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CLASSROOM ACTIVITIES AND SCIENTIFIC PRACTICES RELATED TO STUDENT SITUATIONAL ENGAGEMENT

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ACADEMIC DISSERTATION

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ABSTRACT

This dissertation examined how classroom activities and scientific practices are related to student situational engagement. The research topic, understudied before, shed light on how different activities that science teachers have selected to use in their science lessons are associated with different levels of student situational engagement. Research has traditionally focused on student engagement, measuring it with questionnaires or observations. However, if we want to have a closer look on the activities that engages students, the focus should be on student situational engagement. Student situational engagement was selected as main research subject, because it has several benefits for students' learning. Furthermore, student situational engagement is something that can be enhanced and modified by different activities that teachers decide to use in their science lessons. In this research, student situational engagement was defined as balance between high situational interest of an ongoing task, high evaluation of students' own situational skills and high situational challenge experienced when working on the task. This definition for situational engagement is rather new and was developed during the research. Nevertheless, it has a strong theoretical background in flow-theory and research focusing on situational interest.

This dissertation consists of three original studies. In these studies, the data was collected using experience sampling method (ESM) allowing gathering information from students situationally. In Study I, the data collected with ESM was combined with students' background information including their gender and in which grade level they were. The data was analyzed using z-scores and a multivariate analysis of variance (MANOVA). In Study II and III the data was collected in Southern Finland and Southern Michigan including only students from the 1st year in high school. In Study II and III, three-level hierarchical logistic regression models were used.

Due to the novelty of the research, Study I aimed at uncovering the level of student situational engagement in eight science classes in Helsinki area. The objective of Study I was to observe how the level of student situational engagement varied between gender and grade level. The hypothesis was that student situational engagement would be higher among students who are in the 1st grade in high school compared to students who are in 9th grade, in other words, last year in compulsory school. Study I divided science subjects to exact (chemistry and physics) and life (biology) sciences. Another hypothesis was that girls' situational interest in life science lessons would be higher than their interest in exact science lessons, and boys' situational interest would be higher in exact science lessons compared to life science lessons. Study II and III extended the investigation by focusing on activities used in science classes in an international context. The goal of Study II was to examine how classroom activities used in science classes were associated with student situational engagement while Study III focused on the relationship between student situational engagement and scientific practices. The hypothesis for both Study II and III was that different activities associate differently with student situational engagement.

The first main finding was that student situational engagement varied by their grade level and gender. Girls as a group reported above average situational engagement in life science lessons and boys in exact science lessons. However, there were no statistically significant differences related to students' situational interest in life or exact science lessons. The second main finding was that classroom activities were indeed related to student situational engagement. The result supported previous findings that lecturing was associated with lower levels of situational engagement. However, there were more variation in classroom activities that were related to higher levels of situational engagement in Southern Finland and Southern Michigan. The third main finding was that scientific practices, especially connected to modeling, were related to higher level of student situational engagement.

To conclude, the level of student situational engagement experienced in science classes can vary depending on activities used in science lessons. The result existed when using three-level hierarchical logistic regression models that took account of classroom, student and response levels. Thus, it is reasonable to assume that the role of different activities in science lessons is something that should be emphasized e.g. in teacher education. This information could be used to highlight the role of well-structured lesson plans that include carefully selected activities when teacher training students prepare their practice lessons in pedagogical studies.

Keywords: student situational engagement, classroom activities, scientific practices, experience sampling method, high school students

TIIVISTELMÄ

Väitöstutkimuksen päätavoitteena on tarkastella miten luokkahuoneaktiviteetit ja tiedekäytännöt ovat yhteydessä oppilaiden tilannekohtaiseen sitoutumiseen. Tutkimuksen aihe, jota on vain vähän tutkittu, valaisee miten opettajien oppitunneilleen valitsemat erilaiset aktiviteetit ovat yhteydessä oppilaiden tilannekohtaiseen sitoutumiseen luonnontieteen oppitunneilla. Aikaisempi tutkimus on tyypillisesti keskittynyt oppilaiden yleiseen sitoutumiseen mitaten sitä kyselylomakkeilla tai havainnoimalla oppitunteja. Jos kuitenkin haluamme saada tarkempaa tietoa niistä aktiviteeteista, jotka sitouttavat oppilaita, tulee huomio kiinnittää oppilaiden tilannekohtaiseen sitoutumiseen. Oppilaiden tilannekohtainen sitoutuminen valikoitui tutkimuksen kohteeksi, koska se hyödyttää oppilaiden oppimista useilla eri tavoilla. Tämän lisäksi tilannekohtaista sitoutumista on mahdollista kehittää ja säädellä erilaisilla aktiviteeteilla, joita opettajat käyttävät oppitunneillaan. Tässä tutkimuksessa oppilaiden tilannekohtainen sitoutuminen määritellään tasapainoksi meneillään olevan tehtävän tarjoaman korkean tilannekohtaisen kiinnostuksen, oppilaiden korkeaksi itsearvioimien tilannekohtaisten taitojen ja tehtävän korkean tilannekohtaisen haasteellisuuden välillä. Tämä tilannekohtaisen sitoutumisen määritelmä on uusi ja kehittyi tutkimuksen aikana. Tästä huolimatta, tutkimuksella on vankka teoreettinen tausta flow-teoriassa ja tutkimuksessa, joka keskittyy tilannekohtaiseen kiinnostukseen.

Väitöskirja koostuu kolmesta artikkelista. Näissä tutkimuksissa aineisto kerättiin kokemusotantamenetelmällä, joka mahdollisti tiedon keräämisen oppilailta tilannekohtaisesti. Osatutkimuksessa I kokemusotantamenetelmällä kerätty aineisto yhdistettiin oppilaiden taustamuuttujiin sisältäen oppilaiden sukupuolen ja luokka-asteen. Aineistoa analysoitiin z-pisteiden avulla käyttäen useamman muuttujan varianssianalyysia. Osatutkimuksissa II ja III aineisto kerättiin eteläisessä Suomessa ja eteläisessä Michiganissa sisältäen vain lukion ensimmäisen luokan oppilaita. Osatutkimuksissa II ja III hyödynnettiin kolmetasoista hierarkkista logistista regressioanalyysia.

Tutkimuksen uutuuden takia osatutkimus I pyrki kartoittamaan, kuinka tilannekohtaisesti sitoutuneita oppilaat olivat kahdeksassa luonnontieteen luokkahuoneessa Helsingissä. Tutkimuksen tavoitteena oli tarkastella, kuinka paljon oppilaiden tilannekohtainen sitoutuminen vaihteli sukupuolen ja luokka-asteiden välillä. Hypoteesin mukaan oppilaiden tilannekohtainen sitoutuminen on korkeampaa lukion ensimmäisen vuosiluokan oppilailla verrattuna 9.-luokan eli pakollisen peruskoulun viimeisen luokan oppilaisiin. Osatutkimus I jakoi luonnontieteet eksakteihin (kemia ja fysiikka) ja elämän (biologia) tieteisiin. Toisen hypoteesin mukaan tyttöjen kiinnostus elämän tieteeseen on korkeampaa kuin heidän kiinnostuksensa eksakteihin tieteisiin.

Osatutkimukset II ja III laajensivat ensimmäistä osatutkimusta keskittyen luonnontieteen oppituntien aktiviteetteihin kansainvälisessä yhteydessä. Osatutkimuksen II tavoitteena oli tutkia miten luokkahuoneaktiviteetit ovat yhteydessä tilannekohtaiseen sitoutumiseen siinä missä osatutkimus III keskittyi tilannekohtaisen sitoutumisen ja tiedekäytäntöjen väliseen yhteyteen. Kummankin osatutkimuksen II ja III hypoteesi on, että erilaiset aktiviteetit ovat eri tavoin yhteydessä oppilaiden tilannekohtaiseen sitoutumiseen.

Ensimmäisen päätuloksen mukaan oppilaiden tilannekohtainen sitoutuminen vaihtelee sukupuolen ja luokka-asteen välillä. Tytöt ryhmänä raportoivat keskiarvoa suurempaa tilannekohtaista sitoutumista elämän tiedon tunneilla ja pojat eksaktien tieteiden tunneilla. Tilastollista eroavaisuutta ei kuitenkaan löytynyt oppilaiden tilannekohtaisesta kiinnostuksesta elämän tai eksaktien tieteiden oppitunneilla. Toisen keskeisen tuloksen mukaan luokkahuoneaktiviteetit ovat yhteydessä oppilaiden tilannekohtaiseen sitoutumiseen. Tämä tulos oli yhtenevä aiemman tutkimuksen kanssa, jonka perusteella luennointi on yhteydessä matalampaan tilannekohtaisen sitoutumisen tasoon. Kuitenkin niiden luokkahuoneaktiviteettien välillä, jotka olivat yhteydessä oppilaiden korkeampaan tilannekohtaiseen sitoutumiseen, oli enemmän vaihtelua. Kolmannen keskeisen tuloksen mukaan tiedekäytännöt, etenkin mallintamiseen liittyvät, ovat yhteydessä oppilaiden tilannekohtaisen sitoutumisen korkeampaan tasoon.

