific interventions or improve the entire learning environment to foster self-regulated learning. The study shows promise in combining questionnaire and trace logs to study self-regulated learning.

Keywords: self-regulation, self-regulated learning, case study, mixed-methods research, learning analytics

Suomenkielinen tiivistelmä: Oppilaan itsesäätelyllä tarkoitetaan kykyä lähestyä tehtäviä aktiivisesti, strategisesti ja tavoitekeskeisesti. Tässä tutkimuksessa tarkastellaan, millä eri tavoilla suomalaisen yläasteen oppilaat säätelevät oppimisprosessiaan matematiikassa ja miten itsesäätöistä oppimista voidaan tukea. Tämä tutkimus on monimenetelmällinen tapaustutkimus, jossa käytetään oppimisanalytiikkaa yhdistämään ja analysoimaan dataa. Tutkimuksessa kahdellekymmenelle 8. vuosiluokan oppilaalle opetettiin kolmen oppitunnin ajan prosenttilaskun perusteita käyttäen tutkimuksessa kehitettyä digitaalista materiaalia. Oppilaiden käsityksiä omasta itsesäätelystä kerättiin kyselyllä, ja heidän vuorovaikutuksiansa opetusmateriaalien kanssa tallennettiin tapahtumalokeihin. Klusterianalyysin perusteella oppilaat käyttivät viisi oppimistaktiikkaa ja kolme erilaista oppimisstrategiaa oppiakseen prosenttilaskennasta. Tuloksien perusteella oppilaat pitivät heille annetusta vapaudesta säädellä oppimistaan, mutta joiltakin oppilailta puuttuivat tarvittavat kyvyt käyttämään kaikkia tarjottuja oppimisresursseja tehokkaasti. Tähän opettajat voivat yksitellen puuttua oppilaiden toimintaan taikka kehittää koko oppimisympäristön tukemaan itsesäätöistä oppimista. Kysely- ja tapahtumalokidatan yhdistäminen itsesäätöisen oppimisen tutkimuksessa vaikuttaa lupaavalta saatujen tuloksien valossa.

Avainsanat: itsesäätely, itsesäätöinen oppiminen, tapaustutkimus, monimenetelmätutkimus, oppimisanalytiikka

Preface

"Huh, what's the point of that?"

That was the thought that sparked the original concept for this thesis a whole year ago. At that moment, I was completing my teacher practice remotely and was looking at the digital book for high school mathematics. After a worked example, there were two buttons, "I understand this" and "I don't understand". When pressed on the latter, the book suggested completing specific tasks. As an education technology student, this seemed lacklustre to me: "Surely more can be done to help students? It's digital material, after all!" After discussing a bit with the class teacher, Tero Hirvi, I thought I found an exciting goal: improving learning analytics in mathematics. This led me to a rabbit hole of learning analytics, self-regulated learning and digital material production, culminating in this pilot work.

Throughout all the work, my instructor Tommi Kärkkäinen aided me immensely by not only giving technical guidance on analysing data but also helping with acquiring the necessary server for study use. Thank you for always being there to help, even in these busy distance-working days.

I want to express special gratitude towards Tero Hirvi and Niina-Marika Rekiö-Viinikainen. Not only did they provide valuable feedback and helped to orchestrate the empirical part, they enormously aided in observations. Thank you for such great interest in and involvement in this work. Without you this wouldn't be half of what it is right now.

To Polina ja Jussi: thanks for putting up with my schedule; you're the best. Sorry for not coming to help with woodchopping every weekend. I'll try to make up for it.

In Jyväskylä on June 23, 2021

Denis Zhidkikh

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1 Introduction

By and large, contemporary education in Finland is considered high-quality (Reinikainen 2012; Välijärvi and Sulkunen 2016). The Finnish primary education heavily builds upon the constructivist theory and readily embraces novel approaches to pedagogy and educational technology. Lately, particular emphasis has been put on the entire learning environments present in a class and the whole school by promoting social and collaborative values (FNBE 2016b). These and other values of the Finnish primary school education are encompassed in the National Core Curriculum for Basic Education (FNBE 2016a).

One of such values that guides the design and didactics of a Finnish class is *self-regulated learning*. The Core Curriculum provides some guidelines on fostering self-regulation in students:

> The teacher [...] guides the pupils in the use of new working methods, strengthening their ability for self-regulation. (FNBE 2016a, chap. 2.3)
>
> Individual, group and communal working approaches support the pupils' [...] self-regulation. (FNBE 2016a, chap. 15.4.16)

However, while self-regulation is listed as one of the skills teachers ought to support in students, there is little information in the Core Curriculum on what doing so entails. At times, this has lead to confusion in requirements imposed on the students and, in turn, negatively affected students' and their parents' perception of education (e.g. Tolpo August 15, 2019).

Like with any educational concept, self-regulated learning must first be understood in the appropriate context before interventions can be applied. In turn, understanding self-regulation requires investigating and evaluating student behaviour. Many such methods exist, and learning analytics is one of them. Learning analytics is a relatively modern approach that allows capturing and processing a vast amount of student data. In their recent mapping study, Viberg, Khalil, and Baars (2020) note that learning analytics have not been used extensively in a junior high school context. At the same time, the use of learning analytics in mathematics has also been widely present but not overly diverse, with most studies done using cognitive tutoring tools (Ramli, Maat, and Khalid 2019).

This study aims to serve two purposes. First, it aims to provide insight into self-regulated learning in a Finnish junior high school by investigating first-hand when and where self-regulation occurs in students. Specifically, self-regulation in a junior high school mathematics class is chosen as a single specific learning context. Secondly, the study contributes to education technology research by examining how learning analytics can be integrated into learning materials. The core driving question of this study is: *How does self-regulated learning occur in Finnish mathematics classes, and how can the phenomenon be supported?*

It must be noted that self-regulated learning is sometimes mixed with self-directed learning. While self-regulated learning generally is more tied to a specific learning context, self-directed learning refers to a longitudinal process of planning one's learning path (Saks and Leijen 2014). This study concentrates on self-regulated learning as its concepts are part of the Finnish National Core Curriculum for Basic Education.

This study is positioned as a case study and is structured into six chapters. In Chapter 2, different theoretical approaches to self-regulated learning are presented, and the commonly used self-regulation measurement techniques are discussed. In Chapter 3, the essential pedagogical backgrounds of mathematics in Finland are discussed, and the development process for the learning materials used in this study is presented. In Chapter 4, learning analytics methods used in this study are introduced. In Chapter 5, the paper's case study approach is elaborated upon, research questions are presented, and the studied case is presented along with the analysis procedure based on techniques shown in previous chapters. In Chapter 6, results of the study are presented. In Chapter 7, a discussion of found results is carried out to answer the research questions. In the final chapter, conclusions are drawn, implications for educational practices and future research are considered.

2 Self-regulated learning

Self-regulation and self-regulated learning (SRL) theories were born near the '90s to attempt to explain how students approach their learning (Zimmerman 1986). As mentioned in the introduction, the concept behind it may be confusing despite the term being known. In this chapter, self-regulated learning is reviewed to create a base theoretical foundation for the study. First, self-regulated learning is defined through core literature. Next, standard models of self-regulated learning are introduced to understand how self-regulation occurs in students. Finally, measurements and supporting interventions for self-regulated learning are inspected through recent studies in the field.

2.1 Defining self-regulated learning

Self-regulated learning refers to a learning process where students, guided by their metacognitive and motivational skills, set goals and adaptively employ various learning strategies to obtain desired academic outcomes (Zimmerman 1990; Winne 1995; Zimmerman and Moylan 2009; Schunk and Greene 2017). Self-regulated learning is viewed as a goal-oriented, cyclical, feedback-driven (Zimmerman 1990), proactive (Zimmerman 2008), strategic (Zimmerman 1986), social (Zimmerman 2005) and context-bound (Ben-Eliyahu and Bernacki 2015) process. In other words, in self-regulated learning, students set goals, plan out their learning, use learning strategies to learn both directly and socially and adjust their learning process based on feedback and changing learning conditions. On a larger scale, self-regulated learning is a belief that students' self-perception as a learner primarily dictates their academic achievement (Zimmerman 1986). The goal of self-regulated learning as a study field is thus to explain how students solve problems and learn in self-directed contexts (Zimmerman and Campillo 2003).

One of the core concepts of self-regulated learning is the usage of learning strategies. Most commonly, learning strategies are defined as actions one knowingly does to acquire information and skills (Zimmerman 1990). Such learning strategies are, for example, rehearsing and memorising, seeking assistance, seeking information and reviewing materials (e.g. Zimmerman and Martinez-Pons 1988). In that sense, self-regulated learning involves strategic planning – that is, choosing correct learning strategies and changing them according to the changing learning goals to reach academic goals effectively (Zimmerman and Moylan 2009). Some researchers suggest using slightly different terminology: for instance, Winne (2001) refers to processes and specific actions to aid learning as learning tactics, while learning strategies are plans to achieve desired academic goals by coordinating a set of learning tactics. Learning tactics are usually tied to the learning environment and thus are such atomic actions as creating, editing or removing notes, linking notes to each other, reading books or viewing instructional videos (e.g. Malmberg, Järvenoja, and Järvelä 2010). In this study, the more fine-grained tactic–strategy terminology is applied because of its more precise formulation.

The previous definitions bring out two aspects of self-regulated learning. Firstly, self-regulated learning can be viewed through motivational and metacognitive aptitudes. Secondly, self-regulated learning could be analysed through how a student carries out the learning process. Both viewpoints are considered next as each provides its framework for explaining self-regulation.

2.1.1 Self-regulated learning as aptitude

Zimmerman and Martinez-Pons were among the first researchers to link self-regulated learning to academic achievement in a natural learning setting. Having developed and tested the Self-Regulated Learning Interview (SRLI), they noted that highly academically achieving students possessed personal initiative, knew how they learned best, were able to adjust their learning strategies, engaged in learning both in and out of the classroom, and were socially active in obtaining both knowledge and feedback (Zimmerman and Martinez-Pons 1986, 1988). Describing the ideal qualities of a self-regulated learner as a means to define self-regulated learning is still used today. For example, Schunk and Greene (2017) summarise self-regulated learners as those who set goals, monitor their progress, and respond to their monitoring and external feedback to adjust their learning to attain said goals.

Winne and Perry (2000) suggested to group these attribute-based definitions and measures as *aptitude measures* of self-regulated learning. Viewing self-regulated learning as aptitude, single learning events and details can be merged into a bigger picture to detect the learner's beliefs and ability to carry out learning. This view can be seen in different questionnaire-based measures such as the earlier mentioned SRLI and Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al. 1991).

2.1.2 Self-regulated learning as an event

An alternative view of self-regulated learning is that of a process-oriented one. In addition to the aptitude viewpoint, Winne and Perry discuss self-regulated learning as an *event*. A self-regulated learning event is comprised of three phases: occurrence, where a learner begins self-regulation; contingency, where the learner makes use of learning tactics; and patterned contingency, where the learner arrays tactics into learning strategies (Winne and Perry 2000). Self-regulated learning is then seen as a collection of such events which have a beginning and an end and which are dependent on previous events (Zimmerman 2008).

Compared to the aptitude view of self-regulated learning, the event-oriented one emphasises learning tactics that students use. One of the first practical examples of event measures was the gStudy software. The software records learners' interaction with the learning material and has tools to detect how specific learning tactics manifested in each student's learning (Winne et al. 2006).

It must be noted, however, that neither event-driven nor aptitude-driven views are exclusive to each other. Both Winne (2001) and Zimmerman (2008) mention that both views complement each other both theoretically and empirically when evaluating students' self-regulated learning skills. Some studies have used both self-report or questionnaire measures and trace logs to study self-regulated learning in various contexts (e.g. Araka et al. 2020).

2.2 Models of self-regulated learning

The theoretical framework of self-regulated learning aims to model how students pick learning strategies and tactics, what cognitive elements are involved in the learning process, and how students adjust them based on feedback. Such models attempt to operationalise the concepts of self-regulated learning into measurable variables. Over the years, multiple models for self-regulated learning have emerged and affected this field of study. In his literature review, Panadero (2017) identified and described six models that conceptualise and measure self-regulated learning. While each model provides new insight, many of them are relatively similar to each other in that they follow the basic cyclical, feedback-oriented pattern mentioned earlier in the chapter.

Next, three core models of self-regulated learning are presented: Winne and Hadwin's, Pintrich's and Järvelä and Hadwin's. The models were chosen because of differences in modelling what can be self-regulated and how it occurs. The choice of the models was considered from the perspective of this study: as the goal is to investigate self-regulated learning through learning analytics, the models themselves should allow for multimodal measurement of both self-regulated learning as aptitude and as a series of events.

2.2.1 Winne and Hadwin: metacognition in learning processes

The model of Winne and Hadwin (1998) attempts to describe the process of studying and how student approach it strategically. Later, the model was explicitly described as a model of self-regulated learning with an emphasis on "self-regulation as event" view (Winne and Perry 2000). The overview of the whole model is depicted in Figure 1.

Winne and Hadwin's model addresses three core concerns: what factors that affect learning can be self-regulated, what the learning process involves and how self-regulation occurs. For the first concern, Winne and Hadwin (1998) provide five *COPES factors* that are present throughout the whole learning process: conditions, operations, products, evaluations and standards. *Conditions* include cognitive and task factors affecting the process. For an example of cognitive conditions, Winne and Hadwin assert that a person's prior knowledge or skill and their beliefs on the subject matter affect the learning process. On the other hand, task conditions are, for example, allocated time and available resources that affect what learning resources a student will utilise. *Operations* are single actions that the learner does and which are usually grouped into learning tactics and learning strategies. *Products* are the operations' results that can be divided into cognitive attributes and external measurable be-

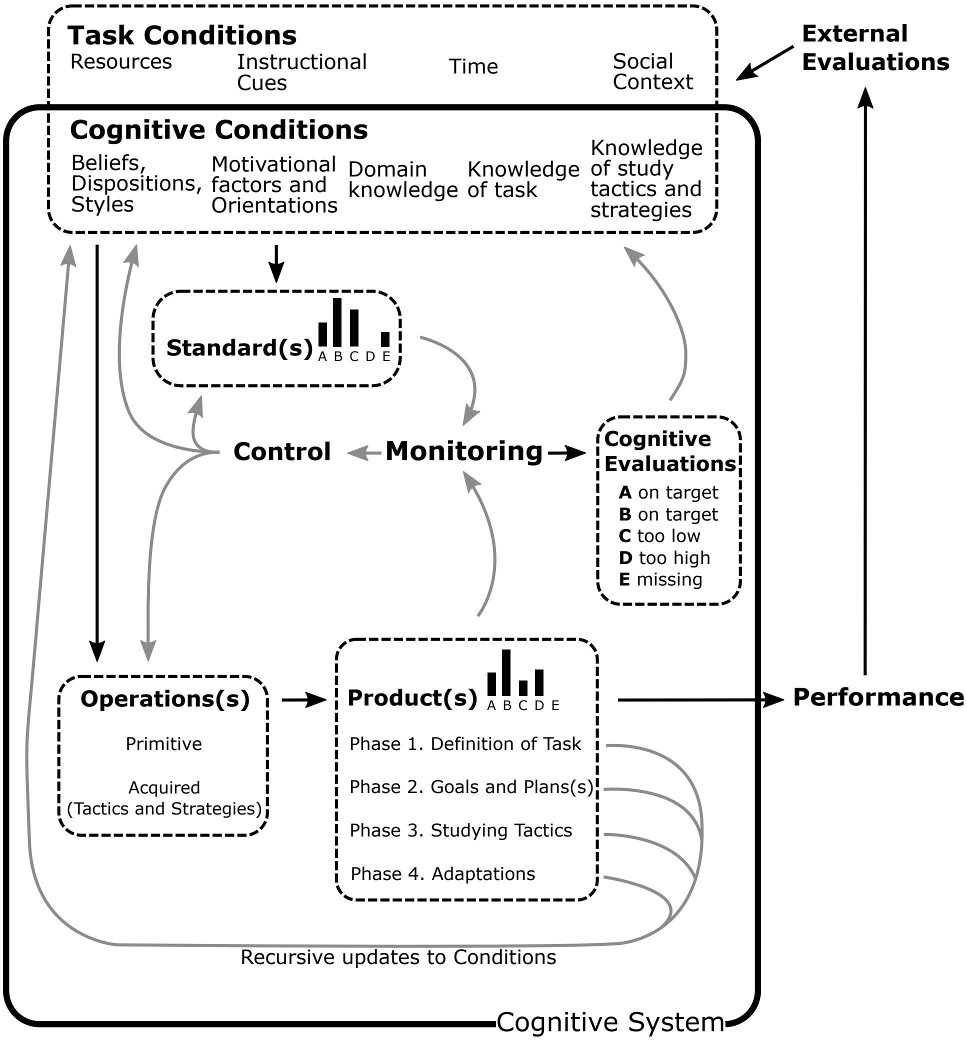


Figure 1: Four-stage model of self-regulated learning of Winne and Hadwin (1998) with visual colouring adapted from Panadero (2017).

haviours. *Evaluations* are created by comparing products to standards either internally via metacognitive monitoring or externally via receiving feedback. Finally, *standards* are sets of criteria depicting the ideal or optimal state. Crucially, Winne and Hadwin (1998) posit that these factors can be regulated and changed before, during and after the learning process.

For the second concern of how self-regulated learning is carried out, Winne and Hadwin (1998) provide a four-stage model that is recursive and weakly coupled. The model describes how a student carries out a task or a group of tasks. The model includes four stages: task definition, goal setting and planning, enacting study tactics and strategies, and metacognitively adapting studying. In the *task definition* stage, the student processes the task along with its conditions and builds a perception of the standards and goals set by the task. Task definition is done either by interpreting the task or inferring information from context. Next, in the *goal setting and planning* stage, the student analyses task standards and goals, after which they reframe them into personal goals and standards depending on their cognitive conditions. From there, the student builds an initial plan on which study tactics and strategies to use. In the *enacting* stage, the student applies the planned strategies, tactics and operations in order to create the required products. Finally, after creating the products, *long-term studying adaptation* occurs in which the student inspects both products and the whole process to adapt their future studying and perceptions to suit the task and subject matter better. The final stage here is thus to enact long-term changes in all of the COPES factors. In addition to long-term adaptation, Winne and Hadwin (1998) also note that quicker evaluations can occur during all the stages to self-regulate behaviour and tactics during the study process itself. This regulation of learning occurs via metacognitive monitoring and control, both of which are described next.

The final concern of how self-regulation manifests throughout learning is addressed in Winne and Hadwin's (1998) model via metacognitive monitoring and control. Metacognitive activity occurs in all the four previously mentioned stages and can dynamically affect all of the COPES factors. In their model, Winne and Hadwin view standards and products in term of attributes: standards contain a set of desired attributes (e.g. "the maths book should be read until page 39") while products are a set of attributes student has achieved through the use of planned operations (e.g. "I've read until page 30"). With this attribute-based view, Winne and Hadwin describe two continuous metacognitive activities that occur at every step of learning. In *metacognitive monitoring* (or simply *evaluation*), attributes of the task's standards are compared to the attributes of the current products. From that, *evaluations* are formed in term of discrepancies between standards and products. The student aims to reduce the discrepancies through *metacognitive control*: the student can *toggle* known study tactics on or off or change their operations in order to approach the task differently. Alternatively, students can *edit* their cognitions or standards in order to bring standard attributes closer to products. In other words, the student can either change their study tactics or change their perception of the task itself either positively or negatively to bring them closer to the products desired of the task.

In summary, the model of Winne and Hadwin attempts to build a clear and systematic description of self-regulation as a metacognitive process. They emphasise that standards are both inferred from tasks and formulated from student's cognitive conditions. Standards can change throughout the task, which can prompt reformulation of conditions and adjust used learning tactics. Their model calls for active evaluation methods where students' performance is monitored by observing their activities throughout the study. Computer-assisted evaluation methods such as trace logs allow to measure much of self-regulated learning as described by this model, especially if paired with aptitude-based questionnaires (Winne and Perry 2000; Winne et al. 2006; Malmberg, Järvenoja, and Järvelä 2010). Further, this model has allowed for looking at self-regulated learning as a sequence of events and analyse the temporal nature of learning tactics and strategies (e.g. Malmberg, Järvenoja, and Järvelä 2013; Matcha et al. 2020).

2.2.2 Pintrich: motivation can be regulated

While the model of Winne and Hadwin provides a fairly rigorous explanation of self-regulated learning, it does not directly address student motivation. In contrast, Pintrich (2000, 2004) approaches self-regulation through motivation theories and introduces an alternative grouping to what can be regulated and how it occurs. The conceptual framework for self-regulated learning of Pintrich describes sixteen areas of activities involved at different times and on different levels that comprise self-regulated learning. These activities are grouped into four phases of learning and four areas of regulation to form a matrix depicted in Table 1. Each activity area is based on empirical evidence obtained from real classrooms (Schunk 2005). Next, the core concepts of the model are summarised: what factors can be regulated, how the learning process is modelled, and how self-regulation of it occurs.

The conceptual framework of Pintrich (2000) introduces four distinct areas of self-regulation: cognition, motivation and affect, behaviour, and context. The first three areas Pintrich (2000) bases on the traditional areas of psychological functioning summarised by Snow, Corno, and Jackson III (1996). *Cognition* refers to student's perception of their knowledge, skill, judge-

	Areas of regulation			
Phases	Cognition	Motivation/Affect	Behaviour	Context
1. Forethought, planning and activation	- Target goal setting - Prior content knowledge activation - Metacognitive content activation	- Goal orientation adoption - Efficacy judgements - Ease of learning judgements - Perceptions of task difficulty - Task value activation - Interest activation	- Time and effort planning - Planning for self-observations of behaviour	- Perceptions of task - Perceptions of context
2. Monitoring	- Monitoring progress toward goals - Monitoring learning and comprehension - Metacognitive awareness	- Awareness and monitoring of motivation and affect	- Awareness and monitoring of effort, time use, need for help - Self-observation of behaviour	- Monitoring changing task and context conditions
3. Control	- Selection and adaptation of cognitive strategies	- Positive self-talk - Extrinsic and intrinsic motivation adjustments - Defensive pessimism and self-handicapping	- Increase/decrease effort - Persist/give up - Help-seeking behaviour	- Change or leave context
4. Reaction and reflection	- Cognitive judgements - Attributions	- Affective reactions - Attributions	- Choice behaviour	- Evaluation of task - Evaluation of context

Table 1: Phases and areas of self-regulated learning adapted from Pintrich (2000) and expanded based on regulation tactics presented by Pintrich (2004). Each cell represents a set of activities that regulate each area throughout the learning activity.

ments, and feelings of learning. In practice, the area is related to the learning tactics and strategies that students make use of to regulate their cognition (Pintrich 2004). *Motivation and affection* refer to student's judgements of ease of learning, evaluations of task value and difficulty and general self-efficacy. *Behaviour* encompasses intentional and observable actions related to learning. Finally, Pintrich (2000) adds *context* as an additional area of self-regulation to emphasise the social aspect of self-regulated learning: the area refers to the perception of a task's nature, general perceptions of different types of tasks and knowledge of the learning environment in the classroom. The core contribution of the framework is the assertion that all of these areas are possible to regulate. The finding that especially student's motivation is regulatable can be considered as one of the main differences between other models of self-regulated learning (Schunk 2005; Panadero 2017). However, Pintrich (2000) reminds that while regulation of motivation is possible and has been observed empirically, it does not imply that students can or will regulate it automatically.

In the framework, the self-regulated learning process itself is separated into four distinct phases: forethought, monitoring, control and reaction. For brevity, the phases are next presented paraphrased and elaborated from original definitions of Pintrich (2000). In the first phase, *forethought and planning* occurs as students plan out their learning, set goals and formulate perceptions of the task and context. Next, during learning, students activate *monitoring* processes for the four regulation areas. Students then proceed to employ *control* activities in order to control the regulation areas. Finally, the long term *reactions and reflections* occur in the four areas to guide future work. Compared to the model of Winne and Hadwin (1998), the phases in the Pintrich (2000) framework play a lesser role: the phases describe learning as a whole instead of just a single task, the phases do not necessarily follow the presented order, and regulation activities of multiple phases can occur concurrently (Pintrich 2000; Pintrich, Wolters, and Baxter 2000). For example, a student can continuously monitor and control their motivation while employing a single cognitive task to persevere towards the goal. On the other hand, a student may not need to control motivation. Instead, they might constantly control their behaviour to find the best learning tactic for the task at hand.

In comparison to the model of Winne and Hadwin (1998), the framework of Pintrich (2000) approaches the process of regulation in a more multifaceted fashion. Pintrich (2004) emphasises that in the framework, self-regulation is not a separate activity or area, but rather it occurs in all areas on multiple levels. In addition, the framework does not provide a single general metacognitive monitor or control process to describe self-regulation. Instead, regulation of each area is considered separately; in Table 1, each column describes regulation activities for the given area throughout the different phases of learning. For example, when students regulate their motivation, they create perceptions of a task's difficulty and activate their self-efficacy judgements. Students then monitor their level of motivation during the task, control it by, for instance, encouraging themselves through positive talk or, conversely, by encouraging them to perform better by outlining how poorly they perform (so-called defensive pessimism) (Pintrich 2000, 2004). Finally, students reflect and react to task outcome and performance. The same kind of regulation definition can be interpreted similarly for each of the regulation areas from Table 1. Thus, Pintrich's framework sees regulation occurring in each phase of learning through the use of specific tactics and strategies.

All in all, Pintrich (2000) provides a comprehensive and practical conceptual framework for self-regulated learning. Compared to the model of Winne and Hadwin (1998) in which there is a clear relationship between the factors and the learning process, this framework appears more abstract in describing the process of self-regulated learning. Instead of specific relations, all areas of regulation and the phases of learning are interconnected: regulation occurs in each area and every phase via various tactics. The framework appears to be less about the process and more about the regulation in general, in which case it can be assumed to represent the "self-regulated learning as aptitude" view. In practice, the framework has been as a basis for the Motivated Strategies for Learning Questionnaire (MSLQ) that allows measuring the level of motivation and self-regulated learning in a classroom (Pintrich et al. 1991; Pintrich et al. 1993). MSLQ was and is continued to be used as a measure for self-regulated learning in both elementary and higher education contexts (e.g. Pintrich 2004; Zimmerman 2008; Araka et al. 2020).

2.2.3 Järvelä and Hadwin: socially shared regulation of learning

From the descriptions of the previous models and self-regulated learning as a concept in general, it is clear that social context has a vital role in the learning process. Students rarely learn everything alone, and for instance both Winne and Hadwin (1998) and Pintrich (2000) mention help seeking as a learning tactic. However, neither models consider deeper social contexts such as group work or collaborative learning in general. To describe the role of self-regulation in collaborative environments and for the sake of completeness, the recent model of Järvelä and Hadwin (2013) is presented next.

Coming from the research area of computer-supported collaborative learning, Järvelä and Hadwin (2013) initially proposed a general conceptual framework to distinguish different

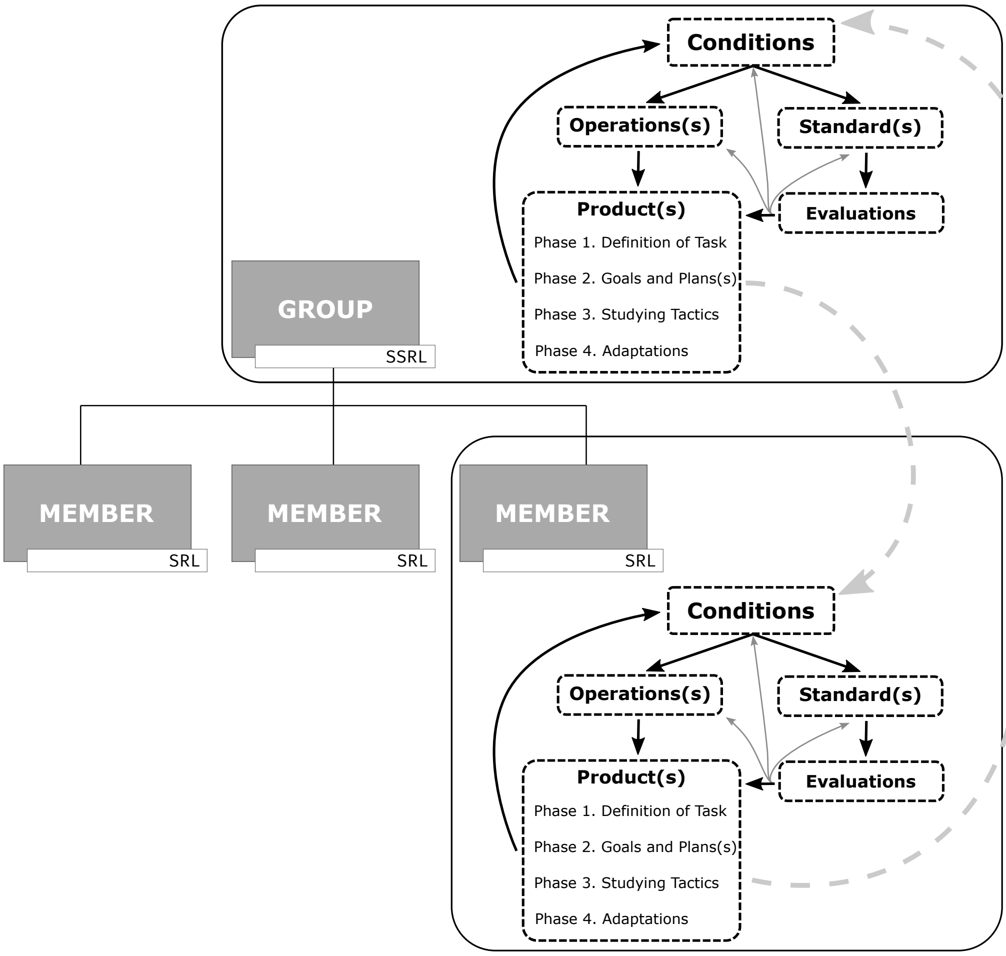


Figure 2: Model of Socially Shared Regulation of Learning of Järvelä and Hadwin (2013) describing the relationship between different levels of regulation of learning. Diagram adapted from Hadwin, Järvelä, and Miller (2017) and updated to depict better how evaluations affect products via updates to standards and operations.

levels of regulation of learning in collaborative learning environments. While the initial framework conceptualised regulation of learning on a general level borrowing general descriptions of Zimmerman (2008), the more recent iteration presented by Hadwin, Järvelä, and Miller (2017) is a direct extension of the COPES factor model described in Section 2.2.1. The core difference between the two lies in different layers of regulation: while the original model of Winne and Hadwin (1998) only is concerned with self-regulation, Järvelä and Hadwin (2013) consider the COPES factors on both personal and group level. Interactions between personal and group-level COPES factors are depicted in Figure 2. In this section, the questions of what factors can be regulated, what the learning process includes and how regulation occurs are answered in the same manner as for the COPES factor model.

In this model, three different types of regulation of learning are defined: self-regulated learning (SRL), co-regulated learning (CoRL) and socially shared regulation of learning (SSRL). *Self-regulated learning* refers to learner's regulation of their learning and involves invoking personal planning, task enacting and reflection strategies (Hadwin, Järvelä, and Miller 2017). Self-regulation occurs when a student carries out their role as part of a more complex group task – it is the "I" level of regulation in a group (Järvelä and Hadwin 2013). In turn, *socially shared regulation of learning* (or just *shared regulation*) refers to the whole group regulating task perceptions and goals (Järvelä and Hadwin 2013). Shared regulation is a balanced process where all groups members regulate on cognitive, metacognitive, motivational and emotional level (Panadero and Järvelä 2015). The general factors and processes of shared regulation are similar to that of the self-regulatory COPES factor model (Hadwin, Järvelä, and Miller 2017). In shared regulation, students do not have to regulate each other – it is genuinely the "we" level of regulation (Järvelä and Hadwin 2013). Finally, *co-regulated learning* (or just *co-regulation*) refers to students stimulating regulation of each other, commonly via interactions in the group (Hadwin, Järvelä, and Miller 2017). It can be seen as awareness of other student's goals and progress and as temporary support of another student's regulation (e.g. by delegating or sharing task effort) (Järvelä and Hadwin 2013). Co-regulation often occurs when there is a need to redirect some of the regulation areas temporarily, for example, in order to clarify the task criteria, evaluate the work of a group member or check the available resources (Hadwin, Järvelä, and Miller 2017). It is a more unbalanced type of regulation where some group members regulate other members – it is thus the "you" level of regulation (Järvelä and Hadwin 2013; Panadero and Järvelä 2015).

Therefore, the process of regulating learning in collaborative contexts involves interoperation between self-regulation, co-regulation and shared regulation. Hadwin, Järvelä, and Miller (2017) outline that in collaboration, each group members create shared perceptions of the task and generate shared conditions. From that, each student regulates their learning towards achieving group effort. In turn, members' products affect the group's conditions (e.g. how much of the task is done), which affect the whole group's product and shape each member's conditions (cf. Figure 2). In a successful collaborative effort, shared regulation and self-regulation are intertwined with occasional shifts to co-regulation in order to monitor each others' process and to react to changed conditions (Järvelä and Hadwin 2013; Panadero and Järvelä 2015).

All in all, Hadwin, Järvelä, and Miller (2017) provide a simple, yet powerful extension to original model of Winne and Hadwin (1998). In practice, the model is still young, and there are still inconsistencies with the usage of certain concepts: for example, Panadero and Järvelä (2015) have demonstrated that concepts of co-regulation and shared regulation are sometimes understood as synonyms. Further, there is a call for more varied research on the topic. While mixed methods such as observations and questionnaires have been used (e.g. Panadero and Järvelä 2015; Panadero et al. 2015), usage of multimodal data sources and learning analytics are suggested to be used (e.g. Hadwin et al. 2010; Hadwin, Järvelä, and Miller 2017).

2.3 Measuring self-regulation in classrooms

Based on the previous descriptions and theoretical models, self-regulated learning is a multifaceted concept. Over the last few decades of the research field's existence, there has been a steady development in the set of methods used to study self-regulated learning. The development of such methods appears to align well with that of the general paradigm of self-regulated learning research. Zimmerman (2008) summarises this by defining research "waves": At first, self-regulated learning research concerned validation of the emerging theory via standard quantitative methods – this was coined by Zimmerman (2008) as the "first wave". Over time the research transferred to investigating learning in real-time authentic contexts with the help of online logging and self-report tools – Zimmerman (2008) called this the "second wave". In other words, measurement has developed from aptitude-centred methods (cf. Section 2.1.1) to more event-based methods (cf. Section 2.1.2). Next, different measurement tools for self-regulated learning are presented.

The first wave of self-regulated learning research primarily made use of questionnaires, interviews and surveys in order to validate the existing theory (Zimmerman 2008). This gave birth to various scale-based measures such as the Learning And Study Strategies Inventory (*LASSI*; Weinstein, Palmer, and Schulte 1987) and the Motivated Strategies for Learning Questionnaire (*MSLQ*; Pintrich et al. 1991). All of these and many others instruments use Likert scales and are analysed usually via correlation analysis or more general factor analysis to measure various areas of self-regulation like motivation and strategic learning (Roth, Ogrin, and Schmitz 2016). While questionnaires can be seen as first wave measures, they are still being used actively in self-regulation learning research thanks to their simplicity and robustness proven over time (e.g. Roth, Ogrin, and Schmitz 2016; Panadero, Jonsson, and Botella 2017). Finally, questionnaire instruments are still being developed: one of the newer questionnaire-based measures is the Online Self-regulated Learning Questionnaire (*OSLQ* Barnard et al. 2009). Additionally, for instance, Jansen et al. (2017) have combined multiple prior robust self-regulated learning measures like MSLQ and OSLQ into one single 53-item Likert scale instrument in order to measure the self-regulation process throughout a whole task (definition, goal setting, usage of strategies, regulation of strategies). All in all, questionnaires and similar self-report tools are some of the more common methods to study self-regulated learning even up to this day.

With the rise of online classrooms and emphasis on researching the self-regulated learning process in authentic scenarios, new research tools began gaining popularity in the so-called second wave of self-regulated learning research (Zimmerman 2008). Winne and Perry (2000) describe a set of event-based measuring tools used in the second wave: In *think-aloud protocols* students report immediate thoughts and cognitive processes while performing a task. With *error detection method* students are purposefully given partially faulty materials to observe how they process it. *Trace logs* that are logs of single actions (e.g. reading a page or watching a video) a student performs during a task can be used for self-regulated learning analysis. Finally, Winne and Perry (2000) note that classic *observations* of students is too a usable research method for self-regulated learning. In addition, Zimmerman (2008) gives mention to *structured diaries* as a long-term self-report alternative to think-aloud protocols and *microanalytic measures* which are short questionnaire-based tools to measure specific and well-known self-regulatory processes before, during and after the task. Thus, compared to tools of the first wave, these methods attempt to look at self-regulated learning as it happens and capture student's immediate actions from which level of self-regulated learning can be analysed. The second wave tools are used extensively in online learning environments (Araka et al. 2020) and more methods utilizing latest computational tools are being developed (e.g. Saint et al. 2020; Li, Baker, and Warschauer 2020).