Tämä väitöstutkimus osoittaa, että oppilaiden tilannekohtainen sitoutuminen luonnontieteen luokkahuoneessa on yhteydessä luonnontiedon oppitunneilla käytettäviin aktiviteetteihin. Tämä tulos esiintyi kolmetasoisessa hierarkkisessa logistisessa regressioanalyysissa, jossa huomioitiin luokkahuoneen, oppilaan ja yksittäisten oppilaiden vastausten tasot. Täten on järkevää olettaa, että erilaisten luonnontieteen oppitunneilla olevien aktiviteettien asemaa tulisi korostaa esimerkiksi opettajankoulutuksessa. Tietoa voidaan käyttää korostamaan hyvin suunnitellun ja tarkoin valittuja aktiviteetteja sisältävän tuntisuunnitelman merkitystä opetusharjoittelijoille, kun he suunnittelevat heidän ensimmäisiä oppituntejaan osana pedagogisia opintoja.

Avainsanat: oppilaiden tilannekohtainen sitoutuminen, luokkahuone-aktiviteetit, tiedekäytännöt, kokemusotantamenetelmä, lukio-oppilaat

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Helsinki, July 2020
Janna Inkinen

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following publications:

I Linnansaari, J., Viljaranta, J., Lavonen, J., Schneider, B., & Salmela-Aro, K. (2015). Finnish students' engagement in science lessons. *NorDiNa: Nordisk tidsskrift I naturfagdidaktikk, 11(2), 192–206.* https://doi.org/10.5617/nordina.2047

II Inkinen, J., Klager, C., Schneider, B., Juuti, K., Krajcik, J., Lavonen, J., & Salmela-Aro, K. (2019). Science classroom activities and student situational engagement. *International Journal of Science Education, 41(3), 316–329.* https://doi.org/10.1080/09500693.2018.1549372

III Inkinen, J., Klager, C., Juuti, K., Schneider, B., Salmela-Aro, K., Krajcik, J., & Lavonen, J. (2020). High school students' situational engagement associated with perceived scientific practices in designed science learning situation. *Science Education, 104(4), 667–692.* https://doi.org/10.1002/sce.21570

The publications are referred to in the text by their Roman numerals (Studies I – III). The original publications are reprinted with the kind permission of the copyright holders.

1 INTRODUCTION

The concern about science learning dates back to the 1920s and students' declining interest in science (Bennett, Hogarth, & Lubben, 2003), and has remained the focus of current research (e.g. Potvin & Hasni, 2014). For example, the Relevance of Science Education (ROSE) study, which examines the affective dimensions of how 15-year-old students from 34 different countries relate to science and technology revealed that for most European countries and Japan, school science is less interesting than other subjects (Sjøberg & Schreiner, 2010). The concern about the declining number of science-oriented students has also been highlighted in education policy documents such as the Commission's Horizon 2020 report (Ryan, 2015). In addition to the declining interest in science, research has shown that the level of students' motivation and engagement in science lessons, together with their persistence in science fields, is rather low (e.g. OECD, 2014, p. 20).

In the 1980s, student engagement was conceptualized in order to understand and thus reduce student boredom, alienation and dropping out (Finn & Zimmer, 2012, p. 98; Fredricks, 2011). This was based on the desire to enhance student learning (Reschly & Christenson, 2012, p. 3). It quickly became one of the most popular research topics in the field of educational psychology (Sinatra, Heddy, & Lombardi, 2015). The concept of engagement has offered a way to understand and improve students' learning outcomes (Finn & Zimmer, 2012, p. 97), and to organize classroom experiences to pursue long-term achievement and academic success (Skinner & Pitzer, 2012, p. 21).

In a successful learning process, students' skills and knowledge develop, allowing them to enter into new challenges (Csikszentmihalyi, 2014, p. 28-29). This successful learning process can also be defined as an optimal learning moment (see Schneider et al., 2016) or, in this dissertation, situational engagement. The definition of situational engagement builds on the idea of flow (Csikszentmihalyi, 1990, 1997, 2014). However, it is expanded with situational interest which is needed to catch attention and motivation towards an ongoing task (Brophy, 2004, p. 221).

The definition of the concept of situational engagement and its theoretical framework with research questions and the grain size of measurement all determines which research methods are appropriate (Sinatra et al., 2015). Current understanding of flow and student engagement has been greatly enhanced after the development and use of the experience sampling method (ESM) (e.g. Schmidt, Shernoff, & Csikszentmihalyi, 2014). Student engagement has previously been observed and examined through questionnaires or interviews, which provide information retrospectively. These methods, however, involve the risk of cognitive biases, as they depend on students' ability to memorize experiences correctly (Barrett & Barrett, 2001; Scollon, Kim-Prieto, & Diener, 2003; Zirkel, Garcia, & Murphy, 2015).

To avoid these memory biases and to receive information from actual learning process, the data were collected using ESM which enables gathering information of momentary thoughts, feelings (Hektner, Schmidt, & Csikszentmihalyi, 2007) or even hidden experiences (Zirkel et al., 2015).

Situational engagement in science learning is worth observing because intrinsically rewarding experiences lead students to seek similar activities in the future (Nakamura & Csikszentmihalyi, 2014, p. 92; Shernoff, Csikszentmihalyi, Schneider & Shernoff, 2003). Situational engagement is also something that can be enhanced and modified by new, innovative classroom activities (Singh, Granville, & Dika, 2002). Palmer (2009) has argued that teachers play an important role by using appropriate classroom activities that guide and scaffold the direction of learning and increases the level of student engagement. The role of appropriate classroom activities is crucial, especially in science, which has provided a satisfactory education for the majority of students (Osborne & Dillon, 2008, p. 7), but more for those who already do well in science (Osborne, Simon, & Collins, 2003). Simon and Osborne (2010, p. 238) complete this view by emphasizing that for the majority of students, science appears difficult and inaccessible.

According to Sjøberg and Schreiner (2010), the need to improve science teaching and learning has been a topical problem facing educational authorities – educational policy, national and international organizations (i.e. UNESCO, EU and OECD), researchers, science educators, and science teachers. These improvements should involve the development and sustainment of students' curiosity about the world, a positive image of science, and enjoyment of and interest in science classroom activities (Forsthuber, Motiejunaite, & de Almeida Coutinho, 2011, p. 27; Harlen, 2010). A report by a group of international science education experts highlights that all students should have a basic understanding of scientific ideas and procedures (Harlen, 2010).

This dissertation seeks to better understand how different activities in science classes are associated with students' situational engagement. In the first chapter (Section 1.1), situational engagement is defined by the co-occurence of situational interest, skills and challenge. Because student experiences are influenced by their gender and grade level, these are described in Sections 1.2 and 1.3. Finally, classroom activities and scientific practices are introduced in Section 1.4.

1.1 SITUATIONAL ENGAGEMENT

The definition of engagement varies depending on the nature of the concept observed. For example, it differs in the grain size of the context, from the micro level (students' engagement in a task or an activity) to the macro level (students' engagement in a class) (Sinatra et al., 2015), and in intensity and duration (Fredricks, Blumenfeld, & Paris, 2004). Student engagement reserach has typically been divided into three categories based on the work of Fredricks and colleagues (2004). These categories are behavioral engagement, which includes participation and involvement in activities; emotional engagement, which refers to affective reactions in the classroom; and cognitive engagement, which includes the idea of investment, thoughtfulness and willingness to exert the effort to comprehend ideas and master difficult tasks. When situational engagement is approached through flow theory, it can be related to emotional engagment, because it provides a conceptualization that represents high emotional involvement or investment (Fredricks et al., 2004).

According to Salmela-Aro, Moeller, Schneider, Spicer, and Lavonen (2016), previous resesearch on engagement has traditionally focused on the differences between individuals and has treated situational fluctuations in engagement as measurement errors. However, if we want to learn more about what type of learning process or classroom activities are associated with student engagement in different situations, we need to focus on situational engagement instead of more general engagement. In other words, we need to focus on engagement as a state instead of a trait. Focusing on student situational engagement can inform us of reasons why student experiences vary between situations and contexts and give teachers and teacher educators information on how to promote their students' engagement (Salmela-Aro et al., 2016). Research on student situational engagement is also beneficial when we try to understand why students do not want to get involved or do not want to learn in schools (Csikszentmihalyi, 2014, p. 130). The purpose of this dissertation is to find out if there are situations in the classrooms where students experience higher levels of situational engagement. If these situations are to be found, in the future it could be studied that will these situations also promote student general engagement and, for example, lead to students' better achievement in school.