Recently, self-regulated learning research has been advancing in terms of data modality and new learning contexts. Usage of mixed-methods approach (e.g. Vaculíková 2018; Jansen et al. 2020), emphasis on self-regulation in mobile learning (e.g. Palalas and Wark 2020; Hartley, Bendixen, Olafson, et al. 2020) and especially use of self-regulated learning tools as both measures and interventions to foster self-regulation (e.g. Bellhäuser et al. 2016; Hartley, Bendixen, Gianoutsos, et al. 2020) are but single examples of different directions that have emerged this decade. Panadero, Klug, and Järvelä (2016) propose to view current developments as a new wave in self-regulated learning research: a "third wave" where the assessment of self-regulated learning is interwoven with methods of promoting self-regulation itself. Thus, contemporary research of self-regulated learning stems less from the need to understand self-regulation as a concept but rather to assess and support it in various contexts.

In summary, self-regulated learning is a concept that has been researched relatively well over the last three decades. Self-regulated learning is still of high interest to researchers due to the metacognitive, motivational and strategic aspects it entails. A self-regulated student can achieve not only their academic but also personal goals. As discussed in previous sections, self-regulated learning is well-defined, and there exist multiple models and measures of self-regulation. Moreover, the usage of online tools as both learning environments and tools to analyse the level of self-regulation allows for better assessment and more timely interventions to support learning. The ultimate goal of these tools is to capture students' self-regulation as both aptitude and process. However, self-regulated learning is also tightly bound to the context in which it occurs. In the next chapter, the pedagogy of mathematics in Finland is discussed to establish the context for self-regulated learning in this study.

3 Mathematics education

When it comes to various branches of science, mathematics is in a peculiar position: while one can learn and practice mathematics by itself, its real value is apparent in nearly every other science. Its usage is sometimes so subtle that it is likely no surprise that some – including the author of this work – have questioned how mathematics is ought to be taught. At the same time, education of mathematics in elementary and secondary education is in a particular position where taught concepts have not changed fundamentally in centuries (cf. Barwell 1913, 73). However, while topics have remained the same, the approaches to teaching them have shifted to align better with the current constructivist theory of learning.

As the different approaches to learning shape the learning environment and, in turn, the context where self-regulated learning occurs, understanding the context is vital. In this chapter, the core concepts of mathematics education are reviewed to understand a Finnish mathematics classroom and students better. This information is then used within the chapter to discuss creating digital learning materials suited for teaching mathematics. First, contemporary prevalent learning theories in mathematics are briefly outlined. Next, the core points of Finnish mathematics education are summarised. Finally, the previous information is applied to creating the digital learning materials used in this study.

3.1 Common contemporary directions in mathematics education

Historically mathematics education has long followed the general paradigms of pedagogy. Behaviourism had been prominently present in mathematics, with emphasis on learning by repetition and viewing mathematics from a purely formal perspective (Thompson 2020). Like with other subjects, a more constructivist view on mathematics pedagogy was eventually adopted and has been used since (Confrey and Kazak 2006). Once constructivism was adopted, its stance in mathematics was considered, which in turn prompted heated discussions on the nature of mathematics education (Steffe and Kieren 1994). This divergence of opinion caused divergence in both views on what mathematics is and how it is learned. Next, the current main directions in mathematics education are presented in terms of their core principles and effects in an average mathematics classroom.

Ernest (2010) summarises four current main ideologies on mathematics education: classical constructivism, radical constructivism, enactivism and social constructivism. Based primarily on works of Piaget, *classical constructivism* assumes that (1) knowledge is actively constructed by learners instead of being received passively and (2) that this implies information about reality is subjectively constructed without being able to attain the absolute truth (Lerman 1989). While the second assumption is a place for extensive debates for its implications on the nature of mathematics, practically, constructivism is often viewed in a positive light. For instance, constructivism emphasises learning mathematics by building on prior skills, adapting to students' needs, learning with problem-solving and putting attention to understanding misconceptions in learning (Thompson 2020; Confrey and Kazak 2006; Lerman 1989).

Radical constructivism expands on the second assumption of classical constructivism by asserting that there is no absolute knowledge in mathematics education (Glasersfeld 1974). Being one of the more extreme yet prominent opinions on constructivism, it emphasises the subjectivity of mathematical knowledge and mathematical education knowledge (Ernest 2010). From a practical standpoint, radical constructivism implies there is no absolute way to teach or learn a concept. Instead, radical constructivism encourages the development of didactics from practice: didactics are developed through teacher and design experiments instead of relying on ideology or pure mathematical formalism (Steffe and Kieren 1994; Thompson 2020).

Ernest (2010) also describes *enactivism* as one of the additional views on mathematics education. In enactivism, learning is posited to occur when learners are part of the learning environment and interact in it. While being one of the less explored ideologies, enactivism can be seen in practice via the usage of objects, environments and students themselves as part of a mathematics learning environment (Thompson 2020; Ernest 2010).

Finally, *social constructivism* emphasises role of human language and social constructs in both teaching mathematics and building mathematics itself (Ernest 1991, 42; Thompson 2020). While most social constructivist ideas in mathematics build on top of works of

Vygotsky regarding the social aspects of learning, there is no single base assumption for social constructivism (Ernest 2010). Nevertheless, social constructivism appears to be at the moment the most widely used paradigm in mathematics education research and practice (Lerman 2000; Confrey and Kazak 2006; Thompson 2020; Sriraman and English 2010). In a mathematics classroom, social constructivism can be seen in the emphasis on teacher-student relations and use of individual and group work tasks (Thompson 2020).

While principles of constructivism are now well established in mathematics education, there still have been developments in mathematics pedagogy over the last few decades. Most notably, with the appearance of computers and seminal work of Papert (1980), digital pedagogy is now strongly imbued into mathematics education (e.g. Tabesh 2018). Moreover, computational thinking, initially formulated by Wing (2006) is now actively studied and used in schools (e.g. Barr and Stephenson 2011). Computational thinking includes panoply mathematical skills such as abstraction, logical thinking, modelling skills, recognition of patterns and collaboration (Fagerlund et al. 2021). The developments notwithstanding, debates on how mathematics is to be taught have been going for decades and are still ongoing: from the role of the teachers, problem-solving and inquiry in a math classroom to the extent to which calculators and other information technology ought to be used (Ernest 1991). Even to this day, the role of constructivism and the need to "follow other educational fields" is discussed (e.g. Sriraman and English 2010). All this shows that while the current didactics are based on the constructivist view, pedagogical views can change with the coming of new ideologies and technologies. Next, the current core values of Finnish mathematics education are presented.

3.2 Mathematics education in Finland

At a time, the Finnish primary education system was ranked highly in international measures (Reinikainen 2012), and even though the results have not been consistent over time, they still can be considered relatively exceptional (Välijärvi and Sulkunen 2016). These high results can be attributed to the academic nature of teacher education: all primary and secondary school teachers are academically educated and hold a Master's degree (Niemi 2016); teachers are not taught specific didactics, but instead, they are given the freedom to build the learning environment how they see fit in their classroom (Toom and Husu 2016). Additionally, Finnish education is held in high regard on the national level, and there are constant pushes to develop educational practices and keep up-to-date with the latest paradigms in education (Välijärvi and Sulkunen 2016). This forward-mindedness creates an environment where education practices are ever-evolving and where basing one's pedagogy on research and evidence instead of pure ideology is encouraged. The current didactical practices that stem from such an environment are outlined next.

The general pedagogy of mathematics in Finland aligns mostly with current constructivist views. For example, Silfverberg and Haapasalo (2010) conducted multiple questionnaires on Finnish students' views on mathematics education and concluded that education practices vary from pre-constructivist (teacher chooses learner active but materials and methods) to learner-centred constructivist (learner active in all parts of the learning process). In addition, they noticed that usage of information technology in mathematics was present but varied from highly restricted task-specific use to giving learners complete freedom of choice. In the last decade, the use of information technology and mathematics has further improved. For example, the latest pushes for multiliteracy skills in education and digital pedagogy have advanced the use of digital tools in all subjects and, in turn, changed approaches to how all subjects are taught in a school (e.g. Kulju, Kupiainen, and Pienimäki 2020).

Like other subjects, mathematics in Finnish primary and secondary schools are taught by academically educated teachers who are given the freedom to implement the National Core Curriculum for Basic Education how they see it best. Over time, specifics related to mathematics education have been discovered and researched better to understand the learning environment of a Finnish mathematics classroom. Firstly, lessons are structured around routines, completing tasks and setting goals (Kaasila and Pehkonen 2009; Hemmi and Ryve 2014). In addition, Hemmi and Ryve (2014) found from discussions with Swedish and Finnish teachers that in Finland, teachers still prefer to play a proactive role in classes: lessons are often structured around short collective teacher-led presentations after which students complete tasks set by the teacher. Secondly, and at the same time, lessons are student-centric, with teachers tailoring tasks for different students and encouraging collaboration (Silfverberg and Haapasalo 2010; Kaasila and Pehkonen 2009). Thirdly, while there is freedom, many teachers use ready math books and specific didactical principles to teach mathematics (Krzywacki, Pehkonen, and Laine 2016). Finally, there is a high emphasis on student equality: there are no level groups, and instead, different levelled students are encouraged to work together (Krzywacki, Pehkonen, and Laine 2016; Boaler 2020).

One must note that while Finland has performed well in international student assessments such as the Programme for International Students Assessment (PISA), students' international ranking in mathematical skills has dropped down during the last decade (e.g. Saarela 2017, 14). This result is especially peculiar as, in general, junior high school students still perform well in other subjects despite the same underlying didactical values (Saarela 2017, 77–78). Such observation complements the discussions on whether mathematics education should be based on its ideology rather than following the current pedagogical trends (cf. Section 3.1). Crucially, the findings of Saarela (2017) on students' mathematical achievement in Finland emphasise the need to understand the underlying reasons for students' performance. As such, self-regulated learning theories may provide a glimpse into how Finnish students learn mathematics on a per-student level.

All in all, the Finnish mathematics classroom appears to be built on solid social constructivist standards: learner-centricity, inclusion and collaboration are present, and teachers base their choices on research. The use of tasks and goal-orientation form a prime learning environment to investigate how self-regulated learning manifests during class. On the other hand, as reported by studies, teachers' proactivity may imply that results cannot be easily hypothesised: since teachers still play a high role in mathematics education, students could lack the necessary skills for regulating their mathematics learning. Moreover, lack of level groups means that there is likely high variation in learning processes used by different students. Thus Finnish math classrooms create a context where measuring self-regulation of learning may provide very different learning results between learners. Finally, students' declining results in international measures further encourage understanding how students can learn mathematics.

3.3 Creating digital learning materials using Open edX platform

As mentioned in the previous section, written textbooks, workbooks and similar premade materials are an essential part of the learning environment in Finland: more than 80 % of teachers base their lessons on textbook materials (Mullis et al. 2012, 394). Moreover, usage of digital tools in mathematics education is on the rise in Finland, with more than 50 % of the students actively having access to computers in mathematics classes (Mullis et al. 2020, 495). This use of digital technologies in learning allows analysing students' ways of regulating their learning in various ways. For instance, student behaviour in mathematics can be analysed via event logs (Sun and Xie 2020; Valle Torre, Tan, and Hauff 2020; Jovanović et al. 2017), students' answers to tasks (Erickson et al. 2020; Long, Holstein, and Aleven 2018) and students' self-assessments (Tempelaar, Rienties, and Giesbers 2015; Tempelaar et al. 2018). Using the standard didactical practices of teaching mathematics in Finland as the base, digital materials were developed for this study due to different analysis possibilities. Next, the material design considerations and brief overview are presented.

For this study, an introduction into the calculation with per cent was chosen as the topic to be taught. The main reasoning for choosing such a topic was its simple nature, availability of ready materials and practical methodological reasonings (cf. Chapter 5). Before the material development, the pedagogical needs and assessment requirements were considered. Krzywacki, Pehkonen, and Laine (2016) list main features of a Finnish mathematics textbook: there are different types of materials for problem-solving; problems are divided into basic and advanced levels; the structure is logical and explicit; the book includes solutions for almost all tasks for self-assessment; exercises are varied between theoretical and applied, and there is room for students to advance at their own pace. Based on these criteria and review of currently used secondary school mathematics textbooks in Finland, the topic was divided into three sections: "definition of per cent", "computing p % of a value" and "per cent as a fraction". Different learning resources were developed for each of these topics, emphasising features commonly found in Finnish mathematics textbooks. All resources, their usage description and used sources are listed in Table 2.

In this study, Open edX[1] was chosen as the virtual learning environment where all learning

1. https://open.edx.org/

Learning resource	Description	Sources
Theory text	Regular text material present in most textbooks. Short but high level of abstraction and generally heavy on theory.	- Avoin matematiikka - Otavia courses
Videos	Video materials on the topic. Videos can contain both theoretical contents and worked examples. Videos contain visual aids and animations that text may not provide.	- Math.fi - Halu oppia - Opetus.tv
Worked examples	A task and a solution for it presented in text form. The solution shows the steps involved in solving the problem. The theory is presented via examples.	- Avoin matematiikka - Otavia courses - Self-produced
Simple exercises	Simple tasks that do not have a specific topic to them. Each task includes hints that suggest what theory to apply to the task. The system automatically evaluates every task, and students receive instant feedback for their answers.	- Avoin matematiikka - Self-produced
Advanced exercises	Exercises that require learners to apply and extend the learned knowledge. Includes more complex tasks and applied worded exercises. Hints are included where possible. The system automatically evaluates every task, and students receive instant feedback for their answers.	- Avoin matematiikka - Self-produced
Graded tasks	These tasks are written exercises that students must turn in before proceeding to the next subject. The teacher and the researcher evaluate graded tasks for each student.	- Avoin matematiikka - Self-produced

Table 2: Learning resources present in developed material along with their sources. The learning material consisted of three subjects in which all of the resources are present.

materials and tasks were hosted. The chosen environment is an open-source and community-supported release of the general edX platform. Open edX is highly configurable, simple to set up and in part localised to Finnish. More importantly, Open edX collects extensive trace logs and saves information about students' answers. Open edX includes various tools and task types made explicitly for mathematics courses, making the system fitting for creating digital learning materials. In the study, Tutor[2] – a minimal simple-to-install distribution of Open edX – was hosted on the university's servers so that all trace logs and user information is not stored externally.

Once the sources, learning resources and assessment criteria have been chosen and planned

2. https://github.com/overhangio/tutor

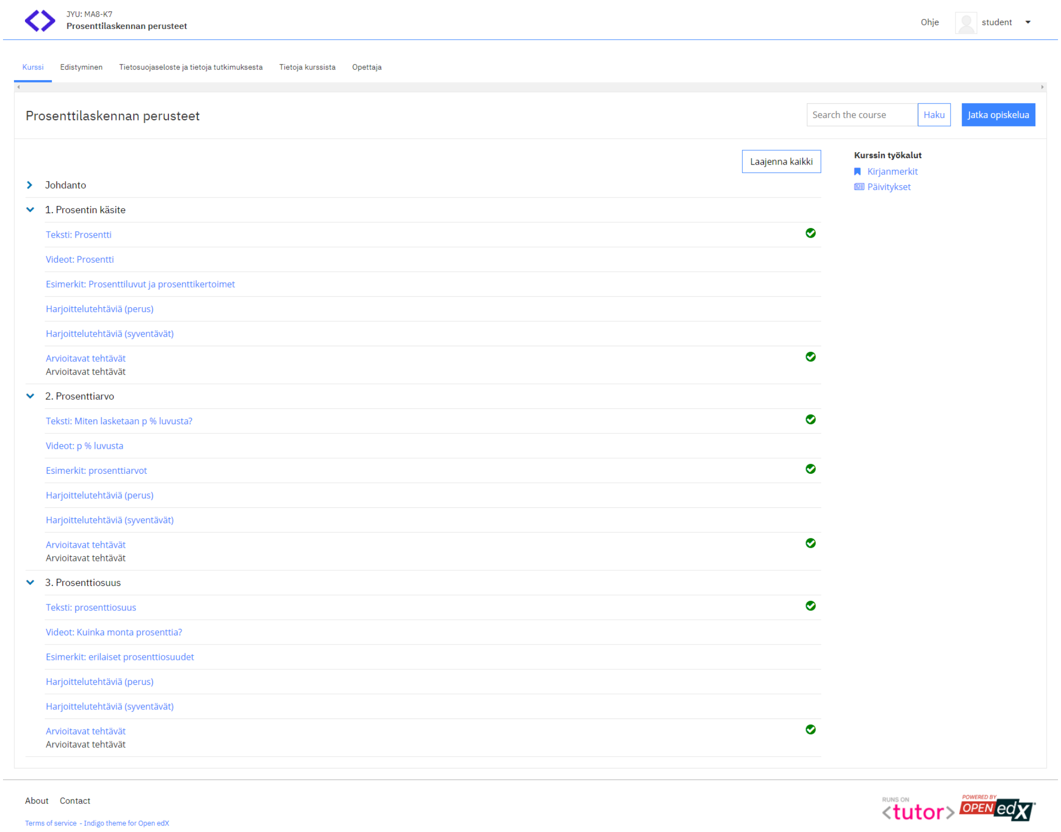


Figure 3: Example dashboard of the learning materials for a student. All topics are expanded to showcase the available learning resources.

out, the materials were implemented directly into Open edX. The developed course materials are available on GitHub[3] under the CC-BY 3.0 license. Figure 3 displays the final structure of the material. For each of the three topics, an Open edX section was allocated. In each section, every learning resource was added as a subsection in the same order as listed in Table 2. Finally, every learning resource was divided into multiple smaller units to groups similar texts or tasks together. Thus resulted materials resembled typical Finnish mathematics books as closely as possible.