As pointed out by Singh and colleagues (2002), the low level of student engagement has long been a concern to educators and school administrators. For example, students who are not engaged tend to inactively participate in classroom and school activities, and do not become cognitively involved in learning nor gain a sense of school belonging (Finn & Zimmer, 2012, p. 99). Osborne and Dillon (2008, p. 15) highlight that the reason for students' low level of engagement is a mix of a lack of perceived relevance of learning, a pedagogy that lacks variety, and less engaging quality of teaching compared to other school subjects.

Students who are engaged have a lower level of school dropout (Appleton, Christenson, & Furlong, 2008; Corso, Bundick, Quaglic, & Haywood, 2013), show long-term invovelement in schooling (Sinatra et al., 2015), and gain better achievement in school and on their academic and vocational paths (Gettinger & Walter, 2012, p. 654; OECD, 2007, p. 139; Salmela-Aro & Upadyaya, 2014; Upadyaya & Salmela-Aro, 2013). Furthermore, engaged students are hard-working, they concentrate on learning, complete assignments and hold positive attitudes toward school subjects such as science (Finn & Zimmer, 2012, p. 98; Reschly & Christenson, 2012, p. 4). In science learning situations, engaged students are in a motivational state that allows them to expend effort and persistence when they encounter difficulties and try to seek help from their teachers, peers or parents (Schunk & Mullen, 2012, p. 225; Skinner & Pitzer, 2012, p. 24). Ongoing engagement, which can be the result of long-lasting experiences of situational engagement, together with constructive coping strategies and re-engagement after setbacks, may help students shape their academic development (Skinner & Pitzer, 2012, p. 24).

The present research defines situational engagement in a similar way to how Schneider and colleagues (2016) define an optimal learning moment. According to the definition, student situational engagement consists of episodically occuring moments during which students have the necessary skills and fortitude to meet the challenge of a personally interesting task (Schneider et al., 2016). Situational engagement is a state that requires preconditions – situational skills, interest and challenge – to be high. Situational skills and situational challenge are related to the activity or task at hand. Situational skills illustrate situational resources that students have while participating in activities while situational challenge is a positive characteristic of a task which makes it worthwile of pursueing. Situational interest, on the other hand, is content or context specific and depends on students' knowledge, values and feelings. From these preconditions, situational interest has the strongest theoretical background.

Figure 1 presents the overall optimal learning moment model (see Schneider et al., 2016). In the model, for students to experience an optimal learning moment or, in this dissertation, to be situationally engaged, the preconditions or properties of engagement are required. Furthermore, an increase in optimal learning moments or times during which a student is situationally engaged enhances science learning or social and emotional development. Thus, the experience of high-level situational skills, interest and challenge will lead to optimal science learning. The model also presents other situational experiences and subjective feelings which can enhance or detract from students' learning. However, these enhancers, detractors or accelerants were not the focus of this dissertation and are to be found from publication of Schneider and others (2016) or from the book *Learning Science: The Value of Crafting Engagement in Science Environments* (Schneider, Krajcik, Lavonen, & Salmela-Aro, 2020).

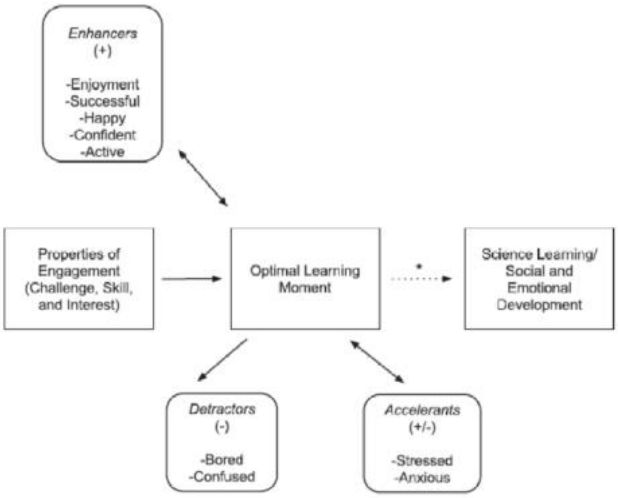

Figure 1 Model for optimal learning moment or situational engagement (see Schneider et al., 2016)

The following Sections 1.1.1 to 1.1.3 describe the preconditions of situational engagement in more detail.

1.1.1 SITUATIONAL INTEREST

Interest has a long history in both educational and psychological research (Renninger & Bachrach, 2015). The importance of interest was already recognized in the late 19th century and the value of the concept increased in the 20th century (Hidi, 2006), when researchers aimed to better understand learning conditions and decisions regarding educational or career choices (Krapp & Prenzel, 2011). The concept of interest is used in many different ways (Krapp & Prenzel, 2011), and is usually differentiated as individual (also topic or personal interest) and situational interest (Brophy, 2004; Hidi, 2006; Lavonen, Byman, Juuti, Meisalo, & Uitto, 2005a). Sources of interest vary from genetically based temperament and the basic needs of a human being to the relevance and qualities of the task (Ainley, 2012, p. 286; Hidi, 2006; Krapp, 2007).

Interest is the result of interaction between personal and situational factors, and it can be present for a shorter or a longer period of time (Krapp, 2007). At its simplest level, interest is a core psychological process that energizes and directs students' interaction with classroom activities, whereas at more complex levels it is dependent on the immediate situation and students' past experiences, which characterizes the interest as individual or personal (Ainley, 2012). When the focus is on interest that energizes and directs students' learning in a situation, the concept of situational interest is used. Different theories, such as the person-object theory of interest (POI) (Hidi & Renninger, 2006; Krapp, 2002, 2007), Hidi's and Renninger's (2006) four-phase model and Krapp's (2007) three step process, have been used to describe how situational interest develops into individual or personal interest. However, the focus of this research was only on situational interest, i.e., the interest students have in a specific task at a specific moment.

Interest that is relevant for learning exists for only a limited period of time (Krapp, 2007), and is defined by the context and characteristics of a specific task (Schneider et al., 2016; Schraw & Lehman, 2001). Thus, it is partially under the control of teachers (Schraw, Flowerday, & Lehman, 2001) and can be influenced by classroom activities and the contents or contexts of the subject (Ainley, 2012, p. 286; Bennett et al., 2003; Fairbrother, 2000, p. 7; Krapp, 2002; Lavonen, Juuti, Uitto, Meisalo, & Byman, 2005b; Renninger & Bachrach, 2015). The level of student situational interest is also dependent on gender (Lavonen et al., 2005a & 2005b).

The situation, from which situational interest originates, is often unusual, unexpected or personally relevant within a particular context (Schraw & Lehman, 2001). Situational interest directs attention and motivation to focus on an ongoing task and explore it further (Brophy, 2004, p. 221). Interest in a subject or a learning moment can influence the intensity and continuity of student engagement, which can further deepen the understanding of the subject (Lavonen & Laaksonen, 2009). Research examining 24 599 students from the 8th grade in the US showed that early interest in science is related to educational and career aspirations together with achievement in science (Singh et al., 2002). Brophy (2004 p. 307) concludes that science classes have students who are apathetic, in other words, uninterested in learning, do not find studying science worthwhile or meaningful, and do not want to engage in the learning process. According to Harlen (2010 p. 10–11), the low level of student interest in science learning might be the result of students lacking awareness of the links between science classroom activities and the world around them.

1.1.2 SITUATIONAL SKILLS

As a concept, students' skills include different aspects of how they evaluate their competence in a specific task or a subject. For example, self-efficacy can be defined as students believing in their own abilities or capabilities to handle tasks effectively and to overcome difficulties, while self-concept refers to students' beliefs in their own academic abilities (Bandura, 1994). In this dissertation, students' skills are defined in a similar way to that of Schneider and colleagues (2016). Students' situational skills reflects their cognitive performance in a situation and are separated from affective dimensions such as interest (Snow, 1994). Furthermore, situational skills are domain-specific and can develop incrementally (Brophy, 2004 p. 76). The new theory of intelligence proposes that abilities are situated and reflected in the tuning of a particular person to the particular demands and opportunities of a situation (Snow, 1994).