An Open edX unit is the smallest part of a learning resource. An example unit is presented in Figure 4. Students can freely move between units within the same subsection (i.e. learning resource) using navigation buttons provided by Open edX. However, there is no clear inbuilt way to freely navigate between learning resources and subjects themselves as suggested

3. https://github.com/dezhidki/math-percent-edx-fi

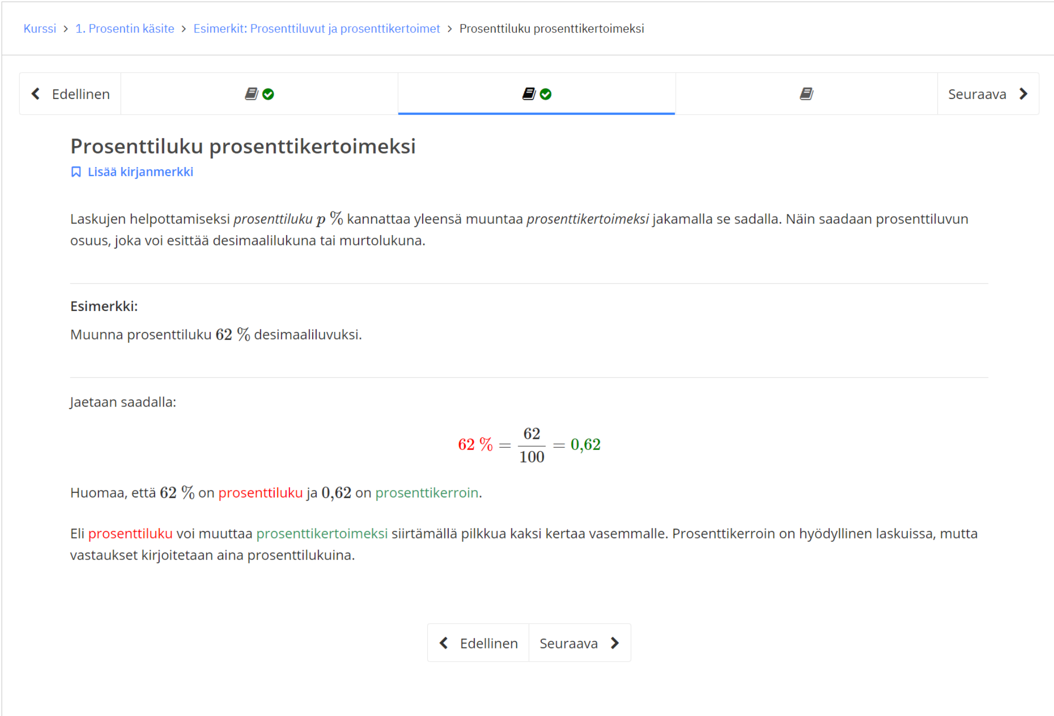


Figure 4: An example unit of the developed mathematics materials. A unit is a single part of a learning resource that a student can use. Open edX provides controls to move between units within the same section freely.

by Krzywacki, Pehkonen, and Laine (2016). To address this, an introductory section that demonstrates moving to resources via dashboard was added. In addition, a prompt text was added at the end of each last unit of each subsection. The prompt notifies a student that the learning resource is exhausted and that the student can choose another resource by going back to the dashboard. This approach allows students to be aware of the non-linear fashion of the materials and help them find the learning resource they want.

All in all, Finnish mathematics education can be described as primarily constructivist. Building learning materials according to the Finnish education principles is crucial as mathematics teachers generally rely on textbooks. At the same time, evaluating self-regulated learning must happen in authentic contexts as noted in Chapter 2. Open edX allows the collection of various data from student interaction with the virtual learning environment. Analysis of such data can be done via learning analytics which is discussed in the next chapter.

4 Learning analytics

Learning analytics (LA) refers to the process of collecting, analysing and reporting learner data to enhance the learning environment (Siemens 2013). Learning analytics can be used to aid in analysing learners via automated pattern discovery tools and providing helpful information for learners and instructors (Siemens and Baker 2012). LA mainly uses existing techniques such as data visualisation, prediction models, clustering, relationship mining, model-based discovery and data separation for its purposes (Avella et al. 2016).

In this chapter, learning analytics methods relevant to this study are presented. First, the general use of LA in self-regulated learning is briefly reviewed and standard methods used are noted. Next, analysis of the Motivated Strategies for Learning Questionnaire mentioned in Section 2.2.2 is discussed in more detail. Finally, analysis of trace event logs obtained from the Open edX platform presented in Section 3.3 is discussed.

4.1 Learning analytics in self-regulated learning

Learning analytics have been extensively used to detect and visualise self-regulated learning. In their latest mapping study, Viberg, Khalil, and Baars (2020) investigated the various ways LA is used in self-regulated learning studies. According to their findings, LA is often applied to data generated from a student–material interaction. Such data can be, for instance, trace logs, students' answers, and other assessments. Moreover, trace logs are analysed in various ways with the help of data visualisation, relationship mining and cluster analysis (Avella et al. 2016).

In the self-regulated learning context, learning analytics has different potential uses. For instance, Viberg, Khalil, and Baars (2020) note that learning analytics can improve teaching quality by helping in assessing course quality and enhancing learner support by visualising progress and providing instant feedback to the students. The usefulness of LA in evaluating self-regulated learning has been recognised, and various tools have been developed for this purpose. There exist general frameworks for carrying out trace log analysis such as Trace-SRL (Saint et al. 2020) and tools for adding ready analysis tools for known virtual learning environments like edX (Valle Torre, Tan, and Hauff 2020), Moodle (Lopes and Soares 2016) and Desire2Learn (Sun and Xie 2020). Additionally, there exist ready cognitive tutoring tools that are built with self-regulation visualisation support in mind, such as gStudy (Winne et al. 2006) and SoftLearn (Groba et al. 2014). In general, it appears that most tools for studying self-regulated learning revolve around analysing student behaviour via trace logs and analysing self-regulation from learning events. Thus, using the measurement terminology presented in Section 2.1.1 and Section 2.1.2, such learning analytics represent mostly "self-regulation as events" approach.

Learning analytics apply to studying self-regulation in mathematics as well. In their literature mapping study, Ramli, Maat, and Khalid (2019) summarise that learning analytics can be used in mathematics to help evaluate course quality, predict student achievement and provide means to visualise student progress. According to their findings, learning analytics in mathematics is mainly used in online settings, cognitive tutoring tools (special programs for studying a topic) and game-based learning (Ramli, Maat, and Khalid 2020). When it comes to the analysis of self-regulation in mathematics, analysis and clustering of trace data has been used primarily to find out students' learning profiles (e.g. Jovanović et al. 2017; Kim et al. 2018; Sun and Xie 2020). However, many studies of self-regulated learning in mathematics still rely on questionnaires instead of analysing student behaviour from learning events (e.g. Ramdass and Zimmerman 2008; Hodges 2009; DiGiacomo 2014). Nevertheless, questionnaire data can also be processed and enhanced with the help of learning analytics. Because of that, this study attempts to use both questionnaire and log event data as the basis for analysis to cover both "self-regulation as aptitude" and "self-regulation as events" views. In the next section, the analysis of MSLQ, a questionnaire used in this study, is discussed.

4.2 Analysing the Motivated Strategies for Learning Questionnaire

In this study, the Motivated Strategies for Learning Questionnaire (MSLQ) is used as one data source to analyse student self-regulation skills. MSLQ is a Likert scale (value range 1–7) questionnaire comprised of 81 questions to measure motivation and usage of learning strategies (Pintrich 2004). These questions are combined into derived scales that describe cognitive, metacognitive and resource management regulation skills. Combined, the scales

Scale	Items Comprising the Scale (Kontturi 2016, Appendix 1)
Cognitive and metacognitive strategies	
Rehearsal	8, 15, 28, 41
Elaboration	22, 31, 33, 36, 38, 50
Organisation	1, 11, 18, 32
Critical thinking	7, 16, 20, 45, 40
Metacognitive Self-Regulation	2 (reversed), 5, 10, 13, 23, 24, 25, 26 (reversed), 30, 45, 47, 48
Resource management strategies	
Time and Study Environment Management	4, 12, 21 (reversed), 34, 39, 42, 46 (reversed), 49 (reversed)
Effort Regulation	6 (reversed), 17, 29 (reversed), 43
Peer Learning	3, 14, 19
Help Seeking	9 (reversed) 27, 37, 44

Table 3: MSLQ scales and questionnaire items comprising the scale. Questionnaire items are adapted from Kontturi (2016, Appendix 1) with original scale of Pintrich et al. (1991).

of MSLQ measure students' perceived self-regulation skills in four areas of regulation: cognition, motivation and affection, behaviour and context (cf. Table 1). In this study, a modified version provided by Kontturi (2016) was used, which includes only 50 questions and measures only three out of four areas of regulation, leaving out the "motivation and affection" area. The modified version was chosen for it having already been translated into Finnish and its successful prior use by Kontturi (2016). The measured MSLQ scales and question items that comprise them are presented in Table 3.

The ways to use MSLQ vary between studies and can include simple descriptive statistics, visualisations and more complex statistic analyses (Duncan and McKeachie 2005). In this case study, MSLQ is used to group students by perceived self-regulation skills. In this case, one can use cluster analysis which groups each data points together by their similarity (Aggarwal and Reddy 2014).

Cluster analysis thus works by computing similarity between data and grouping the points based on the similarity measure. Such similarity measure depends on the number of data points and the type of data to analyse. Most importantly, normality and the size of data affects the choice of analysis methods. MSLQ is a pure Likert scale tool, and this is a case study with a relatively low number of participants (cf. Chapter 5). As such, the distribution of students' MSLQ scores may deviate from the commonly assumed Gaussian distribution. Because of that, measures based on normality may not be as reliable (Huber and Ronchetti 2009, 1–2; Hettmansperger and McKean 2010, 1). One must note, however, that normality assumptions of Likert scales depend on the researcher: while some consider low-range Likert scales not normally distributed (e.g. Saarela and Kärkkäinen 2017; Wu and Leung 2017), others do not see it preventing the use of classic statistical measures for analysis (e.g. Carifio and Perla 2008; Norman 2010). Nevertheless, to increase the reliability of the results in this study, the analysis will be done using robust methods which are more susceptible to deviations from normal distribution while still providing reasonable efficiency (Huber and Ronchetti 2009, 5–6).

All in all, the analysis of MSLQ is carried out in this study using cluster analysis and robust methods. First, MSLQ scales for each student are computed using Table 3. Next, basic descriptive statistics for all scales are computed. In line with using robust measures, the spatial median is computed instead of the data mean. The spatial median is a robust multidimensional measure that approximates the mean of a data set and that has multiple preferable statistical properties in addition to its robustness (Kärkkäinen and Heikkola 2004; Hämäläinen, Jauhiainen, and Kärkkäinen 2017). Finally, computed scales are clustered using agglomerative hierarchical clustering (Aggarwal and Reddy 2014, 103). The ℓ_1-norm is used instead of the usual Euclidean norm to increase the robustness of clustering. Both fitting cluster count and linkage type are determined from a dendrogram since both parameters may depend on data used (Aggarwal and Reddy 2014, 101–102). Final clusters are labelled, and students within clusters investigated.

4.3 Analysing self-regulation via trace logs

In this study, event logs are obtained from the Open edX virtual learning environment that was presented in Section 3.3. Open edX saves all student events as JSON objects that contain relevant information about the event, such as event type, timestamp, student identifier and additional event metadata. A simplified example of an event produced by Open edX is presented in Figure 5. Once the whole log is obtained, each Open edX event is converted

```json
{
  "name": "edx.ui.lms.link_clicked",
  "time": "2021-01-13T14:05:08.824351+00:00",
  "username": "example_user",
  "session": "bd554446a67c26f273f779c0e4a51e3f",
  "page": "/courses/course-v1:JYU+Test+2021_K1/course/",
  "context": {
    "user_id": 3,
    "course_id": "course-v1:JYU+Test+2021_K1"
  },
  "event": {
    "current_url": "/courses/course-v1:JYU+Test+2021_K1/course/",
    "target_url": "/course/course-v1:JYU+Test+2021_K1"
  }
}
```

Figure 5: An example event produced by an interaction of a user with Open edX. Each event is given its unique name with additional helpful metadata. Some metadata related to the user's browser and page accessed was omitted from this example for clarity.

into a triple `(usr, event, timestamp)` where `usr` is the student's unique number and `timestamp` is the time at which the event occurred. Each `event` code is derived from Open edX event name and metadata according to Table 4. All triples are saved into a CSV file for the discovery and clustering of student behaviour.

Event logs are used in self-regulated learning studies to discover students' learning strategies, group and link them to academic outcomes (Zimmerman 2008; Winne and Perry 2000). In such an approach, event logs capture event occurrences, and the goal of the analysis is to attempt to infer contingence and patterns to gain insight into used learning tactics (cf. Section 2.1.2). As grouping and pattern detection is involved, one way to approach analysis is by clustering trace logs to discover students' behaviour patterns. Generally, trace log clustering can be done in various ways. For example, Ferreira and Gillblad (2009) propose a method in which clustering can be done on unlabelled data (that is, a simple stream of event codes). Most other approaches instead attempt to represent a trace as a n-vector and cluster it using distance-based clustering with a specialised distance metric (e.g. De Medeiros et al. 2008; Bose and Van Der Aalst 2010; Jovanović et al. 2017). This study makes use of a combined approach of Jovanović et al. (2017) and Matcha et al. (2020) who attempt to discover used

Event	Event code	Open edX event name or RegEx pattern	Description
E_1	assignment	.*/handler/upload_assignment	Student completes a graded assignment and uploads it to the system.
E_2	help_seeking	-	Student receives instruction or help from the teacher. Student receives help either for a specific task or gets general instruction for the topic.
E_3	task_basic_correct	problem_check	Student answers correctly to a basic ungraded task.
E_4	task_basic_incorrect	problem_check	Student answers incorrectly to a basic ungraded task.
E_5	task_advanced_correct	problem_check	Student answers correctly to an advanced ungraded task.
E_6	task_advanced_incorrect	problem_check	Student answers incorrectly to an advanced ungraded task.
E_7	task_hint	edx.problem.hint.demandhint_displayed	Student opens a single hint message for an ungraded task.
E_8	see_answer	problem_show	Students opens the correct answer display for an ungraded task.
E_9	video_play	play_video	Students plays a video.
E_{10}	video_pause	pause_video	Students pauses a video.
E_{11}	video_seek	seek_video	Students seeks a video to some location.
E_{12}	video_stop	stop_video	Students stops a video or a video ends.
E_{13}	theory_text	.*/courses/course-v1	Student clicks on a link that points to theory text.
E_{14}	worked_example	.*/courses/course-v1	Student clicks on a link that points to a worked example.

Table 4: Table of captured actions from Open edX event logs or external observations. Each event code corresponds to an Open edX name captured from JSON data presented in Figure 5.

learning strategies by discovering and clustering specific learning tactics. The method is outlined in more detail next.

Once events have been extracted, specific learning sessions are formed for each student. A learning session is a sequence of consecutive event occurrences that are not too far apart from each other. Jovanović et al. (2017) nor Matcha et al. (2020) specify criteria for determining "close" events. First, because events are expected to be collected during a mathematics class (cf. Chapter 5), a cut-off value for learning session duration is chosen to be half of the class' duration to account for students taking at least one break. In other words, if the time between two consecutive events is lower than the cut-off value, events are included in the same learning session. Next, too short learning sessions are removed by rejecting sessions with just one event. Finally, learning sessions more prolonged than the 95th percentile of all captured session lengths are removed as well as suggested by Jovanović et al. (2017).

After learning sessions are captured and processed, they are converted into a first-order

	E_{start}	E_1	E_2	E_3	$\cdots$	E_{14}	E_{end}
E_{start}	0	1	0	0	$\cdots$	0	0
E_1		0.1	0.9	0	$\cdots$	0	0
E_2			0	0.25	$\cdots$	0	0
E_3				0.3	$\cdots$	0.7	0
$\vdots$					$\ddots$	0	0
E_{14}						0	1
E_{end}							0

Table 5: An example of a first-order Markov model matrix M that represents a single learning session. Events $E_1, \ldots, E_{14}$ represent possible events listed in Table 4 and E_{start} with E_{end} represent session start and end. Each cell represents a probability for an event to occur after another event. In this example, probability for event E_2 occur after event E_1 in an event log is $P(E_2|E_1) = M_{E_2,E_1} = 0.9$.

Markov model (FOMMs) representation. In a first-order Markov model, a learning session is represented as a triangular matrix. In such a matrix, each cell represents the probability for two events to occur consecutively. An example of a FOMM of a learning session in this study is depicted in Table 5. Based on the example, let

$$\mathscr{E} = \{E_{\text{start}}, E_1, E_2, \ldots, E_{14}, E_{\text{end}}\}$$

be a group of all possible events presented in Table 4 along with special nodes E_{start} and E_{end} that represent start and end of a learning session. For each learning session, a FOMM matrix is approximated by first computing transition frequencies between every consecutive event and writing the frequencies into a triangular matrix M. After that, every row of the matrix is scaled so that

$$\sum_{E' \in \mathscr{E}} M_{E,E'} = 1$$

for every event $E \in \mathscr{E}$.

Having FOMMs formed, they can be clustered into groups. Following the methodology suggested by Matcha et al. (2020), the Expectation Maximisation (EM) algorithm is used for clustering here. EM is used to solve probabilistic models in which data points are assumed to be taken from some Gaussian distributions (Aggarwal and Reddy 2014, 61). While EM is considered a reasonably novel model for analysing event logs (Saint et al. 2020), its main attraction is that they are reasonably flexible, and there is no need to choose or develop a distance metric for it (Aggarwal and Reddy 2014, 5). Resulting clusters represent specific *learning tactics* which describe specific action patterns used by a student (cf. Section 2.1).

The discovered learning tactics are then used to build each student's learning profile and to group these into final learning strategies. For this, process presented by Matcha et al. (2020) is carried out as is: Let

$$TA = \{ta_1, ta_2, \ldots, ta_{K_{\text{tactics}}}\}$$

be a set of learning tactic clusters. For each students, their learning profile is represented as a $(K_{\text{tactics}} + 1)$-vector

$$(taN_1, taN_2, \ldots, taN_{K_{\text{tactics}}}, \Sigma taN)$$

where taN_i is a number of student's learning sessions that belong to the learning tactic ta_i and

$$\Sigma taN = \sum_{i=1}^{K_{\text{tactics}}} taN_i.$$

These profile vectors are clustered using agglomerative hierarchical clustering same way as the MSLQ scales. Final clusters then represent groups of applied learning tactics which can be considered *learning strategies* (cf. Section 2.1). These strategies can then be labelled and further analysed.

In conclusion, learning analytics represents a set of tools to analyse learner data and generate useful visualisations from them. In this chapter, the primary learning analytics tools and analysis processes used in this study were presented. However, exact data analysis methods depend on the methodology the study follows. The study's methodology and the technical tools used for the analysis are discussed in detail in the next chapter.

5 The study

The core goal of this study is to understand how self-regulated learning occurs in Finnish mathematics classes and how self-regulation can be supported there. This research problem was chosen to be approached as a case study. While case study can often be considered as a flexible and easy-to-adopt method (e.g. Simons 2012, 23), systematic and scientific approach to it requires rigour (Yin 2018, chap. 1). More importantly, the choice of case study as leading methodology itself ought to be elaborated on.

In this chapter, the design and technical specifics of this study are discussed. First, methodological considerations are presented, and the chosen study type is described. Next, the context of the study, such as timeframe, participants and place, are introduced. Finally, the study procedure is detailed in terms of used materials, used learning environment, collected data, and analysis methods applied to the obtained data. The case study design and report structure is based on guidelines of Yin (2018).

5.1 Background of the study

While the research of self-regulation in mathematics is not novel, the context of a Finnish junior high school mathematics education using learning analytics appears less explored. There indeed have been some works exploring self-regulation in Finnish junior high schools (e.g. Myllymäki 2011; Kontturi 2016; Harjupatana 2020), however none of the found works approached self-regulation from a learning analytics standpoint in mathematics. As presented in Chapter 1 and Chapter 3, Finnish mathematics education is high level and guides students towards independent and creative use of mathematics. Given these goals, it becomes interesting to understand how self-regulated learning transforms into concrete learning actions and how those can be supported further.