Velayutham, Aldridge, and Fraser (2013) argue that one of the endeavours of science is to empower students by nurturing their beliefs that they can succeed in science learning. Based on Lavonen and Laaksonen (2009), successful learners are usually confident in their abilities, and believe that investment in learning can make a difference and help learners overcome possible difficulties. Students' own experiences and expectations of success in science determine their attitudes and engagement toward learning the subject (Singh et al., 2002; Schunk & Mullen, 2012, p. 224), by, for example, increasing the level of enjoyment while learning (Hektner & Asakawa, 2000, p. 96–97). Pianta, Hamre, and Allen (2012, p. 371) claim that the connection between students' real-life experiences and their academic skills and knowledge are a universal way of fostering their engagement.

1.1.3 SITUATIONAL CHALLENGE

Challenge can be seen as a positive characteristic of a task that makes individuals concentrate and intensively work on it. Thus, challenge is not something that is given by a teacher; it is something that comes into existence through different classroom activities (Csikszentmihalyi, 2014, p. 150). Situational challenge can be seen as an engine that pushes situational skills and situational interest to new levels of capacity while energizing and guiding behavior toward the mastery of a particular goal (Schneider et al., 2016). Schneider and colleagues (2016) conceptualize situational challenge in the same way as Dweck (2006) conceptualizes the growth mindset. In the growth mindset, students who are learning new things are likely to show higher levels of achievement when they encounter difficult challenges (Schneider et al., 2016).

According to Lonka and Ketonen (2012), working on a highly challenging task can promote student situational engagement. When a student is situationally engaged, high challenge is linked to feelings of enjoyment, self-worth, ongoing development (Hektner & Asakawa, 2000, p. 100), and reaching goals (Shernoff, Knauth, & Makris, 2000 p. 141). Shernoff and colleagues (2003) claim that teachers play an important role in offering students classroom activities that are slightly too difficult for them to master at their present skill level, but which can be mastered with the acquisition of new skills. Pianta and colleagues (2012, p. 370) support this claim by suggesting that students are engaged in science classroom activities that are within reach and provide a sense of self-efficacy and control.

1.1.4 THE BALANCE BETWEEN SITUATIONAL INTEREST, SKILLS AND CHALLENGE

For situational engagement, the balance between situational interest, skills and challenge is crucial. Situational engagement is likely to be higher in classes in which teachers use activities that are both challenging and interesting to the students at the same time (Fredricks, 2011) and when students experience a high rate of situational skills while being challenged (Gettinger & Walter, 2012, p. 667). Schmidt and colleagues (2014) underline, based on their literature review, that students tend to report greater levels of situational interest when situational skills and situational challenge are above average. Moreover, a study of 107 Finnish first-year teacher training students, using a questionnaire, revealed that when students reported being engaged, they also reported high levels of challenge and strong competence together with positive academic emotions (Lonka & Ketonen, 2012). On the contrary, studies have shown that students' situational interest in a task can decrease if they perceive the material as too challenging in terms of their previous knowledge and skills (Osborne et al., 2003; Schneider et al., 2016).

The balance between situational challenge and situational skills can be delineated by a graph in which the horizontal axis represents situational skills and the vertical axis represents situational challenges (see Csikszentmihalyi, 2014, p. 28). To be situationally engaged, students' situational skills must increase in the balance of situational challenges. If this balance is destabilized, other emotions, such as apathy, relaxation and anxiety can arise in a situation (Nakamura & Csikzentmihalyi, 2014, p. 95; Shernoff & Csikszentmihalyi, 2009, p. 132). When the situational challenges of the task exceed the students' situational skills, students first become vigilant and then anxious. In contrast, when their situational skills exceed the situational challenges, students first become relaxed and then bored. Brophy (2009, p. 14) supports the existence of these emotions by highlighting that constant situational engagement would be exhausting for students. Furthermore, students vary in their desire for situational engagement. For example, some students prefer the boredom of safety over the risk of facing the situational challenges of the on-going task (Brophy, 2009, p. 14).

1.2 GENDER DIFFERENCES RELATED TO SCIENCE SUBJECTS

Study I of this dissertation examined how Finnish students' situational engagement varied according to gender and grade. Students' gender and sense of identity have been connected to their choices of subjects at school (Osborne & Dillon, 2008, p. 16) and their motivation and engagement levels in, for example, science (Forsthuber et al., 2011, p. 50). The popular traditional consensus is that boys are better at physics than girls. However, based on the Programme for International Student Assessment (PISA) (OECD, 2018, p. 4) report, girls in Finland tend to perform better than boys in PISA and other international comparisons. There has also been a debate, especially in the popular press, on how the gender gap in science is disappearing (Britner, 2008), or that gender itself contributes in only a minor way to students' success in science (Osborne et al., 2003).

Gender differences and the possible gender gap varies according to the area of science and the level of educational attainment examined (Britner, 2008). According to Osborne and Dillon (2008, p. 13), students often see science and technology as interesting. However, this interest is not reflected in student engagement in science learning at school, especially among girls (Osborne & Dillon, 2008, p. 13). A research report by Krapp and Prenzel (2011) revealed that boys are more interested in "exact" sciences (physics and chemistry) than girls. This finding is supported by other research. Barnes, McInerey, and Marsh (2005), who collected data on 450 (223 boys, 226 girls) Australian high school students using the science enrolment questionnaire revealed that girls tend to find physical sciences less interesting than biological sciences. The international ROSE study of 3626 Finnish students from the 9th grade revealed that girls were more interested than boys in physical phenomena that are not easily explained or explained at all by school physics (Lavonen et al., 2005b). The ROSE study (Lavonen et al., 2005a, 2005b; Lavonen & Laaksonen, 2009) also revealed that boys' interest in the technological aspects of science is higher than that of girls.

Cheung (2009) examined 954 chemistry students whose age varied between 14 and 19, using a questionnaire. The results showed that students' attitudes towards chemistry varied according to gender across grade levels. Furthermore, the content of chemistry lessons played a major role in students' attitudes towards chemistry. Students' physical-related interest decreases over the school years, especially among girls (Hoffmann, 2002; Lavonen, Angell, Byman, Henriksen, & Koponen, 2007; Osborne et al., 2003). In their literature review, Osborne and colleagues (2003) present an enigma according to which girls do not pursue science despite being as competent as boys and believe in their capacities to succeed in science.

Britner (2008) states that girls have traditionally been attracted to biology and life science courses and careers. The ROSE study of 3626 Finnish students revealed that girls and boys have partially different interests related to biology – boys preferring basic biology processes more than girls, and girls preferring human biology and health education subjects (Lavonen et al., 2005a; Uitto, Juuti, Lavonen, & Meisalo, 2006). These results were supported by a study of 321 (49% girls) 11th grade students in Finland (Uitto, 2014). Another study of 2989 (48% girls) Finnish 9th grade students demonstrated that girls performed better than boys in biology, and that their attitude dimensions were more positive (Uitto & Kärnä, 2014, p. 318). These findings were in line with research on 502 (233 boys, 269 girls) high school students in the US (Britner, 2008).

Gender differences can also be related to science classroom activities. For example, Juuti, Lavonen, Uitto, Byman, and Meisalo (2010) concluded in their study of 3626 (1843 boys, 1772 girls) 9th grade students in Finland that girls desired more classroom activities that emphasized interaction, whereas boys were more satisfied with current science teaching. Hoffmann (2002) argues that physics instructions and classroom activities seem to be more important for the development of girls' interest because they seem to have less pre- and out-of-school experiences related to physics than boys. How equally boys and girls experience their suitability for science studies and careers is also dependent on the teacher. For example, teachers tend to express higher expectations of boys in terms of their achievements in science than of girls (Hoffmann, 2002). Many countries have substantial gender differences in enrolments in elective science courses despite concerted efforts to change this in recent years (Barnes et al., 2005). Even though the number of women earning degrees in physical science have increased, the percentage of degrees earned by men remains higher at all levels (Britner, 2008).

Women are represented in the life science fields to a much greater extent than in the physical science fields, which means that role models in biology are often females and role models in physical science often males (Britner, 2008; Griffth, 2010). The low enrolment in physics at the university level may lead to a lack of technological expertise in industrial, technology-based science and science education careers, which will have direct consequences on the economy (Oon & Subramaniam, 2011). These concerns about the declining number of science-focused students also apply to science education careers. For example, there is pronounced concern that in the future, schools will have no qualified physics teachers to teach the subject due to the declining number of physics-oriented students (Oon & Subramaniam, 2011; Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003).

1.3 GRADE LEVEL DIFFERENCES RELATED TO STUDENT SITUATIONAL ENGAGEMENT

In addition to gender differences, another interest of the Study I, which focused only on Finnish students, was in how student situational engagement varied between grades. Students' developmental tasks, changes and challenges related to physical milestones and societal expectations can have an impact on their situational engagement (Mahatmya, Lohman, Matjasko, & Farb, 2012, p. 47). For example, students constantly experience growth in their intellectual and social capacities and competencies. Moreover, they may value different things and have different role models during their school years, which might also affect their behavior and situational engagement. In Finland, 9th grade is the last compulsory grade for all students. After this, students choose to go to high school, vocational school or to enter work-life. Thus, it is assumed that students in the 9th grade and 1st year of high school might also have different levels of situational engagement at school.