To answer the questions in a timely and detailed manner, the choice of a proper methodology is crucial as it shapes which and to what extent questions can be answered, and it gives means for other researchers to interpret the results (Clark, Lotto, and Astuto 1984; Burton 2002). The need to elaborate on methodological choices is significant for information technology and education technology research fields where methodological analyses frequently are left out as often-used quantitative approaches are assumed not to require methodological discussions (Case and Light 2011). In this study, the choice of methodology requires special care as the study theme is cross-cutting: the study combines mathematics education, self-regulated learning and learning analytics research. Here, the research problem was chosen to be approached as a mixed-methods theory-driven case study. Next, justifications of the chosen stance are laid out.

On a high level, the study approach was chosen to be empirical. While there is theoretical research into self-regulated learning, it often concerns conceptualising and modelling self-regulated learning (cf. Chapter 2). As self-regulated learning itself bears its origins from cognitive psychology research (Saks and Leijen 2014), theoretical results ought to be backed by empirical data. Moreover, the context of Finnish junior high school mathematics classes is still less explored in terms of self-regulated learning. Given the practical research problem and new context, it is reasonable to seek the answers through empirical research to build theory on top of factual data.

When it comes to collecting data, there is a common dilemma of choosing between quantitative and qualitative methods as they bring their own set of methodological considerations (Twining 2010). When it comes to self-regulated learning, the models presented in Chapter 2 use both method types when studying self-regulation in students. While the COPES factor model of Winne and Hadwin (1998) implied usage of live event-based self-report measures and observations, the conceptual framework of Pintrich (2000) called for questionnaire-based factor analysis of different self-regulation aspects, and a recent model of shared regulation of Järvelä and Hadwin (2013) has been applied to both learning analytics, diaries and observations. As this study aims to capture a detailed description of self-regulatory processes in a mathematics classroom, it was chosen to view it from the perspective of all three models. This choice requires an approach where quantitative analytical student data to describe self-regulation processes and qualitative description of the surrounding context are obtained and studied jointly. This research approach is often described as a *mixed-methods research* where both quantitative and qualitative approaches are integrated in order to answer the set research questions (Clark and Ivankova 2016). Mixed-methods research couples qualitative observations with quantitative data to enrich interpretations of numbers and complement limitations of just applying a single approach (Johnson and Onwuegbuzie 2004).

Finally, a leading specific methodology should be considered that directs data analysis and justifies the final study setup. Given the explorative nature of the research questions along with the social and context-tied nature of self-regulated learning, *case study* methodology was adopted. The case study research is an approach where a particular instance of a class of contexts, phenomena or people are studied with rigour in order to understand the case better or to draw generalisations (Hammersley and Gomm 2011). Case studies are generally applicable to researches where there is (or there is a need for) little behavioural control, and the studied phenomenon is contemporary (Yin 2018, chap. 1). Both requirements are fulfilled here: the goal of the study is to describe self-regulated learning in an authentic mathematics classroom, and self-regulated learning itself is a relevant topic in mathematics as shown in Chapter 3. Moreover, case studies have often been used to collect insights on a policy or approach in an authentic environment in order to advocate for more general practices (Flyvbjerg 2001). In that sense, this study aims to fulfil such a goal: to advocate for or against learning analytics in junior high school mathematics to understand students better and support their learning. Finally, the mixed-methods approach adopted here is fitting of case studies which often are designed to collect and analyse different kinds of data (Simons 2012, 14; Yin 2018, chap. 2).

In summary, this study can be classified as an empirical case study that utilises a mixed-methods approach in collecting necessary data. With this choice, the study's design issues and considerations can surface. Especially when designing the study as a case study, one also adopts a set of methodological issues within. Next, these points are presented and addressed.

5.1.1 Case study design considerations

Yin (2018, chap. 1) outlines five core research concerns of case studies that are discussed next in the context of this study. First, case studies can suffer from *lack of rigour* owing to being too open-ended without following a proper systematic design. In this study, rigour is induced by using a straightforward research procedure outlined by Yin (2018) and Simons

(2012) along with separately assessing this study's validity. Following and related, case studies *may lack research aspect* and thus become a simple description of cases. This study uses known researched self-regulated learning measures, has a clear description of analytical methods, and considers limitations of the results, ensuring this study is proper research. Additionally, case studies often have issues with *generalising conclusions*. However, various case study design literature notes that generalizability of case studies is no more special than generalizability of any study (e.g. Simons 2012, 164; Yin 2018, chap. 1); as such, the goal is to generalise theories and provide results for further generalisation. The fourth concern is related to the perception of *level of effort required to describe the case*. According to Yin (2018, chap. 1) this often comes from mixing case studies with ethnography or narrative analysis. In this study, this is accounted for by using a clear and concise case and methods reporting style suggested by Yin (2018, chap. 6). Finally, the question of *comparative advantage* relative to other research methods is posed. Here, the choice of case study as a leading methodology has already been discussed: case studies allow to concentrate on a single case and study it in detail to provide insights on the chosen phenomenon.

Finally, the usage of the case study approach opens up new prospects for evaluating the study. As with other empirical studies, there are quality considerations for case studies as well. Yin (2018, chap. 2) emphasises the need to evaluate *construct validity* (how well concepts are operationalised and measured), *internal validity* (how well causality between concepts if measured, if there is one to measure), *external validity* (how well the findings can be generalised), and *reliability* (how well results can be repeated with the same study design). These quality considerations ought to be addressed at various points of the study to improve the trustworthiness of the findings (Simons 2012, 127). The choices to ensure the validity of this study are summarised in a later section after study choices are presented. Moreover, similar validity concerns are discussed when study's limitations are explored.

5.2 Research questions

As presented in Chapter 1, this study's goal is to understand better the nature of self-regulated learning in junior high school mathematics classes. In order to structure the study, the research problem is subdivided into three core research questions:

RQ1 How is self-regulated learning present in a junior high school mathematics class?

RQ2 What learning strategies and tactics students can employ to learn a new mathematics concept?

RQ3 How can usage of self-regulated learning strategies be supported in a junior high school mathematics classroom?

The questions were formulated to emphasise the study's exploratory nature: "how", "why" and exploratory "what" questions are the ones that case studies often address (Yin 2018, chap. 1). The first two questions, RQ1 and RQ2, are studied empirically using learning analytics tools presented in Chapter 4. Finally, RQ3 concerns combining answers of RQ1 and RQ2 with current knowledge of junior high school education to exploratively seek possible solutions to support detected learning strategies and self-regulated learning in general.

5.3 Case description

For this study, the studied case unit was chosen to be a junior high school mathematics class. The study was designed as a single-case embedded study: the picked class represents the case while the students become subcases. A single case study is often fitting for common cases or when the nature of the study is longitudinal – that is, the case is studied from multiple aspects (Yin 2018, chap. 2). Both criteria apply here: for this study, a standard junior high school class was searched to capture authentic self-regulated learning, and self-regulated learning is studied using multiple models of self-regulation presented in Chapter 2. Additionally, the choice is practical: time constraints and usage of different learning analytics techniques for in-depth analysis of a single case were considered reasonable justifications for a single-case study. Choice of a single case is also often justified if the provided data is enough to answer the research questions (Simons 2012, 25). In other words, in this study, studying a single case is balanced by using a multitude of data collection measures and multiple background theories to investigate self-regulated learning from different perspectives.

The selected case consisted of twenty 8th grade students. All students were from the same class studying in the Teacher Training School of the University of Jyväskylä. The teacher training school was chosen for multiple reasons. Firstly, each student in the school is given

Lesson	Main topic	Goals given to students
1	Definition of per cent	- Go freely through the first subject - Do graded tasks for subject 1
2	Computing p % of a value	- Check feedback for previous graded tasks - Do graded tasks for the first subject if they are not done - Go freely through the second subject - Do graded tasks for the second subject
3	Per cent as a fraction	- Check feedback for previous graded tasks - (30 min) Go through the third subject and do at least three ungraded tasks - (30 min) Do graded tasks for the third subject

Table 6: Table of all lessons conducted for the study. At the start of each lesson, students were briefed on the day's topic and goals for the lesson. After that, students were allowed to interact with the materials to achieve the set goals freely. Goals were different from day to day based on observations and discussion with the teacher.

a tablet that they use for studying, which means that data collection needed for learning analytics can be done for each participant without special arrangements. Secondly, students' mathematical skills and willingness were discussed with the class's mathematics teacher and the students to ensure the class skill level is heterogeneous and students themselves are willing to participate in the study. Thirdly, the school is part of a university, which simplified communication and practical arrangements for the study. Finally, the Teacher Training School does not favour any students when enrolling them, which means that the attending students are demographically similar to those of any other local city school. These choices can be considered valid for instrumental case studies in which case selection is guided by the opportunity to collect desired data (Simons 2012, 30).

During the study, students learned about computations with per cent for three 75-minute lessons in spring 2021. The topic was chosen from the class' curriculum after discussing with the class teacher so that the collected data came from authentic lessons. The development process and design considerations for the materials used in the lessons are presented in Section 3.3.

Before the first lesson, the researcher handed out a note of research (Appendix A), instructed students on how to log in to Open edX and provided initial guidance on using it. Additionally, students completed the Motivated Strategies for Learning Questionnaire described in Section 5.4.1 before the first lesson. During the three primary lessons, the class was briefed on their general progress at the start of each lesson. After the briefing, goals for the current lesson were presented. Each lesson's topic and goals are presented in Table 6. After instructing on the lesson's goals, students were allowed to interact with the virtual learning environment and materials freely. Students were given the freedom to follow the general pace or to work on their own. Students were also actively encouraged to seek help from instructors when needed.

The researcher's role in case studies is crucial to decide as it can affect data collection (Simons 2012, 36). During the lessons, the researcher participated as a co-instructor to ensure the virtual learning environment is used optimally and collect observations. Student help was given classically on a one-on-one basis. Simultaneously, the researcher observed how many students worked in groups and what kind of group work it was. The researcher briefly noted the observations for later comparison with the quantitative data. Co-instruction was chosen to aid students faster and because it allows the researcher to gain more first-hand observations.

At the end of the study, students were asked to provide brief feedback on the topic and the used system. The final questionnaire involved students better in the research process and supplemented observations made during class.

5.4 Case study data

In this study, data was collected in three ways: trace logs of student interaction with the learning material along with score and performance data were obtained from the Open edX platform, students' assessment of used learning strategies were collected with MSLQ, and observations of student work during class were obtained by the researcher while co-instructing. In addition, general student feedback was collected and paired with observations. Multiple analysis methods were used to process and visualise the data. MSLQ scores were computed, and the scores were used to group students via cluster analysis. Trace logs were split into per-student learning sessions from which students' learning tactics and strategies were extracted via cluster analysis. Found learning strategies and tactics were cross-tabulated with MSLQ score groups and students' scores from graded assignments. Finally, observations were paired with quantitative results to gain a better understanding of the results. Next, data collection and analysis are presented in greater detail.

5.4.1 Data collection

Data about student's self-regulated learning was collected using three data sources: trace logs, MSLQ and observations. Each of the chosen data sources was motivated by different models of self-regulated learning presented in Chapter 2. While each model provides its theory of how self-regulated learning occurs, they all share the notion of using learning strategies and tactics to complete learning tasks. The main goal of data collection is to capture data from which the learning process and learning strategies can be extracted. In that sense, self-regulated learning during data collection is seen as a pattern of certain learning event occurrences and students' evaluations. All collected data included student-identifying information to allow the consolidation of data from multiple sources for each student.

The primary data source of the study is trace logs of students interacting with the virtual learning environment. Trace logs represent the COPES factor view of self-regulated learning of Winne and Hadwin (1998). For this, logs obtained directly from the Open edX system were used. A brief overview of Open edX and the design process of the learning materials is presented in Section 3.3.

Since trace logs capture student's learning event occurrences, it does not capture "self-regulated learning as aptitude" view presented in Section 2.1.1. For that, the Motivates Strategies of Learning Questionnaire (MSLQ) was chosen to capture students' perceptions of their self-regulated learning skills. The questionnaire was chosen for its relation to the conceptual framework of Pintrich (2000) presented in Chapter 2, its modularity and wide usage in self-regulated learning research (Duncan and McKeachie 2005).

Finally, to supplement quantitative data, students were observed by the researcher during lessons. Observations were primarily done to detect possible group work and help-seeking. As noted in Chapter 2, socially regulated learning and the related general model of Järvelä and Hadwin (2013) allow the research of phenomena through observation. Direct observations can be used and have been commonly used in various case studies to supplement other sources (Yin 2018, chap. 3). Here, observations of notable events related to group work or other forms of collaborations were written down. The following information was captured for each observation: time, place, people involved and a brief description of the event. Events were noted down as-is without instant analysis in the form of shared or co-regulation, increasing the quality of acquired data (Simons 2012, 62).

5.4.2 Data analysis

Data analysis consisted of standard descriptive statistics, learning analytics methods like data visualisations, cluster analysis, and pairing quantitative data with observations. All data was pseudonymised before analysis was carried out: student names and usernames for the Open edX system were converted into generic indexed user labels. This approach allowed linking MSLQ scores and observations to event logs. First, MSLQ scores were computed, descriptive statistics produced and students clustered by scores following the procedure outlined in Section 4.2. Next, trace logs obtained from Open edX were simplified and processed into single per-student learning sessions. Observations of help-seeking were included in the trace logs as separate events. Learning sessions were then clustered to obtain learning tactics from which each student's learning profiles were constructed. Finally, students' learning profiles were grouped into general learning strategies with cluster analysis. The exact process for analysing trace logs is discussed in Section 4.3.

As a result of the analysis, two descriptions of self-regulated learning in a mathematics class are obtained: as a group of MSLQ learning strategy types perceived by students and as a group of learning strategy types used by the students while interacting with the learning materials. Combined with each student's scores for the graded tasks, the groups are cross-tabulated and analysed for dependence on how well the detected groups predict performance. These general results are further interpreted using the collected observations.

Quantitative analysis is carried out using statistical libraries available in Python. General data processing is done using Pandas (Reback et al. 2021). Trace event logs are processed and further visualised using the PM4Py library (Berti, Zelst, and Aalst 2019). All clustering algorithms used in this study are directly available in scikit-learn (Pedregosa et al. 2011). Finally, additional necessary statistical tests are carried out using SciPy (Virtanen et al. 2020) and Pingouin (Vallat 2018).

5.5 Validity of study design

As mentioned in Section 5.4.1, case studies require assessment of validity just like in any other study approach. Here, arguments for the validity of the study design are summarised through the choices presented earlier in the chapter. Given the explanatory nature of the study, of interest are construct validity, external validity and reliability of the study.

Construct validity pertains to how well the selected phenomenon is operationalised (Yin 2018, chap. 2). Here, validity is ensured by considering multiple measures of self-regulated learning. By using trace logs, a questionnaire and direct observation, self-regulated learning is viewed through theoretical models presented in Chapter 2. Crucially, self-regulated learning is measured both as event occurrences through trace logs and aptitude through different MSLQ scale scores. As mentioned in this study, the lack of more cases is balanced with multifaceted data and analysis.

External validity, in turn, refers to the ability to generalise results. Yin (2018, chap. 2) notes that usage of a theoretical framework and well-posed research questions help external validity of case studies. This study heavily relies on the established theory of self-regulated learning to measure and explain self-regulatory processes present during learning. In addition, while not all research questions of this study are of “how” or “why” forms preferred in case studies, they are still explanatory. Notably, the study design was done according to well-established case study design literature (Simons 2012; Yin 2018, e.g.) which ensures the generalisability is on par with any other case study.

Finally, reliability is related to how well the study can be repeated with the same results (Yin 2018, chap. 2). In order to increase the reliability of the study, the study design was described in this chapter with care: selected case, researcher role, data collection and data analysis choices were presented along with justifications for each. Moreover, the developed teaching material is released for use in similar studies, and all used analysis techniques are rigorously described in a dedicated chapter. All in all, the author believes the presented information ought to be enough to replicate the study to provide similar results (or ones undiscovered by this single case).

6 Results

In this chapter, the results of the analysis are presented. Results are viewed in the order they were discussed in Section 5.4.2. First, student self-regulation profiles based on MSLQ cluster analysis are viewed. Next, extracted student learning tactics and strategies obtained from event logs are presented. Following that, student performance and dependency between found clusters from assignment grades and previous results are tested. Finally, direct observations and descriptions of the learning process are described. At the end of each section, the presented results are briefly summarised.

6.1 Motivated Strategies for Learning Questionnaire

All students part of the study answered the MSLQ before the first lesson. A box plot with computed MSLQ scales for all answers ($N = 20$) with computed spatial medians is depicted in Figure 6. Based on the boxplot, students `usr2` and `usr12` can be seen to be clear outliers in multiple scales, which may affect cluster analysis. Cronbach alpha was computed for each scale to check for internal consistency. Resulting alpha values ranged between 0.50 and 0.90 for all the scales but "Peer learning" ($\alpha = 0.43$). The values are mostly consistent with guiding values presented by Pintrich et al. (1991) ($\alpha \in [0.52, 0.80]$). Thus, the computed MSLQ scales have good internal consistency and are mostly on par with the reference values.

Next, students were clustered by their MSLQ scores using agglomerative hierarchical clustering using the procedure outlined in Section 4.2. In order to determine the optimal linkage, the ℓ_1-norm Silhouette Coefficient was computed for each of the linkage types and different cluster sizes. Figure 7 shows the plot of Silhouette Coefficient values for different cluster linkage types and the resulting dendrogram using the average linkage. As such, the average linkage was chosen based on the plotted cluster value index and resulting dendrogram. Based on the figure and the coefficient values, seven clusters can be seen in Figure 7a: four groups of students and three outliers. More specifically, students `usr2`, `usr12` and `usr19` can be seen most distant from other students in the dendrogram. In order to verify the finding, these students' MSLQ scores were removed, and the remaining answers ($N = 17$) were clustered

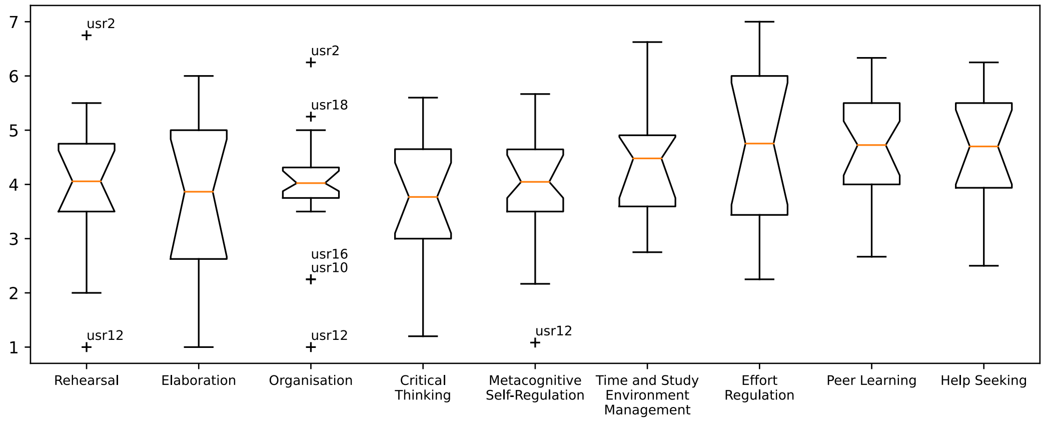
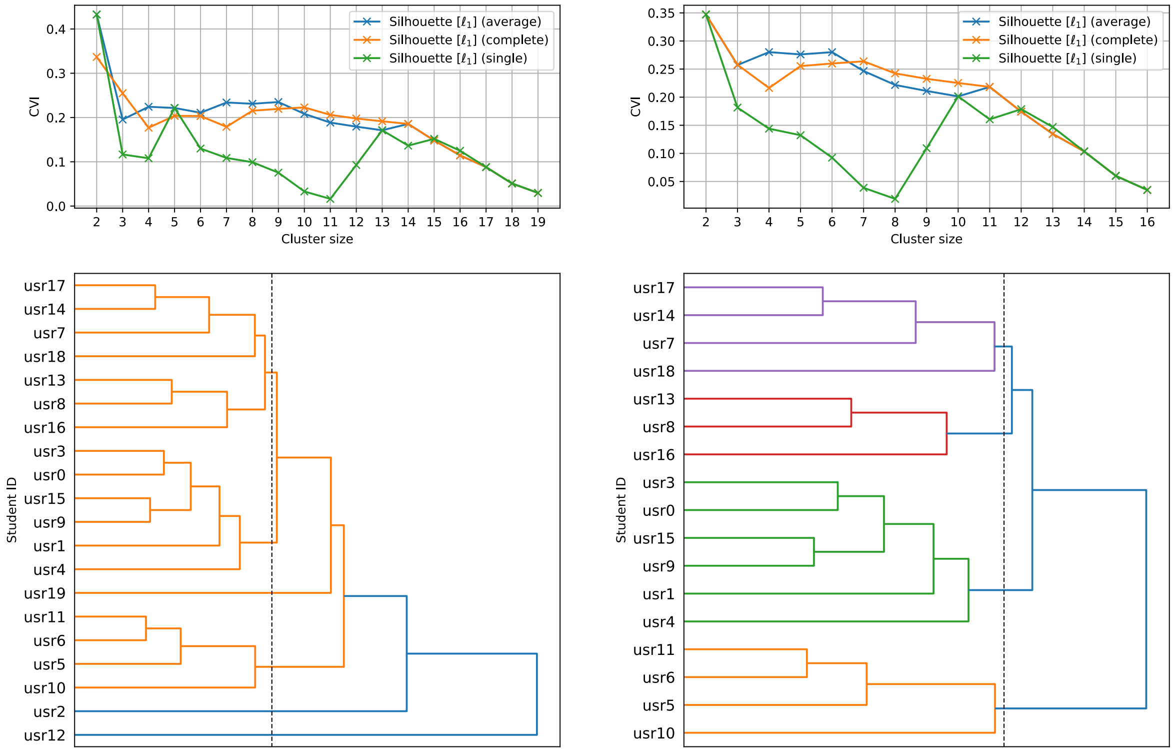


Figure 6: A boxplot of all MSLQ scale values computed for every student ($N = 20$). The centre lines estimating the middle value represents the spatial median of the scores. The spatial median is computed using a modified Weiszfeld algorithm (Vardi and Zhang 2001).

again, which resulted in plots of Figure 7b. Since the removal of the three students improved cluster quality, four clusters in Figure 7b were chosen with three students viewed separately.

Features of the found four clusters and three students are presented in Figure 8. With the figure, the clusters can be classified as follows:

- *Low use of cognitive strategies ($N = 4$)*: Student assesses to have lower cognitive and metacognitive self-regulation skills than the average value. They assess to resort to social strategies more than cognitive ones.
- *High use of different self-regulation strategies ($N = 4$)*: Student assesses to use various cognitive, metacognitive and resource management strategies to achieve academic goals.
- *Normal use of self-regulation strategies ($N = 6$)*: Student assesses their use of self-regulation strategies to be largely average. There is no emphasis on a specific strategy when learning mathematics.
- *High use of resource management strategies ($N = 3$)*: Student assesses to emphasise resource management strategies, like regulating their time and effort used on a task. Such student also prefers social strategies like peer learning and help-seeking over cognitive strategies.



(a) All students included ($N = 20, K_{\text{MSLQ}} = 7$).

(b) Students usr2, usr12 and usr19 removed ($N = 17, K_{\text{MSLQ}} = 4$).

Figure 7: The plot of the Silhouette Coefficients for different linkage types and a dendrogram of students clustered by their MSLQ scores using average linkage. Clustering is done first for all students and then with three outliers removed to detect the final clusters. The cut-off lines in the dendrogram represent chosen cluster counts.

In general, most students in the studied class tend to rely on social resource management skills, like peer learning and help-seeking. The core differences in clusters thus are in how the students apply other strategies. Moreover, the three outliers that were found appear to differ from clusters primarily by how a specific strategy is used. Cluster sizes, average MSLQ scores, labels and descriptions are shown in Table 7.

In summary, students rated their peer learning and help-seeking skills the best, but the use of other strategies varied enormously. In total, four MSLQ self-regulation profiles were identified: low cognitive strategy use, high self-regulation strategy use, normal self-regulation strategy use and high resource management strategy use. Most students identified their self-

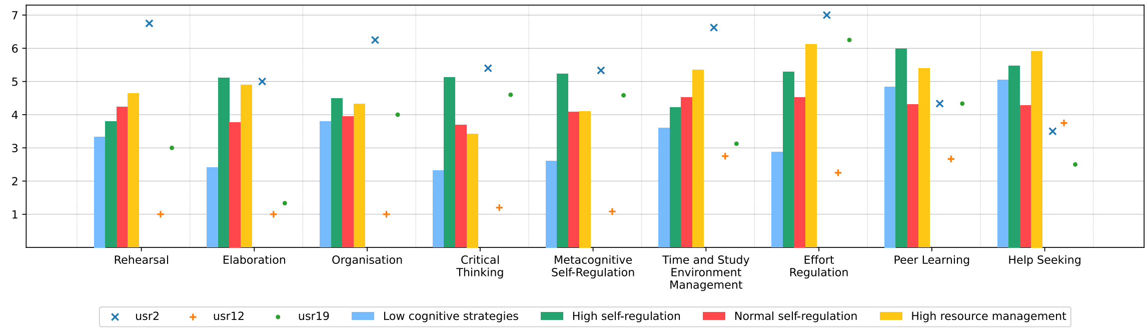


Figure 8: Bar plot of the MSLQ scores' spatial medians for the picked clusters and three outlier students.

Cluster	N	Mean MSLQ Score	Name
MSLQ1	4	3.43	Low cognitive strategies
MSLQ2	4	4.97	High self-regulation
MSLQ3	6	4.15	Normal self-regulation
MSLQ4	3	4.91	High resource management
Student		**Mean MSLQ Score**	**Description**
`usr2`		5.58	High use of all learning strategies, low use of social strategies
`usr12`		1.86	Low use of all self-regulation skills, normal use of social strategies
`usr19`		3.75	Normal skills, emphasis on effort regulation and peer learning

Table 7: Descriptive table for detected MSLQ score clusters and outlier students along with cluster labels. For clusters, the mean MSLQ score is computed by taking the mean of cluster's spatial median components from Figure 8. For students, the mean MSLQ score is the mean of student's MSLQ scale values.

regulation strategy usage as normal, while only three students emphasised resource management strategies over cognitive ones. Out of all students, three did not fit into any detected profile.

6.2 Trace logs

During the study period, 83 distinct learning sessions with session lengths ranging in $[1, 256]$ were recorded. After removing the short sessions with only one event and sessions over the 95th percentile in session length ($Q_{95\%} = 54$), 68 valid learning sessions were left for

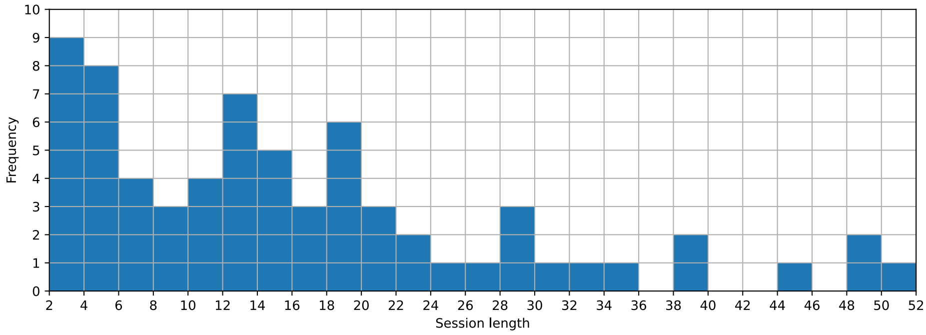


Figure 9: Lengths of valid analysed sessions ($N = 68$) as a histogram.

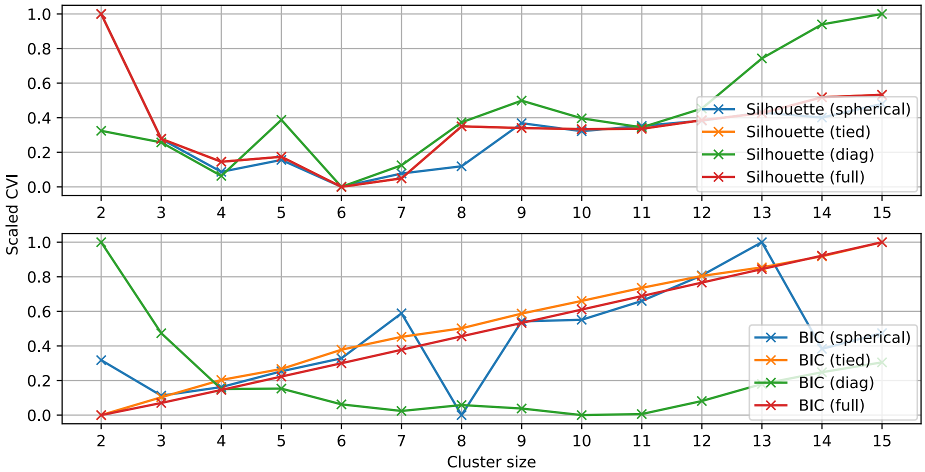


Figure 10: The Silhouette Coefficient and the Bayesian Information Criterion (BIC) for different cluster sizes in learning session cluster analysis. Both indices are scaled to $[0,1]$ to simplify the comparison of improvement speed.

further analysis. A histogram of further analysed and clustered sessions' lengths is shown in Figure 9.

The learning tactics were extracted from the included learning sessions following the procedure outlined in Section 4.3. The Silhouette Coefficient and the Bayesian Information Criterion were computed to determine the correct cluster size and covariance parameters for the EM algorithm. Values were scaled to range $[0,1]$ to allow easier comparison of improvement speed of each cluster value index. The plot of both scaled cluster value indices is presented in Figure 10. Based on the cluster value indices, it was chosen to give each cluster a separate diagonal covariance metric (i.e. the `diag` covariance type) as it gives better

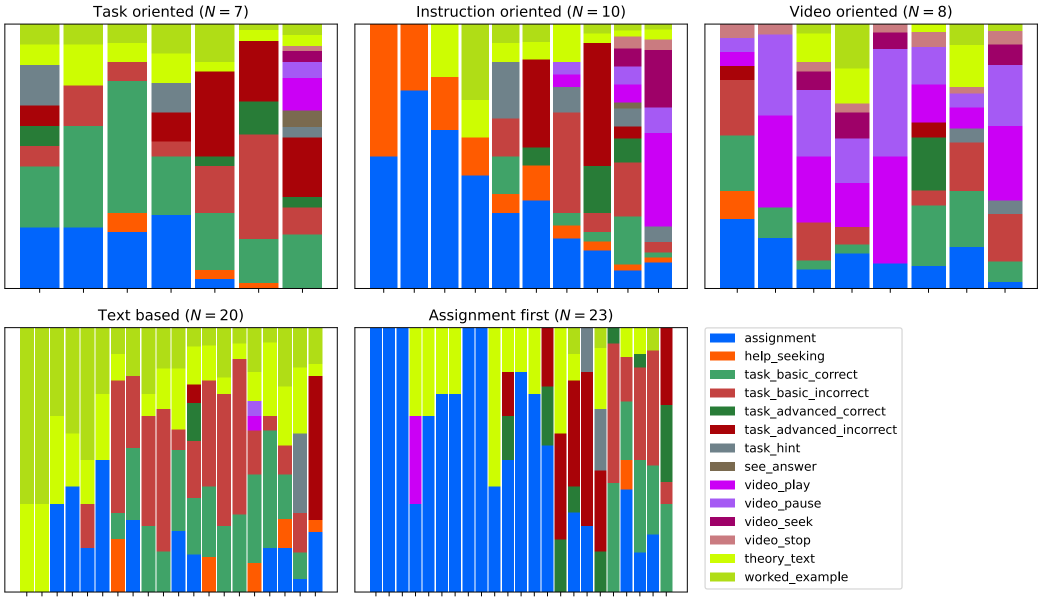
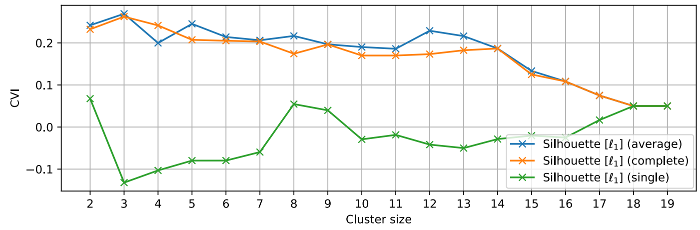


Figure 11: Depiction of each learning tactic and the observed learning sessions that belong to the tactic. Each learning session is depicted as a vertical bar divided into coloured areas. Areas' sizes correlate to the frequency of the learning events (Table 4) in a session.

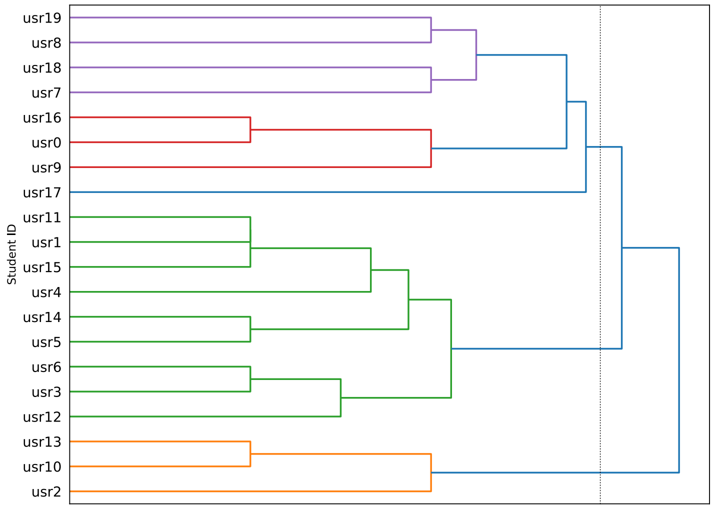
clustering results. Finally, cluster count $K_{\text{tactics}} = 5$ was chosen as it provides a high local Silhouette Coefficient score and because the labelling of learning tactics is more manageable with a lower cluster count than with a higher one.

Next, the discovered learning tactic types were identified. Each learning session in a cluster was inspected by identifying specific learning events, their frequencies and the order in which they were carried out. As a result, the detected learning tactics were labelled as follows:

- *Task oriented ($N = 7$)* tactic where learning is carried out primarily by completing ungraded tasks either before or after completing the graded assignments.
- *Instruction oriented ($N = 10$)* tactic where help-seeking or general teacher instruction is actively used at various points of task completion. Help is used primarily to solve graded assignments.
- *Video oriented ($N = 8$)* tactic where video materials are used as the primary resource alongside completing ungraded tasks.
- *Text based ($N = 20$)* tactic where text materials such as theory, worked examples and ungraded tasks are used as the primary learning resource.



(a) Silhouette coefficients for student learning strategies.



(b) Dendrogram of student learning strategies.

Figure 12: Silhouette Coefficients and dendrogram from cluster analysis of students' learning tactics. The cut-off line in the dendrogram depicts the chosen cluster size $K_{\text{strategies}} = 3$.

- *Assignment first ($N = 23$)* tactic where completion of the graded assignment is prioritised before interacting with the other learning resources. In this tactic, students use other learning resources to complete the graded assignment as fast as possible.

The exact composition of learning actions within the learning tactics is shown in Figure 11.

Finally, learning strategies were extracted by analysing student profiles using the approach presented in Section 4.3. Here, agglomerative clustering with ℓ_1-norm was used on student profile vectors. Cluster size and linkage type were determined using Silhouette Coefficient with ℓ_1-norm. The resulting cluster value index plot is in Figure 12a. Based on this and dendrogram of student profiles (Figure 12b), cluster size $K_{\text{strategies}} = 3$ with average linkage was chosen. Each cluster contains each students' learning profile which in turn group students' specific learning sessions. Thus, these clusters can be considered to depict the final learning

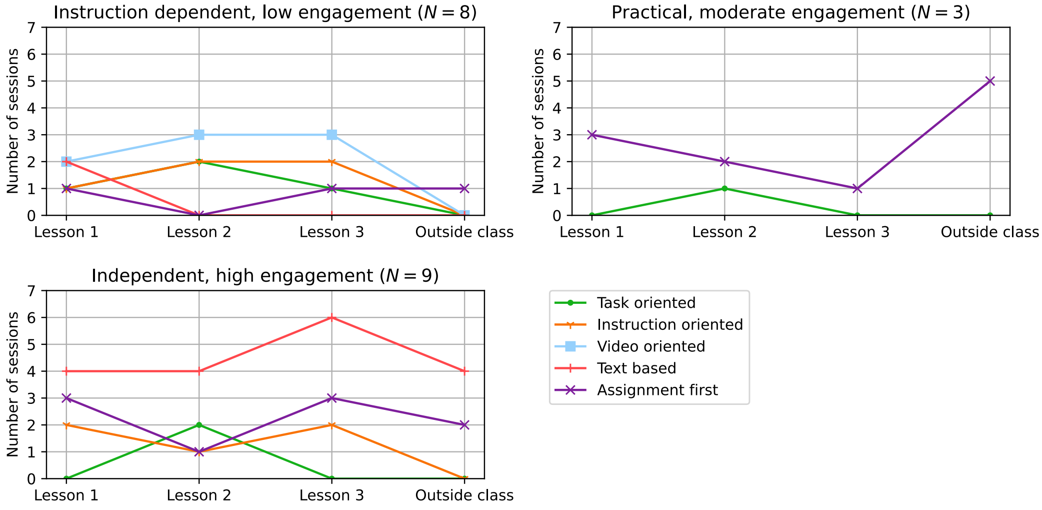


Figure 13: Learning strategy clusters depicted by the frequency of applied learning tactics per lesson.

strategies as they group students by which learning tactics they used in each lesson.