According to Fredricks and colleagues (2004), student engagement takes different forms during the school years, because students become deeply invested in learning after they have the intellectual capacity to self-regulate learning, which tends to occur at later ages. This is supported by Mahatmya and colleagues (2012, p. 47) who state that middle childhood includes continued growth in intellectual capacities and competencies together with learning of fundamental skills and values that are associated with their particular environment. Griffths and colleagues (2012, p. 563), who conducted research in the US on 92 600 students from the 9th and 11th grades found that one third of high school students reported decreased engagement in school science during their teen years. A longitudinal study of student engagement focusing on students from the age of 5 until the age of 20 revealed that students with high engagement levels by the age of 10 appeared most likely to maintain these levels in the future, whereas students with moderate or low levels of engagement were more open to change (Wylie & Hodgen, 2012, p. 28). In contrast, Osborne and Dillon (2008, p. 16) specify that student engagement and interest in science learning is largely formed by the age of 14. This finding is supported by Itzek-Greulich and Vollmer (2017), who state that students' interest in science declines in secondary school.

Environment, such as school culture, can also have an impact on students' situational engagement during the developmental period. For example, when students become adolescents, academic expectations increase in complexity (Mahatmya et al., 2012, p. 47). Furthermore, students' interest in science learning also varies according to subjects. Williams and colleagues (2003) found that even though students enter high school with an equal liking of biology and physics, thinking of them more like as "science", their interest in physics tends to decline but their interest in biology remains reasonably stable. Since engagement develops over a period of years, it is important to support students' situational engagement throughout their school years, from elementary school to middle school and even into high school (Finn & Zimmer, 2012).

1.4 WORKING IN SCIENCE CLASSES

If educators want to fully understand the variety of student situational engagement in school, the most fruitful approach is to focus on classes, because engagement is specific to a particular context (Corso et al., 2013). In science classes, student situational engagement can be influenced by other students, the teacher, and the overall culture of the classroom (Corso et al., 2013; Csikszentmihalyi, 2014; Fredricks, 2011; Hipkins, 2012; Juvonen, Espinoza, & Knifsend, 2012; Osborne & Dillon, 2008; Pianta et al., 2012). In addition, student situational engagement may be increased by the choices of classroom activities. In this dissertation, the aim was to observe how classroom activities and scientific practices are associated with student situational engagement. Most science teachers agree that one of their greatest desires is to deeply engage their students in science learning (Schmidt et al., 2018, p. 19). Teachers can create opportunities for students to situationally engage through the selection of curriculum content that focuses on conceptualizing and creating meaning and relevance between content and a learner (Singh et al., 2002, p. 330). One way to increase student situational engagement in science learning and their achievements in these subjects is to develop and extend the ways in which science is taught in schools (Fortshuber et al., 2011, p. 59; Osborne & Dillon, 2008, p. 21).

1.4.1 CLASSROOM ACTIVITIES

Even though teaching-learning processes are complex and, thus, difficult to reduce to well-designed algorithms or a string of sequences, different activities can still be recognized in the process (Leach & Scott, 2000, p. 54). When a group of classroom activities are observed, they can be categorized according to, for example, the roles of the students and the teacher. For example, Lavonen and colleagues (2007) divided classroom activities into three categories: teacher-delivered instruction, student-directed learning and student-centered learning. Many different measures have been taken to reverse students' lack of interest in and enjoyment of science learning. Much of the previous research has focused on practical work (Abrahams & Millar, 2008; Hampden-Thompson & Bennett, 2013; Millar, 2011), hands-on activities (Holsterman, Grube, & Bögenholz, 2010; Toplis, 2012), and inquiry-based learning (Harlen, 2010). Other pedagogies that have attempted to create actively thinking students as opposed to passively listening students have been co-operative or collaborative learning, active learning, case-based learning and hands-on learning (Mestre, 2005).

Science teachers design and use different classroom activities for students to achieve their curriculum aims. According to Lavonen and Laaksonen (2009), a good science lesson has both a clear goal and a clear structure that engages students in learning and allows them to draw conclusions and make interpretations. Harlen (2010, p. 10) states that instead of completing tasks or particular grades, the aim of classroom activities should be to deepen students' understanding of scientific ideas and at the same time foster their attitudes toward and capabilities for science learning. In addition to the selection of appropriate classroom activities, the quality of teaching science is also influenced by the type of learning material used during lessons (Forsthuber et al., 2011, p. 80).

The problem with the classroom activities and instructions that teachers present is that by necessity they are aimed at an average level of complexity in relation to the individual skills of students, which makes these activities or materials too easy for some so that they will become bored, and too difficult for others so that they become anxious (Csikszentmihalyi, 2014, p. 167). To avoid directing classroom activities toward only some particular students, students and teachers need to know and use a range of activities, as different activities will suite different students (Fairbrother, 2000, p. 7; Lavonen et al., 2007; Lavonen et al., 2005b). These classroom activities should be innovative (Osborne & Dillon, 2008, p. 6), meaningful and worthwhile to students (Brophy, 2004, p. xii; Lavonen & Laaksonen, 2009). Classroom activities that students experience positively can increase students' interest and engagement in science learning together with longer term memorability (King, Ritchie, Sandhu, & Henderson, 2015), and alter negative attitudes towards science learning (Singh et al., 2002). Furthermore, structured and productive classroom activities will produce more opportunities for students to be situationally engaged (Shernoff et al., 2000, p. 143).

Students tend to prefer classroom activities that they feel competent enough to accomplish (Schunk & Mullen, 2012, p. 224), which might differ from activities that are best for learning (Juuti et al., 2010). For teachers to be able to continuously improve their teaching through adapting and transforming their practices, they should be provided with continuous support (Osborne & Dillon, 2008, p. 20). In this study, the students were given different classroom activities without categorization, focusing on frequently used activities that were easily recognized by students themselves (see Juuti & Lavonen, 2016). These classroom activities – listening, discussion, calculation, assessment, computer use, group work, laboratory work, and presenting – are described in more detail in Study II of this dissertation (Inkinen et al., 2019). These selected classroom activities were goal-oriented and emphasized social interactions among students or between students and their teachers (Juuti et al., 2010; Lavonen et al., 2007; Lavonen & Laaksonen, 2009). This dissertation aims to discover the classroom activities that situationally engages students the most, and thus have long-lasting benefits for students' science learning. Some previous ESM research has focused on the association between student situational engagement and classroom activities and has conceptualized situational engagement in a different way to the current study.

Based on a review by Bennett and colleagues (2003), there is increasing anecdotal evidence that many science lessons start with students listening passively to lectures and taking down notes about the intended learning outcomes of the lesson. This result is supported by Juuti and Lavonen (2016) who examined 2949 Finnish students in their final year of comprehensive school (aged 15–16), and found that in Finnish science classes, teachers typically teach new content by giving lectures, and students learn by writing notes, which is followed by practical work. Research by Shernoff and colleagues (2000) and Toplis (2012) have shown that teachers prefer to use a mixture of classroom activities such as lecturing, discussion and individual work. For example, a study conducted in the UK, observing science lessons and interviewing 29 students whose age varied between 13 and 16, revealed that teachers most often used three to five classroom activities in the same lesson (Toplis, 2012). Schmidt and colleagues (2018) analyzed data on 244 students in the US using ESM in their science classes. Based on their results, the most common classroom activities in science lessons were laboratory work (25%), followed by tests (17%), individual work (16%) and lecturing (13%). Another ESM study of 526 high school students in the US revealed that students spent one third of their classroom time passively listening to the lecture and more than half doing independent work (Shernoff et al., 2003).

Schmidt and colleagues (2018) conducted a study among high school students in the US. They collected data using ESM and video recordings of 12 science classes, once in the fall and once in the spring. Each period of data collection lasted five school days. The students were divided in half to maximize the variety of classroom activities recorded, and each student answered the ESM questionnaire twice during a science lesson. According to the results, individual work and listening to lectures do not situationally engage students in optimal ways. When students take a test, they experience some level of situational engagement, indicating that they recognize the high importance of the test, but do not necessarily derive interest or enjoyment while doing it. The results also revealed that laboratory work has great potential to increase students' situational engagement, but often fails to live up to this potential.