Because learning sessions are time-bound, each learning strategy cluster can be depicted as a frequency of used learning tactics per lesson (cf. Jovanović et al. 2017). From this, learning strategy clusters are depicted and identified in Figure 13. Found learning strategies can be described as follows:

- *Instruction dependent ($N = 8$)*: Student relies on interactive and instruction-based tactics to learn. The student seeks help or gets direct instructions on how to learn. They also primarily learn in class with almost no learning outside class.
- *Practical ($N = 3$)*: Student concentrates on graded assignments and uses other resources minimally. In this strategy, work is actively done outside class.
- *Independent ($N = 9$)*: Student uses various learning tactics to learn. The primary learning sources are text materials and tasks. The student uses multiple learning resources and is actively engaged with the material.

In summary, during the three lessons, students completed 68 learning sessions with varying lengths. These sessions were grouped into five learning tactics: task-oriented, instruction oriented, video-oriented, text-based and assignment first. Out of the learning tactics, the "assignment first" tactic was the most used tactic while "task-oriented" was the least used.

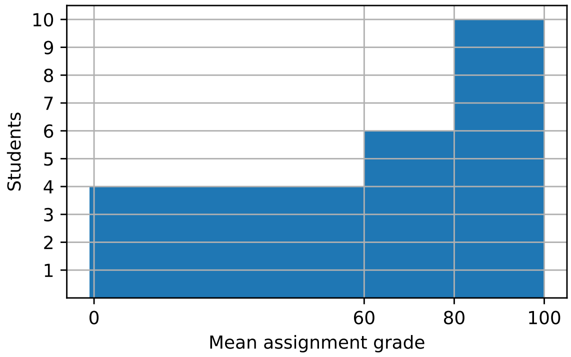


Figure 14: Distribution of graded assignment grade means as a histogram. The grades are divided into three groups: low ($[0,60)$), middle ($[60,80)$) and high ($[80,100]$).

Learning tactics were then used to create student profiles. Student profiles were grouped into three learning strategies: instruction-dependent, practical and independent. When learning the concept of per cent, most students used an independent learning strategy, while only a few students applied a highly selective, assignment-centred practical strategy.

6.3 Student performance

All in all, every student was given 11 graded assignments to complete during the study. In this study, the researcher graded each assignment with 0–100 points where 100 represented perfect solution, and 0 represented that the student turned in no solution. A histogram of the grade means is shown in Figure 14. From this, students were divided into three grade groups: low (mean grade in the range $[0,60)$), middle (mean grade in the range $[60,80)$) and high (mean grade in the range $[80,100]$).

Students' performance and their dependency on learning strategy use can be investigated using found MSLQ profiles, learning tactics and learning strategies. For this, five cross-tables were formed: student distribution of MSLQ profiles to learning strategies (Table 8a); student distribution of MSLQ profiles to assignment grade groups (Table 8b); student distribution of learning strategies to assignment grade groups (Table 8c); learning session distribution of MSLQ profiles to learning tactics (Table 8d); and learning session distribution of MSLQ profiles to learning strategies (Table 8). From a visual inspection, there appears to be negli-

	Instruction dependent	Practical	Independent
Low cognitive	0	1	3
High	3	0	1
Normal	2	0	4
High resource	2	1	0

(a) Cross-table of MSLQ profiles to learning strategies in students ($N = 17$).

	Low	Middle	High
Low cognitive	2	0	2
High	0	1	3
Normal	2	3	1
High resource	0	1	2

(b) Cross-table of MSLQ profiles to mean grade groups in students ($N = 17$).

	Low	Middle	High
Instruction dependent	0	4	4
Practical	0	0	3
Independent	4	2	3

(c) Cross-table of learning strategies to mean grade groups in student count ($N = 20$).

	Low cognitive	High	Normal	High resource
Task oriented	1	3	1	0
Instruction oriented	1	4	5	0
Video oriented	0	0	4	3
Text based	7	4	7	0
Assignment first	6	2	4	4

(d) Cross-table of learning tactics to MSLQ profiles in learning sessions ($N = 56$).

	Low cognitive	High	Normal	High resource
Instruction dependent	0	9	7	4
Practical	4	0	0	3
Independent	11	4	14	0

(e) Cross-table of learning strategies to MSLQ profiles in learning sessions ($N = 56$).

Table 8: Cross-tabulation of MSLQ results, learning strategies and assignment grades.

gible dependence between discovered student groups. In order to verify this, statistical tests for independence were used. Commonly, the χ^2 test for independence is used; however, if the expected frequencies of a cross-table are less than 1, Fisher-Irwin's test is preferable (Campbell 2007). Based on the tests for independence,

- association between MSLQ profiles and learning strategies (Table 8a) in users is statistically insignificant (Fisher-Irwin, $p = 0.108$);
- association between MSLQ profiles and mean grade groups (Table 8b) is statistically insignificant (Fisher-Irwin, $p = 0.388$);
- association between learning strategies and mean grade groups (Table 8c) is statistically insignificant (Fisher-Irwin, $p = 0.091$);

- association between learning tactics and MSLQ profiles (Table 8d) is statistically significant ($\chi^2(12) = 24.74$, $p < 0.05$);
- association between learning strategies and MSLQ profiles in terms of learning sessions (Table 8e) is statistically significant ($\chi^2(6) = 29.16$, $p < 0.001$).

In summary, most students performed well during the study. When analysing dependency between student grades, MSLQ self-regulation profiles, learning tactics and learning strategies, detected dependency is twofold. On the one hand, no significant dependency was found between student grades and learning strategies. This result means that, in general, students who got good grades in the study used all different detected learning strategies. At the same time, many students used the high-variation "independent" strategy regardless of their perceptions of their self-regulation skills. On the other hand, there is a dependency between used learning tactics, strategies and MSLQ profiles. Students who rated their self-regulation strategy usage more normal tended to vary their tactics more. Moreover, students with higher self-regulation strategy usage skills tended to use help-seeking more than the specialised groups. All in all, there is a clear dependency between MSLQ profiles and detected learning strategies despite being obtained from two separate data sources.

6.4 Observations from the learning experiment

At every lesson, the teacher, a special education teacher and the researcher were present as instructors. In addition, at every lesson, a varying number of student teachers were present, some of whom occasionally interacted with the students. Through the course of the three lessons, both direct observations and accounts from instructors were collected. In this section, the observed student behaviour and experiences are presented.

During all three lessons, students were active in interacting with the instructors. This behaviour was relatively common for the studied class, as noted by the special education teacher. In general, there were two kinds of interactions observed: student-initiated, where a student asked directly for help to complete a task or a graded assignment, and instructor-initiated, where the instructor checked on the student and instructed on how to proceed. While all students used the former interaction type, the latter was applied only to specific students. For example, students `usr0` and `usr1` required periodic interventions by the instructors to complete each lesson's goals. When inquired, the teacher noted that those were generally the same students who usually tended to slack off in class. On the other hand, some students required instruction on how to pace the tasks and which one to complete. Such need for instruction was especially true for the first two lessons as students were not instructed on how to pace out the tasks (cf. Table 6). There were no similar questions related to pacing their learning in the final third lesson, and most "forced" instruction was focused on particular slow-performing students. Some students like `usr2` and `usr17` required interventions to pick more advanced tasks instead of just basic ones that they considered to be too easy. Overall, both the class teacher and the special education teacher noted that students generally appeared motivated and sought help themselves when they needed to.

When it came to using the learning resources and carrying the learning goals, students tended to use different approaches. As was noted by all three instructors, while some students usually read through the theory first, some jumped over it entirely and went for the tasks. Many students were observed jumping directly to the graded assignments before inspecting other materials despite being instructed to use the available learning resources (cf. Section 5.3). When the researcher evaluated graded assignments after each lesson, it was noted that half of the students regarded graded assignments as homework: they tended to do part of the graded assignments during class and the rest at home before the next lesson. When this was brought up with the students after the first lesson, a few students also expressed that they wanted to do assignments at home but could not as they forgot the link to the virtual learning environment. However, when inquired collectively from all students, only a couple told that they checked the received grade and written feedback of their own volition, while the rest had to be explicitly instructed to look at the feedback for the graded assignments. All in all, the class teacher and the special education teacher commented that the assignment completion rate was slightly lower than that of regular homework, with a few students not turning in some assignments at all. When asked about missing assignments, students claimed to either have misunderstood the assignments not being part of the mandatory goals or had external reasons like lack of time or effort.

During the lessons, different kinds of collaboration were observed. Students were not restricted on group work, which led to the spontaneous creation of temporary dyads and triads in the class. The duration of each collaboration effort varied between a few minutes to the entire duration of the lesson. The observed collaboration type varied from student to student. All in all, the following distinct types of collaboration were identified:

- *Peer instruction* (e.g. (`usr18`, `usr0`) and (`usr4`, `usr14`)) – A student instructed another on completing a task or an assignment. During it, a student usually instructed the other on completing a task or using a learning resource. Here, one of the students has often already completed the task. The duration of peer instruction varied from student to student, from two minutes to an entire lesson.
- *Sharing results* (e.g. (`usr19`, `usr3`) and (`usr16`, `usr7`)) – Students share their answers to the tasks with each other. Here, deep collaboration was not observed. Instead, two students usually complete different tasks and then share answers and explanations. These collaborations were very short but frequent.
- *Co-learning* (`usr4` and `usr6`) – Both students complete the same tasks and use similar learning resources. They discuss solving a task, share answers and insights on completed tasks. This collaboration usually lasted for the entire lesson, but it was observed only for two students in the studied class.
- *"Company"* (`usr2`, `usr12` and `usr15`) – This was the only active triad observed in the class. In this group, students completed different tasks and did not generally share their results. The group appeared to exist primarily for motivational and social support. This group was formed in every single lesson for the entirety of the class.

Finally, student experiences with the learning materials were generally positive. In a short discussion after each lesson, both the class teacher and the special education teacher expressed that students appeared motivated by the learning materials. During the lessons, it was noted that all available materials were used on some level. Students were especially actively using the instant feedback the virtual learning environment provided when solving ungraded tasks: students tended first to solve a task quickly. Then, based on the instant automated feedback, they often used other available resources to gain the necessary knowledge to solve the task. Both the teacher and the special education teacher noted the benefit of automated instant feedback in post-lesson discussions.

At the end of the last lesson, students were asked to give anonymous feedback on the materials and the teaching approach used in the lessons. Most students regarded both materials and a more self-regulated learning approach well:

> I think this [study experiment] worked quite well, the materials were fine, learning was nice, and I am not sure what I would change. (An anonymous feedback)

> It was quite nice. The materials sometimes was bugging out a little. More free lessons were very nice. [...] (An anonymous feedback)

At the same time, some enjoyed the given freedom but were less fond of the materials:

> The materials were boring and quite useless, [but] more freedom in lessons was fun. [...] (An anonymous feedback)

One student would have preferred using a desktop for interacting with the materials:

> The material didn't work out, and I didn't like this teaching method. I'd prefer doing the task on a PC in the future. Other than that, the lessons were interesting and nice. (An anonymous feedback)

In summary, student observations partially match the detected learning strategies. For example, observation of students jumping to assignments first correlates with the detected "assignment first" learning tactic. Main observations regarded instructor–student and student–student interactions. Both interaction types were present and in line with how highly students evaluated their help-seeking and peer learning skills with MSLQ. Despite students' different approaches to using the provided learning resources, the anonymous feedback was overwhelmingly positive. Out of 19 anonymous answers, 13 were positive, four are neutral, and only 2 contain negative feedback. In the end, while students had different opinions on materials, they all appreciated the freedom given to choose and complete tasks at their own pace.

7 Discussion

The core purpose of the study is to gain an understanding of self-regulated learning in a mathematics class. Self-regulated learning can emerge in various ways before, during and after carrying out learning tasks (cf. Chapter 2). In this chapter, results presented in Chapter 6 are summarised, and connections are drawn to the three models of self-regulated learning. Primary emphasis is put on answering the three main research questions set in Section 5.2:

RQ1 How is self-regulated learning present in a junior high school mathematics class?
RQ2 What learning strategies and tactics students can employ to learn a new mathematics concept?
RQ3 How can usage of self-regulated learning strategies be supported in a junior high school mathematics classroom?

In addition, the limitations of the study are discussed both in terms of chosen methodology and collected data.

7.1 How is self-regulated learning present in a junior high school mathematics class?

Self-regulated learning is a multifaceted phenomenon: it is part of the entire learning process from when a task is given until the student evaluates his work. Self-regulation can emerge in different forms: how students regulate their cognition, motivation, behaviour and context (e.g. Pintrich 2000), what learning tactics they employ (e.g. Winne and Hadwin 1998) and how they interact with peers and instructors (e.g. Hadwin, Järvelä, and Miller 2017). In this study, emphasis is put on detecting self-regulation in a junior high school mathematics class. Based on the results, students' self-regulation in a mathematics class can be seen in three ways: how they perceive their skills, how they act and how they interact.

Students' self-regulation may be seen in a mathematics class relates to how they view their skills and how aware they are of different available learning strategies. Here, this was seen in how students answer the MSLQ and how the answer related to the learning strategies they used in class. More importantly, the results show that students' perceptions of the learning task and mathematics learning generally affect which learning strategies and tactics they use in a classroom. For example, the studied class generally rated their use of help-seeking and peer learning strategies high (Figure 6), and they were indeed observed to be active in seeking help and work in groups (cf. Section 6.4). On the other hand, the opposite trend can also be seen: those who rated their cognitive strategy use low tended to use more text and assignment oriented tactics (Table 8d). Given the textbook-centred teaching style in Finnish mathematics (cf. Section 3.2), students with a lower perception of their self-regulatory skills opted in for a learning style with which they were familiar. Both examples can be seen as a manifestation of self-regulated learning: in the model of Winne and Hadwin (1998), student's metacognitive evaluations affect future cognitive conditions and, in turn, what kind of learning tactics they choose to employ. Similar is described by Pintrich (2000), where student's reactions and reflections of completed tasks affect future forethought and planning. In this particular case, if students evaluated their skills to be poor, they were likely to stick to tactics they know, unlike students with higher metacognitive evaluation who can better vary their tactics. All in all, student's perceptions of the topic and their skills indeed provide insight into how they self-regulate.

Next, student actions during the lesson provide a view into their self-regulation skills. Self-regulation manifested in two significant ways in actions: use of learning resources and use of time resources in the studied class. For example, three students specifically rated their effort and time regulation skills higher than the use of specific strategies (Table 7) yet chose to use video and assignment oriented tactics primarily as seen in the cross-tabulation Table 8d. Generally, students who rated all their self-regulation skills higher ended up applying strategies with more varied tactics and ended up with higher assignment grades (Table 8b). Additionally, students who used a practical learning strategy scored high results from assignments while still mainly using assignment oriented tactics (Table 8). As such, students' evaluations did indeed correlate with their actions: those who used the learning resources in a more varied manner also evaluated their self-regulation skills higher. Interestingly and importantly, while actions told about students' self-regulation skills, their grades do not. In this study, all three learning strategies include students with high assignment grades as shown in Table 8. Thus observing students purely by their graded task performance may not give directly any information about how well students self-regulate their learning. As for time management, self-regulation was observed primarily as how the students paced out their learning. For instance, those who applied practical learning strategy did most work outside class as seen in Figure 13. It was also observed that many students could not manage their time during classes as some, for example, jumped to assignments first or did not take breaks despite the long 75-minute lessons. These behavioural differences are consistent with different regulation areas described by Pintrich (2000): students with better self-regulation skills can monitor their resources better and use learning time more efficiently.

Finally, the social aspect appears to show well how students can self-regulate their learning. This view was especially apparent in the studied class in which students were active in interacting with the instructors and each other. The most important manifestation of self-regulation appeared in instructor–student interaction: while most students sought or received help from instructors, the type of instruction provided varied. For instance, some students sought out help themselves for a task, while others had to be guided directly by the instructor. This observation can be interpreted from the perspective of Pintrich (2000) as an indicator of self-regulation: those with better self-regulation skills used instructors as a help-seeking resource. In contrast, the instructor used direct interventions to guide students in choosing specific learning tactics externally. Furthermore, students' interaction with each other varied according to how well they could self-regulate and co-regulate their learning. As noted in Section 6.4, students freely formed pairs or groups at different times of the lesson. Different kinds of peer learning were observed: while some students shared results or instructed their peers, two observed students truly learned together and collectively regulated learning of each other. These observations are consistent with the model of Hadwin, Järvelä, and Miller (2017) in which these interactions can be identified as examples of co-regulated learning and socially shared regulation of learning.

In summary, self-regulated learning occurs on many levels. Most importantly, pure assignment grades are not an indicator of self-regulated learning. While a student's use of various learning tactics may predict a grade (e.g. Vaculíková 2018), the inverse may not be accurate. In this study, this was seen as independence between assignment grades and discovered strategies. For example, students who used various learning strategies managed to get both low and high grades as cross-tabulated in Table 8. The same results have also been observed, for instance, by Malmberg, Järvenoja, and Järvelä (2010) who noticed that frequency of used tactics contributes less to learning than how a tactic is carried out. As such, to truly understand self-regulated learning, one indeed must be able to assess it via student actions and perceptions instead of just student performance (e.g. Winne and Perry 2000; Zimmerman 2008).

7.2 What learning strategies and tactics students can employ to learn a new mathematics concept?

Choice of learning strategies and tactics can depend on the taught topic, prior experiences and available resources (Winne and Hadwin 1998). In this study, students were learning about the concept per cent for the first time. The choice of applied tactics can be limited by students' prior knowledge and available learning resources. Students were given study materials that attempted to match the typical Finnish textbook's standard structure and task types (cf. Section 3.3). Nevertheless, in this study, all available resources were used, and different ways students interact with the resources were successfully identified. In total, five tactics and three strategies of learning the concept of per cent were discovered.

Learning tactics refer to a pattern of specific actions that a learner carries out. Students applied five tactics with the given learning materials when learning a new mathematics concept in this study. First, a student can concentrate on learning by *completing tasks* and make use of instant automated feedback to correct their behaviour. While only seven sessions were identified to follow this pattern, it showcases that some students may choose to learn by doing and receiving instant feedback. This tactic represents a "learn by mistake" approach in which a student learns by reflecting on the tasks they complete. Compared to similar studies, a similar tactic cluster was detected in analysing self-regulation in mathematics by Jovanović et al. (2017). Moreover, this strategy appears to be related to self-correction strategies that students may use in learning mathematics as part of their self-regulation (e.g. Ramdass and Zimmerman 2008).