Shernoff and others (2003) also conducted a study of student situational engagement and classroom activities using ESM. They examined 526 high school students across the US. The data were collected as part of the Sloan Study of Youth and Social Development (SSYD) which is a US national longitudinal study. The students answered the ESM questionnaire eight times per day from 7.30 am to 10.30 pm over the course of seven days. The study focused on the students' answers in the classes regardless of the subject. According to the results, lack of challenge or meaning of the task lead the students to experience a low level of situational engagement. This happened especially when listening to lectures. The students experience a high level of situational engagement when they worked either individually or as a group. The results thus highlight the importance of classroom activities that encourages students to be active, and that support students' sense of competency and autonomy.

Classroom activities have also been retrospectively examined using a questionnaire or observations. For example, data on 42 754 students in the US revealed that lecturing was the least preferred type of classroom activity (Yazzie-Mintz & McCormick, 2012). The same research showed that the majority of students experienced group work and discussion as exciting and engaging. Lavonen and colleagues (2005b) examined 3626 Finnish students in science classes using a survey. The study revealed that 30% of the students wanted to reduce the amount of teacher-led studying, such as listening to lectures. However, the students responded positively to a lecturing when the teacher introduced new information to them, and then demonstrated how this information could be used to solve problems in performing tasks. The same research by Lavonen and colleagues (2005b) revealed that the majority of students wanted more group work activities, such as projects.

Based on the results of Juuti and Lavonen (2016) concerning 2949 high school students in Finland, discussion was connected to students' active thinking, enrolment intention and feeling of importance. However, the students felt that they had rare opportunities to discuss difficult concepts with their teacher on in small groups. The need for discussion was also highlighted in PISA 2003, which focused on 3626 students in the 9th grade (Juuti et al., 2010), and results concerning 825 high school students in Finland (Lavonen et al., 2007).

PISA 2006, focusing on 4456 US students, highlighted the role of student investigations and hands-on activities in increasing student engagement in science learning (Grabau & Ma, 2017). Furthermore, the research emphasized that classroom activities were consistent predictors of science-related engagement. Laboratory work also seemed to improve schoolwork engagement among 1530 Finnish vocational track students (Salmela-Aro & Upadyaya, 2012).

As shown above, previous research has revealed that classroom activities are related to student engagement regardless of whether the research was conducted retrospectively using questionnaires or observations, or situationally using ESM. Some patterns were found in the previous results. For example, listening to a lecture was related to a low level of engagement, whereas discussion increased engagement. Because this research field is still under-studied, this dissertation aims to support these previous findings.

1.4.2 SCIENTIFIC PRACTICES

Study III of this dissertation focused on how scientific practices are related to student situational engagement. The focus on scientific practices became more popular in 1960–1990, when interest in and support of scientific inquiry as an approach to science teaching in emphasizing learning science concepts through the use of skills and abilities of inquiry grew (Bybee, 2011). Scientific practices are based on the assumption that science learning is about more than just learning facts, concepts, theories and laws (Bybee, 2011; Evagorou, Erduran, & Mäntylä, 2015). It includes multiple ways in which scientists explore and understand the world (Bybee, 2012; Krajcik & Merritt, 2012). Scientific practices are based on processes of perpetual evaluation and critique that support progress in explaining nature (Ford, 2015). For students to be able to efficiently learn science context (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014), and engage in authentic science learning in particular (McNeill, 2009), they need to be situationally engaged in scientific practices. Even though they may not be able to think and act as exactly scientifically as scientists, students can be taught some basic forms of scientific reasoning and acting that capture the essence of science (Ford, 2015).

Students can be supported in scientific practices by helping them know and understand what to do (Berland et al., 2016; Ford, 2015). In other words, by encouraging them to be active participants in the learning process. According to Ford (2015), participation in scientific practices requires knowledge of how to execute performances appropriately, which implies knowledge of performances and how these are connected and work together when explaining a phenomenon. A previous study of 2949 high school students in Finland revealed that students felt they rather rarely had opportunities to take responsibility for their own learning in science (Juuti & Lavonen, 2016).

The benefits of using scientific practices have also been recognized at school levels by including these practices in, for example, the curriculum. The Finnish science curriculum emphasizes asking questions, designing and evaluating scientific inquiry, interpreting data, explaining phenomena, and using scientific concepts (FMEC, 2013). In the US, scientific practices and Next Generation Science Standards (NGSS) are both based on A Framework for K-12 Science Education (Ford, 2015; Krajcik & Merritt, 2012). A Framework for K-12 Science Education is the first step in a process to create new science standards in K-12 science education, highlighting the power of integrating understanding the ideas of science with engagement in the practices of science and at the same time building students’ proficiency and appreciation of science during the school years (NRC, 2012). The use of scientific practices is also important when making science more attractive to students in groups that are under-represented in science careers (Mody, 2015).

In the research, scientific practices are grouped into three spheres of activity – investigating, developing explanations and solutions, and evaluating

(NRC, 2012; Osborne, 2011). When focusing on individual scientific practices, investigating includes asking questions, planning and conducting investigations, analyzing data and solving math problems; developing explanations and solutions includes developing models, using models and constructing explanations; and evaluating includes using evidence to form arguments and evaluate information. More detailed descriptions of different scientific practices are introduced in Study III (Inkinen et al., 2020).

Most previous studies have focused on developing explanations and solutions (e.g. Harrison & Treagust, 2000; Kenyon, Davis, & Hug, 2011; Matthews, 2007; Schwarz et al., 2009; Schwarz & White, 2005). The majority of research focusing on scientific practices in the classroom context has been more descriptive and does not reveal how these practices are related to student situational engagement. It has studied, for example, the different kinds of questions used in classes (Krajcik et al., 1998; Reiser, Novak, Tipton, & Adams, 2017) or the role of models (Edelson & Reiser, 2006; Evagorou et al., 2015; Harrison & Treagust, 2000; Krajcik & Merritt, 2012; Osborne, 2014; Schwarz & White, 2005). This dissertation thus offers new information on how teachers' use of scientific practices is associated with student situational engagement.

Some previous research has been related to scientific practices and their impact on students' experiences such as engagement. Mestre (2005) presents that asking questions can increase student engagement when students work collaboratively with meaningful questions. In addition, a study of 224 students in the 9th grade in Australia expressed that students were engaged when they proposed investigable questions, made observations, gave explanations, and reported their results (Palmer, 2009). Student engagement can also be increased by using models; through the use of models, teachers can nurture students' engagement to learn (Brophy, 2004). PISA 2006, which looked at 4456 high school students in the US reveled that models are positively related to student engagement, self-concept, enjoyment, instrumental motivation, the general value of science, and the personal value of science (Grabau & Ma, 2017). In addition, argumentation has been related to student engagement in the coordination of conceptual and epistemic goals, and to making students' scientific thinking and reasoning visible to teachers (Osborne et al., 2004).

As described above, there is a lack of research on the association between student situational engagement and scientific practices. However, previous research has shown that scientific practices have multiple benefits for students' learning (Krajcik et al., 2014; McNeill, 2009; Mody, 2015). Thus, it is reasonable to assume that the selection of scientific practices is also related to higher levels of student situational engagement.

1.5 SUMMARY: THE ADOPTED PERSPECTIVE

The situational engagement and science classroom literature presented in Section 1.1 to 1.4 provides a theoretical framework that helps us understand which factors related to science classroom activities and scientific practices are associated with a higher level of student situational engagement. The study uses ESM, which enables the examination of student situational experiences and better re-call than retrospective collected paper questionnaires or interviews (Barrett & Barrett, 2001; Scollon et al., 2003; Zirkel et al., 2015). Student situational engagement can provide teachers, teacher educators and researchers with information on how to increase the number of students who are hard-working, complete assignments and have positive attitudes towards learning (Finn & Zimmer, 2012, p. 99). When the relationship between the different activities used in science classes and student situational engagement is well-known, it is possible to increase the number of students who choose science courses in the future and apply for science careers. This assumption is based on the idea that students tend to seek similar experiences in the future, based on the feeling of an intrinsically rewarding experience (Nakamura & Csikszentmihalyi, 2014 p. 92; Shernoff et al., 2003).

The theoretical perspective presented in Section 1.1. conceptualized student situational engagement as the balance between situational interest, skills and challenge when all these preconditions are higher than average, as reported by the students themselves in a situation (see Schneider et al., 2016). These preconditions all have a strong theoretically justified background. The definition of situational engagement used in this study differs from that previously used by, for example, Shernoff and colleagues (2003). However, it builds strongly on the balance between situational challenge and skills, which is the basis of flow experience (e.g. Csikszentmihalyi, 1990; 1997; 2014; Nakamura, & Csikszentmihalyi, 2014; Schneider et al., 2016; Shenoff, & Csikszentmihalyi, 2009) in addition to situational interest, which directs and energizes learning (Ainley, 2012, p. 286; Brophy, 2004).