The second detected tactic is *use of instruction* and general help-seeking. In this tactic, a student uses the present instructors to get help or guidance on learning. However, this tactic does not describe the nature of the help. As mentioned in observations in Section 6.4, while some students sought help to further their understanding of a topic or get advice on a specific task, some students were directly instructed on what tasks to complete. This note is one of the limitations of this study as the exact nature of each instructor–student interaction was not observed in depth. Nevertheless, the dual purpose of instruction seeking can be seen from the captured learning sessions. For example, in Figure 11, a portion of the sessions have help-seeking as a more frequently used learning action than other actions. This behaviour can be interpreted as students being directly instructed on how to use the materials to complete the minimal goals set by each lesson (cf. Section 5.3). At the same time, some of the sessions include various other learning actions besides help-seeking, which can be interpreted as a student using help-seeking as one of the available learning resources. On the other hand, forced instruction can be seen here as students trying to avoid seeking help directly. For instance, students who evaluated their self-regulation skills lower tended to use help-seeking tactic less than other students in this study. A similar division between help-seeking and avoidance in mathematics has been described prior, for example, by Ryan and Pintrich (1997) who noted that help avoidance could be caused by simply not being interested in learning.

Thirdly, a student can *primarily make use of video materials* in the learning environment. Here, a student mainly interacts with the learning materials via videos while putting much less emphasis on text-based resources. In addition, almost every captured video-oriented session in this study includes a student completing tasks and graded assignments. In this sense, video and instruction oriented sessions are closest to the lesson goals set out in Table 6. A similar video-oriented approach to learning has been detected by Jovanović et al. (2017) despite the different age group studied. Based on observations, this tactic seemed to be used by few students but very consistently. Interestingly, before the study, the participating students seldom used learning videos as a learning resource based on discussions with the class teacher. Thus, students using video-oriented tactics can be interpreted as compensating for the lack of teacher-centred instruction. The videos included in the materials used verbal and visual guidance, akin to an average Finnish teacher-led mathematics class outlined in Section 3.2.

The last two detected tactics were the most used by the students who participated in this study. First, students mostly made use of *text based materials* like theory texts, worked examples and tasks. This tactic represents the most common approach taken in structuring a lesson in a Finnish mathematics class: first, students learn theory, then they apply it in tasks, and finally, they are graded using assignments. Similar tactics are found both in mathematics classes (e.g. Jovanović et al. 2017) and other subjects (e.g. Matcha et al. 2020; Jansen et al. 2020). However, the most common tactic observed in the studied class was an *assignment oriented* one. In it, a student tends to prioritise completing the graded assignment over using other resources. This tactic's use is consistent with observations of both the class teacher and special education teacher: during the three lessons, students often disregarded learning resources and jumped straight into graded assignments first. The behaviour can be interpreted both in terms of time and resource management. On the one hand, students likely desired first to check and attempt solving an assignment to assess which learning resources to use. This approach can be seen as a standards evaluation action in the COPES factor model (Winne and Hadwin 1998). On the other hand, some students could not correctly regulate their effort or time, in which case they opted for completing graded tasks first and then doing nothing else later. This observation shows a lack of behaviour and motivation regulation skills based on grouping of Pintrich (2000). However, one must note that the shorter sessions in the assignment-oriented tactic happened outside lessons, referring to a student completing assignments as homework.

While learning tactics describe behaviour patterns, learning strategies group learning tactics: a learning strategy refers to what learning tactics a student picks and how often they are picked. Thus learning strategies describe self-regulation via the diversity of used tactics (cf. Chapter 2). In this study, learning strategies were labelled by how diverse they are and what kind of behaviour they describe. In total, three learning strategies were used by the students to learn the concept of per cent. In an *instruction dependent* strategy, a student relies on instructors or equivalent video materials to learn while skimping on tasks and assignments. Interestingly, in this strategy, most learning happens in class and almost none outside it, which can be considered a time management issue. In a *practical* strategy, a student mostly does tasks and assignments and makes almost no use of other resources. This strategy is labelled practical as the used tactics revolve around practice and less around the theory. Additionally, students using this strategy did most of the work outside class while keeping in-class work on a lighter side. Finally, in an *independent strategy*, a student appears to vary their learning tactics for each learning session highly. They still tend to use more common tactics like doing tasks and reading texts rather than seek help or watch videos, notwithstanding the variation. Students do work both at home and in lessons in this strategy, and they pick tactics according to lesson topics and goals. All in all, these strategies correlate with strategic and selective learning strategies found by Jovanović et al. (2017) and Matcha et al. (2020).

7.3 How can self-regulated learning strategies be supported?

This study started from the premise that self-regulation of learning must first be detected and understood on a class level to support it effectively. This study shows that while various learning resources can be used in a mathematics class, it is up to the students to use them properly. For instance, those students who rated their use of cognitive strategies low, reserved to mostly doing tasks and assignments, but they more seldom sought help (Table 8d) and ended up with lower assignment grades (Table 8b). On the other hand, student feedback mentioned in Section 6.4 shows that junior high schools students are interested and willing in being given more freedom over their learning. This contrast poses a conundrum: while there is a need for interventions and control to guide students to properly use available time and learning resources, at the same time, there is a desire to be given freedom over the entire learning process. The previous discussions suggest that self-regulated learning and the use of different learning tactics can be supported in two ways: introducing interventions to increase knowledge of tactic management and modifying the entire learning environment to foster self-regulation in the entire class.

As mentioned by Panadero, Klug, and Järvelä (2016), many methods to measure self-regulated learning can be used as an intervention tool by themselves. These interventions can include having students assess their learning formatively via short learning diaries or general assessments. Moreover, students can be directly taught self-regulation skills and tactics during class (e.g. Ramdass and Zimmerman 2008; Stoeger and Ziegler 2008). Students can also be supported by providing them instant feedback on their tactic use and evaluations of their completed task. In this study, both teachers noted the usefulness of instant feedback provided by the learning system and how it allowed students to monitor their progress and pick specific learning actions to correct their mistakes. In general, the use of computer-assisted scaffolding practices like interactive guides for tasks and generally adapting tasks and materials to student actions can be used to assist during various self-regulated learning phases (e.g. Azevedo et al. 2011; Devolder, Braak, and Tondeur 2012).

However, supporting students and fostering their development as self-regulated learners requires more than just specific interventions. This study emphasises the role of the teacher as the builder of the class's learning environment. Not only do junior high school students need access to teacher instruction, but they may benefit from being given the freedom to use the available learning resources. This notion goes on par with a constructivist approach to learning that is being followed in Finland: students learn by formulating knowledge themselves on their skill level. The combination of freedom and instruction poses a complex one, which requires building the entire learning environment around the idea of self-regulation and a growth mindset in which the goal of learning is intrinsic. In Finland, flipped learning has been showing promise as such an approach as of recent years. In flipped learning, the teacher works towards increasing students' self-regulation and self-motivation by fostering freedom, providing multiple learning paths, encouraging collaboration and actively engage with the students (Flipped Learning Network 2014). One of the models currently being studied and used in Finland is that of Toivola, Peura, and Humaloja (2020). Toivola, Peura, and Humaloja (2020) describe various practical methods to help build such a self-regulated environment, like setting clear learning goals for each student, planning out both teaching and work practices in class, using formative assessment and making use of ICT in learning. Even the concrete model notwithstanding, the study results propose that approaching self-regulation on the class level may be one of the core ways to encourage personal self-regulation of learning.

All in all, the teacher has a prominent role in creating the right learning environment. While junior high school students enjoy freedom in mathematics, giving too much may have adverse effects as students may lack the skills necessary to carry out learning strategically. Working with students to create an environment where learning is done for the self and not the teacher seems to be the most potent way to encourage a strategic approach to learning and foster the use of available learning resources effectively. Like Toivola, Peura, and Humaloja (2020) note as well, it may take time to build such an environment. It takes more than a declaration to create a self-regulated class; it needs a shift in the ideology of teaching. Nevertheless, the study results suggest that this may be the proper way of combining both student freedom while retaining the goal-oriented approach of a Finnish mathematics classroom.

7.4 Limitations

This study employed various data collection and analysis methods that all come with their kinds of limitations. The chosen methodology adds its own set of limitations to the study. Therefore, limitations can be divided into two groups: methodological and method-specific ones.

The case study approach by itself carries implicit concerns regarding the generalisability and subjectivity of the study. Indeed, it is impossible to conclusively describe all kinds of ways self-regulated learning occurs in every junior high school mathematics class just by a single case. This limitation can be seen from the study setup described in Section 5.3: a single class of students were taught a single mathematics topic. On the other hand, the study design attempts to increase generalisability by building materials and practices following the standard practices of didactics of mathematics in Finland outlined in Section 3.2. Because instruction and material types were familiar to students, similar results are likely to be observed for other similar junior high school classes. While there are limitations related to case count, case studies in themselves do not necessarily attempt to draw generalisations. In education research, case studies can be understood as a way to gain insights on novel approaches to education and methods of studying it (Case and Light 2011). This case study yields information on studying self-regulated learning in a junior high school context using a mixed-methods approach. Notably, both students and teachers provided valuable opinions on the use of information technology in mathematics. In this aspect, the specific discoveries make up for the lack of proper generalisability. Even then, this study's approach still warrants being extended to more than a single case study to draw more general conclusions and gain more insights.

When considering used methods, the core limitations are based on a lack of more rigorous observations. As discussed earlier, self-regulation can emerge in different interactions and at various times. Capturing these events and their nature in detail thus becomes crucial in uncovering different learning strategies and tactics. This need is especially true for the junior high school context, where learning occurs in classes with the instructor and students actively interacting with each other. In this study, not all methods were successful in providing enough information about all students. For example, student observations were primarily done by a single researcher who, at the same time as observing, worked as the instructor. Because of that, while observations were more detailed like initially intended, the number of observations were lower. Additionally, data collection itself is limited by timing: while MSLQ collected students' perceptions, it was only done at the start before students were given the learning materials. While this study did not aim to measure the development of students' self-regulation during the learning process, the found results and literature suggest that self-evaluation is one of the core way self-regulation can be measured. At the same time, the study lacks a pre–post setup, which could provide a clearer image of how student's perceptions and actions change as they are learning more about a new topic.

Finally, some minor limitations regard data analysis. Because of the low number of students, used analysis methods required adjusted to get as a reliable result as possible. While robust analysis methods are more tolerant to deviations from the norm, they often come at a cost for precision (Huber and Ronchetti 2009, 5). While a low number of students may not be an issue for case study inherently, it does complicate proper quantitative analysis. This issue can be seen, for example, when analysing dependency between the MSLQ profiles, learning strategies and grades. The limitation is attempted to be alleviated by the mixed-methods approach of the study. For instance, many of the strategies and profiles found via MSLQ and trace log analyses were also detected via observations. Additionally, some students' tendency to go first to the graded assignment was captured by cluster analysis of learning sessions and observations. Therefore, while there is a limitation of generalisability, the analysis results still provide an insight into how mathematics is learned in a Finnish junior high school mathematics class.

8 Conclusions

This study aimed to gain insight into how Finnish junior high school students self-regulate their learning in mathematics. Emphasis was put on capturing the instances where self-regulation occurs and how students use the available learning resources. The study was a pilot case study in which a Finnish junior high school class learned a new mathematics concept using the available learning resources without restrictions. Data was collected via the Motivated Strategies for Learning Questionnaire and trace logs of students interacting with the learning materials. Additionally, students were observed, and open feedback was collected at the end of the study. Learning analytics and robust methods such as cluster analysis were the primary analysis tools to consolidate and compare data.

The results obtained by observations were consistent with analytical data. Students' self-regulation was observed in three ways: how students perceived their learning, how they used the available resources and how they interacted with the teacher and their peers. During the study, the students used five different learning tactics with the available materials: they could concentrate on only tasks, seek teacher help, watch videos, use text materials or concentrate on graded assignments over other resources. Students varied these tactics using three strategies. Most students used a varied strategy where they actively switched between the tactics depending on the lesson. Some students relied primarily on instruction-oriented tactics like help-seeking and video watching. A few students practised a highly selective strategy where they structured learning resource usage around solely turning in the graded assignments.

This study provides some empirical findings for teachers regarding teaching mathematics in junior high schools. On a general level, the results show a need for teaching self-regulation skills in mathematics. Self-regulation of learning refers to a student's ability to approach learning tasks strategically and metacognitively. Good self-regulation skills are valuable both in academic and work environments where a person must take hold of their learning effectively. The results imply that junior high school students are willing to learn in an environment where they get more control of their learning. Thus, a junior high school class teacher should put effort into building the entire learning environment to encourage and foster students' self-regulation. One approach suggested by the author is a flipped learning model described by Toivola, Peura, and Humaloja (2020) as it encompasses the self-regulation ideology and provides concrete tools for enhancing the learning environment. Most importantly, relying on student performance to judge student's self-regulation is not reliable. This study results posit that self-regulated learning is not about achieving better grades. Instead, self-regulated learning skills should be developed in students to help them carry out their learning more effectively and help them use the available learning resources more efficiently.

This study includes methods for measuring and analysing the self-regulation of students. However, the study does not suggest that these methods are to be used in regular class as-is. The study setup is quite rigorous. First, the Open edX virtual learning environment was set up and configured, after which appropriate digital learning materials were developed. Next, students were constantly observed and instructed by three instructors, which allowed them to monitor student's self-regulation of learning and provided students with plenty of help-seeking opportunities. Finally, the resulting data was analysed from raw trace logs which required writing custom analysis code. A class teacher may instead opt-in for using ready learning analytics tools and emphasise specific interventions. For example, this study showed the potential of automated task feedback and automated hints as a tool to measure and at the same time encourage the use of different learning resources.

Nevertheless, the study draws considerations for potential future studies. First, questionnaires data and trace events can be used in conjunction with observations for a mixed-methods approach. Using both Motivated Strategies for Learning Questionnaire and trace event logs allows for a simple yet relatively extensive description of students. Secondly, this study repeats the results of other studies in suggesting that self-regulation study tools can be used as interventions. Finally, the previous notes about the complexity of the study setup imply a need to develop more automated tools to make self-regulated learning interventions and evaluations more accessible to teachers.

All in all, this study paints a more detailed picture of how self-regulation can occur in Finnish junior high school mathematics. The study can be considered a pilot study because of its high limitations in terms of size and extendibility. The results obtained here show a path for further research questions and suggestions. Firstly, the study should be extended to more test cases and prolonged to more than three lessons. Student observations can be supplemented by self-report measures and video observations of the class. Secondly, the learning environment and materials can be extended to cover more possible events, like ones used by Jovanović et al. (2017). Moreover, a better understanding of learning resource use might be achieved by analysing how different tactics are used to solve a specific mathematics problem. Thirdly, there is a need to include the effects of the learning environment in future studies. As noted in this study, the teacher can make or break students' self-regulation skills by simply building the principles by which the class works. Thus, it may prove valuable to study how the learning environment can affect how students self-regulate and whether directing a class into some particular ideology (like flipped learning) can affect students' self-regulatory skills.

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Appendices

A Notice of research provided to participants

JYVÄSKYLÄN YLIOPISTO

INFORMAATIOTEKNOLOGIAN
TIEDEKUNTA

27.1.2021

TIEDOTE TUTKIMUKSESTA

Tutkimuksen nimi ja rekisterinpitäjä

Itsesäätöisen oppimisen tarkastelu oppimisanalytiikalla suomalaisen yläasteen matematiikanluokassa: tapaustutkimus

Rekisterinpitäjät ovat Jyväskylän yliopisto sekä tutkija Denis Zhidkikh.

Pyyntö osallistua tutkimukseen

Sinua pyydetään mukaan tutkimukseen, jossa tutkitaan itsesäätöistä oppimista yläasteen matematiikassa. Sinua ja koulusi pyydetään tutkimukseen, koska koulullasi on mahdollisuus suorittaa yksittäisiä opetuskokeiluja. Tämä tiedote kuvaa tutkimusta ja siihen osallistumista. Liitteessä on kerrottu henkilötietojen käsittelystä.

Mukaan pyydetään yksi yläasteluokka, jossa on arvioltaan yhteensä 20 tutkittavaa.

Vapaaehtoisuus

Tähän tutkimukseen osallistuminen on vapaaehtoista. Voit kieltäytyä osallistumasta tutkimukseen tai keskeyttää osallistumisen, milloin tahansa.

Tutkimuksen kulku

Tutkimuksessa havainnoidaan itsesäätöisen oppimisen ilmentymismuotoja matematiikan oppitunneilla. Tutkimuksen aikana järjestetään opetuskokeilu, jossa tutkija opettaa luokalle yhden matematiikan aihealueen. Oppilaat käyttävät tutkijan laatimaa opetusmateriaalia ja tekevät tehtävät sähköisellä verkkoalustalla. Opetuskokeilun kesto on muutama oppitunti riippuen opetettavan aihealueen laajuudesta. Opetettavasta aiheesta tutkija sopii luokkaa opetettavan matematiikan lehtorin kanssa.

Oppilaat vastaavat oppimisstrategioita kartoittavaan kyselyyn ennen opetuskokeilua. Opetuksen aikana oppilaiden vuorovaikutus sähköisen verkkoalustan kanssa sekä tehtävävastaukset tallennetaan automaattisesti. Oppitunneilla tutkija myös havainnoi oppilaita.

Tutkimuksen kustannukset

Tutkimukseen osallistumisesta ei makseta palkkiota.

Y-tunnus:	Puhelin:	Jyväskylän yliopisto
02458947	(014) 260 1211	PL 35
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etunimi.sukunimi@jyu.fi	(014) 260 1021	www.jyu.fi

Tutkimustuloksista tiedottaminen ja tutkimustulokset

Tutkimuksesta valmistuu pro gradu -tutkielma, joka on julkisesti saatavilla JYX-julkaisuarkistossa.

Tutkittavien vakuutusturva

Tutkittavan on hyvä olla tietoinen siitä, että Jyväskylän yliopiston henkilökunta ja toiminta on vakuutettu. Vakuutus sisältää potilasvakuutuksen, toiminnanvastuuvakuutuksen ja vapaaehtoisen tapaturmavakuutuksen. Tutkimuksissa tutkittavat (koehenkilöt) on vakuutettu tutkimuksen ajan ulkoisen syyn aiheuttamien tapaturmien, vahinkojen ja vammojen varalta. Tapaturmavakuutus on voimassa mittauksissa ja niihin välittömästi liittyvillä matkoilla. Tapaturman lisäksi korvataan vakuutetun erityisen ja yksittäisen voimanponnistuksen ja liikkeen välittömästi aiheuttama lihaksen tai jänteen venähdysvamma, johon on annettu lääkärinhoitoa 14 vuorokauden kuluessa vammautumisesta. Korvausta maksetaan enintään kuuden viikon ajan venähdysvamman syntymisestä. Voimanponnistuksen ja liikkeen aiheuttaman venähdysvamman hoitokuluina ei korvata magneettitutkimusta eikä leikkaustoimenpiteitä.

Lisätietojen antajan yhteystiedot

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