The definition of student situational engagement advanced and became more precise between Studies I, II and III. In addition to the definition of the concept, the analytical approaches also progressed along with the studies. However, the ESM questionnaire that the students filled out remained the same. In Study I, we conceptualized student situational engagement as the sum of situational interest, skills and challenge – as in Studies II and III. However, in Study I, situational skills and interest were single items rather than sums. The definitions of situational engagement are shown in Section 4.3.1 in Table 2.

2 AIMS

The overall aim of this dissertation is to investigate student situational engagement in science classes in Helsinki, Finland (Studies I–III) and Southern Michigan, US (Studies II and III). It offers new information on how student situational engagement is associated with activities in science classes. In contrast to research that have conceptualized engagement as a monolithic trait, this dissertation specifically identifies engagement as a state that varies in intensity across different domains and situations. It uses ESM, which enables better recall of cognitive and affective experiences in science learning situations (Jimerson, Campos, & Greif, 2003) compared to, for example, cross-sectional and longitudinal surveys (Tuominen-Soini & Salmela-Aro, 2014). Although researchers agree that engagement is a changeable experience that occurs over time, existing studies have paid limited attention on how students experience science learning situations (Fredricks & McColskey, 2012). Using ESM, the dissertation focuses on the following research questions:

- How does Finnish students' situational engagement vary according to gender and grade in exact and life science lessons? (Study I)
- How are different classroom activities (Study II) and scientific practices (Study III) associated with student situational engagement in Southern Finland and Southern Michigan?

The dissertation consists of three original studies (see Table 3). The aim of Study I was to answer the first research question and uncover the level of student situational engagement among students in the 9th grade and 1st year of high school. Based on a literature review, we hypothesized that student situational engagement would be higher among students in the 1st year of high school than among those in the 9th grade, due to the selectivity of students. Moreover, we expected girls' situational interest in life science lessons (biology) to be higher than their interest in exact (chemistry and physics) lessons, and boys' situational interest would be higher in exact science lessons compared to life science lessons. The second research question was addressed in Studies II and III, which went further and examined how different activities in science lessons were related to student situational engagement. Whereas Study I focused on only Finnish students, Studies II and III included students from Southern Finland and Southern Michigan. The data collection in these countries, whose science curricula emphasize similar scientific practices, was worthwhile because it allowed a more comprehensive picture of the phenomena.

3 CONTEXT : HIGH SCHOOL STUDENTS IN SOUTHERN FINLAND AND SOUTHERN MICHIGAN

Studies II and III included data from both Southern Finland and Southern Michigan. Because the data were collected in only a few schools in a limited area of both countries, the decision was made to change the context from Finland (Study II) to Southern Finland (Study III) and the US (Study II) to Southern Michigan (Study III). For consistency, Southern Finland and Southern Michigan are also used in the dissertation. The idea of international study was not to compare the results of the countries. Instead, the idea was to extend and enrich the national picture by providing a larger context within to interpret the results, as pointed out by the OECD (2007).

3.1 EDUCATION SYSTEMS IN SOUTHERN FINLAND AND SOUTHERN MICHIGAN

The size and history of countries have several outcomes in school cultures. In the US, general political events have affected the changes in science education, according to Reese (2011, p. 1). For example, when the US found themselves lagging behind the Russians in space exploration, policymakers, scientists and educators updated the US curricular content and instruction in order to improve students' science performance (Schneider et al., 2020). In the US, schools have been at the center of attempts to improve the lives of individuals and to ensure the greater good of society (Reese, 2011, p. 249). Since the 1990s, improving science education has been a political agenda for many European countries (Forsthuber et al., 2011, p. 25). For example, a long-term aim of Finnish education policy has been to promote educational equality and raise the general standards of education (Lavonen, 2007, p. 2; Lavonen & Laaksonen, 2009).

In the US, public schools are largely controlled by state laws and are locally governed (Reese, 2011, p. 1). In other words, goals, curricula and the focus of educational systems are left to the discretion of individual states (Lederman & Lederman, 2007, p. 108). This decentralization makes school and education reform and transformation painstakingly slow and frustrating for reformers (Reese, 2011, p. 1). On comparison, in Finland, even though the Finnish National Department of Education is responsible for the implementation of education policy, municipalities and local education providers have strong autonomy (Lavonen & Laaksonen, 2009). In addition, principals or head teachers are responsible for school development and implementing educational policy at the local level.

Finnish school-based decisions are different in comparison to those in many other countries, and thus difficult to understand and adopt (Lavonen, 2007, p. 114). According to Lavonen (2018, p. 4), US and Finnish school systems exemplify two different models: an outcome-based model and the Finnish model. The outcome-based model aims for better learning outcomes, and its focus is often on a product such as a students' success in a test. However, it has been criticized for creating a competitive school culture that ranks students and schools that "teach for the test". The Finnish model, on comparison, has broad aims for teaching or learning, and the focus is on the process in addition to the product itself. The downside of the Finnish model is that comparing the quality of learning outcomes and selecting students for the next level is difficult.

3.2 SCIENCE CURRICULA IN FINLAND AND MICHIGAN

Finland's standard curriculum has gone through changes in recent school history. Finland had an overly flexible curriculum from 1994 to 2000 and, for example, the assessment of students varied between teachers and schools, threatening the equality and comparison of students at the end of comprehensive school (Lavonen, 2007, p. 110 & 2018). Since the beginning of the 1990s, when national-level inspection of learning materials was terminated, schools and teachers have been responsible for choosing teaching methods and learning materials (Lavonen & Laaksonen, 2009). Lavonen (2018, p. 14) maintains that in Finland, flexibility and diversity have been the main guidelines of the National Framework Curriculum. Local education providers are responsible for local curricula, which is seen more as a process than a product and plays a central role in school improvement (Lavonen & Laaksonen, 2009). The recent Finnish National Core Curriculum emphasizes educating students who actively acquire and apply science knowledge and 21st century competences such as attitudes, knowledge and advanced technology skills in their learning.

According to Lavonen and Laaksonen (2009), the Finnish school curriculum gives equal value to all school subjects and has a dynamic balance between humanities and science subjects. The Finnish curriculum has both general and subject-specific goals that are considered to be the guidelines that municipalities and teachers have to follow, and which describe what students are expected to have learned (Lavonen, 2018, p. 14). The curriculum emphasizes classroom activities in which students identify, recognize or observe scientific issues; explain or interpret data or scientific phenomena; and draw conclusions based on the evidence (Lavonen & Laaksonen, 2009). The 2014 Finnish science curriculum (FNBE, 2016) emphasizes students' active role in building knowledge and learning science through collaboration, integrating transversal competences with science aims, digital tools, and scientific practices. Scientific practices are presented in the Finnish science curriculum in either general subject-specific aims or in connection to a specific course. For example, developing explanations and solutions is one of the overall aims in chemistry: "*The objective of the teaching and learning in chemistry is that the student is able to use different models for describing and explaining phenomena and making predictions*" (FNBE, 2016, p. 166). On the other hand, the general aim in physics is: "*- - that the student is able to form, interpret, and evaluate different models*" (FNBE, 2016, p. 161).

The US has had many projects such as Science For All Americans or Project 2061, the National Science Education Standards (NSES) (Lederman & Lederman, 2007, p. 101), and A Framework for K-12 Science Education (NRC, 2012), which provide a vision for scientific literacy students and a set of standards for science education. The latest seminal report produced by the National Research Council of the National Academy of Sciences (NRC) is A Framework for K-12 Science Education. The Next Generation Science Standards (NGSS), following the guidelines given in the framework, offer a new vision for science education and reject earlier conceptions of focusing on scientific facts and superficial understanding of scientific principles. The goal of the framework, and thus of NGSS, is to ensure that by the end of the 12th grade, all students have an appreciation of the beauty and wonder of science, possess sufficient knowledge of science to engage in public discussions, are careful consumers of scientific information related to everyday life, are able to continue learning outside of school, and have the skills to enter the careers of their choice (NRC, 2012). According to McKenzie and Ritter (2014, p. 1), before updating science curricula, science standards for most states were considered to be outdated, reaching back to the 1990s. However, in the early 20th century, all states started the process of creating new standards for student learning and a new curriculum framework to guide instructions (Daling-Hammond, 2004, p. 1054 – 1055).

States can voluntarily adopt NGSS in their K-12 performance expectations, and if they do so, the science standards are called "State K-12 Science Standards" (McKenzie & Ritter, 2014, p. 1). For example, in Southern Michigan, where Studies II and III were conducted, the science standards are called "Michigan K-12 Science Standards". The integration of science standards has been justified by the fact that standards are essential for enhancing all students' learning (NGSS Lead States, 2013). The NGSS include performance expectations to guide for what students should learn in science lessons and how they are to be assessed (Krajcik et al., 2014). Furthermore, performance expectations express the concept and skills to be performed, leaving curricular and instructional decisions to states, districts, schools and teachers (NGSS, 2013). The Michigan K-12 Science Standards give guidance on how to integrate specific scientific practices into science courses. For example, in the "Structure and properties of matter" chemistry course, developing explanations and solutions are described in the course performance expectations of students as: "*Develop models to illustrate the* *changes in the composition of the nucleus of the atom and the energy released during the process of fission, fusion, and radioactive decay*" (MDE, 2015, p. 27). On the other hand, in the "Forces and interactions" physics course, students' performance expectations related to investigations are expressed as: "*Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current"* (MDE, 2015, p. 28).

4 METHODS

4.1 EXPERIENCE SAMPLING METHOD (ESM)

ESM was developed by Csikszentmihalyi in the early 1970s (Csikszentmihalyi, 1997, p. 15), and has been used to measure momentary thoughts, feelings, and actions in people's everyday lives (Barrett & Barrett, 2001; Hetkner et al., 2007; Zirkel et al., 2015). One of the strongest benefits of ESM is that it allows the investigation of complex questions related to consciousness, behavior (Scollon et al., 2003) or even hidden experiences such as boredom or frustration (Zirkel et al., 2015). ESM can reduce the mehodological disadvantages of standard self-reports, such as cognitive biases stemming from students' inability to memorize experiences correctly, by capturing experiences closer to the point of occurrence (Barrett & Barrett, 2001; Scollon et al., 2003; Zirkel et al., 2015).

Through ESM, researchers are able to identify patterns of behavior within a student rather than focusing on patterns of behavior across students (Conner, Tennen, Fleeson, & Barrett, 2009). In addition, ESM allows us to explore questions related to how students' experiences are shaped by contexts and time due to the "nested" nature of ESM data (Fredricks & McColskey, 2012; Zirkel et al., 2015). According to Schneider and colleagues (2016), in order to examine and learn which classroom activities situationally engage students, these experiences should be measured in real time. This supports the idea of Fredricks and colleagues (2004) who call for methods that better measure student engagement in the classroom context.

ESM can be performed in three different signals' schedules: interval-contingent sampling, event-contingent sampling, and signal-contingent sampling (see more Hektner et al., 2007; Scollon et al., 2003). The most typical schedule is signal-contingent sampling (Hektner et al., 2007), in which participants are signaled at random times over the course of several days. The data collection in the present research followed this schedule even though all the students received the ESM questionnaire at the same time, and the times for the schedules were chosen beforehand by the researchers. However, neither the teachers nor the students knew the exact schedule of the signals, and as they varied between the lessons, they were difficult to predict.

According to Csikszentmihalyi (1997, p.15), ESM questionnaires are typically given to participants at random times during the day from early morning to night. According to Schmidt and colleagues (2014), data collection should last over a period of several days to avoid the problem of recall and estimation errors. In my research, the data collection lasted ten to twelve days. ESM was implemented by using smartphones, making coding and data entry easier and not as time consuming compared to, for example, paper and pencil questionnaires (Hektner et al., 2007). The smartphones used an android-based application called Paco to collect the data, which is free software available in play stores. In addition to the Paco application, a website platform was used to construct the ESM questionnaires. The ESM questionnaire, together with collected data, could be transferred between the website and the smartphone when the smartphone was connected to the internet. This process made the data transformation from the website to the SPSS or STATA programs quite easy. However, it took a great deal of time to prepare the phones, which involved labeling them, charging them, preparing them for research purposes, compiling the ESM questionnaires using the website and then loading these onto the phones.

Before conducting ESM research, several things must be carefully planned: the length of the data collection, the times at which the ESM questionnaires will send their signal, and the amount and content of the ESM questions in the questionnaire. Burdening students can lead to missing responses and non-responses, which also have an impact on data analysis (Jeong, 2005, p. 461). Because data collection is intensive when using ESM, it is recommended that students receive compensation for their participation. When a researcher observes situational data during science learning, there are challenges associated with the science learning environment, such as students possibly moving forward in tasks at different phases or the data collection itself disrupting the flow of the learning (Sinatra et al., 2015).

The use of ESM enables collecting data from a large number of individuals (Zirkel et al., 2015), which is also possible using smartphones. A large sample size is also a requirement for more sophisticated analysis methods such as hierarchical regression models. ESM allows within-person analyses, which can reveal interesting patterns that may disappear when focusing on between-person investigations (Scollon et al., 2003). Furthermore, ESM itself allows precise control of timing answers and reduces human errors when managing the data (Barrett & Barrett, 2001). Because the data were collected using a novel research method, I interviewed the students after the data collection. Their experiences of using the smartphones were positive because the phones were familiar to the students, simple to use and interesting. The students who answered almost all of the ESM questionnaires downloaded several applications onto their smartphone and were allowed to use the phone as their own; for example, they could take photos not related to the data collection.

4.2 PARTICIPANTS AND PROCEDURES

All the datasets used in this study were drawn from four international research projects: "EAGER: Opetuksen ja opettajankoulutuksen kehittäminen tutkimalla oppilaiden kiinnostuksen syntymistä matematiikan, luonnontieteiden ja insinööritieteiden opiskelua kohtaan: Kansainvälinen tutkimusyhteistyö" (Funded by Academy of Finland, 2013–2015, Grant

265915), "STEM: Engaging Learning Environments in STEM: Collaboration with Finland and Chile" (Funded by Academy of Finland, 2016-2018, Grant 294228), "An International Study of Student Engagement: An EaGER Grant" (Funded by National Science Foundation, 2014-2016, 1450756) and "PIRE: Crafting Optimal Learning in Science Environments" (Funded by National Science Foundation, 2015-2021, 1545684). EAGER and PIRE projects were collaborative projects between Finland and the US, whereas one of the projects was conducted in collaboration with Chile. I was involved in the Finnish projects from the very beginning and participated in all stages of the data collection. The ESM questionnaire was designed collaboratively in the projects, as described later in Section 4.3. I was also responsible for preparing the smartphones used in Studies I, II and III, and for the data collection in the schools.

All of the studies were based on ESM questionnaire data collected using smartphones. In all of the studies, the data were collected from high school students in Southern Finland and Southern Michigan (except for Study I, which focused on only students from Southern Finland, and included students from 9th grade). ESM data were also collected from outside science classes, but the data used in Studies I–III included responses from only science lessons. The length of Studies I, II and III varied. In Study I, the data were collected in spring 2013 and fall 2013. In spring 2013, the study lasted two weeks and in fall 2013 only one week. In Study II, the data were collected in spring and fall 2015 over twelve days. Study III was conducted during the school year of 2015–2016. The data collection lasted twelve days, but the teachers planned their teaching around scientific practices on six of these days. Thus, the data in Study III were from these six days.

4.2.1 PARTICIPANTS

For an overview of the participants in each individual study, see Table 1. In Study I, students were selected from two school in Southern Finland in which the participating teachers were already familiar to the University of Helsinki researchers. In these schools, the teachers reacted positively to the different projects and data collections. The high schools were very popular, and the schools were able to select their students. Altogether 68 students (31 girls, 37 boys) from the 9th grade and 67 students (46 girls, 21 boys) from the 1st year of high school participated in the study. The data were collected from three biology, two chemistry and three physics courses.

Study II included students from both Southern Finland and Southern Michigan. The data were collected from two biology, six chemistry, and four physics classes in Southern Finland. A total of 247 students (77 girls, 39 boys, 131 unknown) from the high school participated in the study. In Southern Michigan the data were also collected from two biology, six chemistry and four physics classes. Overall, 281 students (91 girls, 88 boys, 103 unknown) from the high school took part. The participating students were mainly from the 1st year of high school in both countries.

Study III focused only on chemistry and physics classes. This decision was made because the focus of the project changed towards the use of scientific practices. As part of the data collection, the researchers helped the teachers design their science lessons along the lines of scientific practices. Altogether 133 students (79 girls, 54 boys) participated in Southern Finland, from six chemistry and six physics classes. In Southern Michigan, 142 students (69 girls, 73 boys) participated in the data collection, also from six chemistry and six physics classes. As in Study II, the students were mainly from the 1st year of high school.

Table 1 *The details of the participants in Study I-III.*

Study	Country	N	Gender	Grade	Science teachers
Study I	Southern Finland	135	Girls 57% Boys 43%	9th 1st high school	Biology 3 Chemistry 2 Physics 3
Study II	Southern Finland	247	Girls 31% Boys 16% Unknown 53%	1st high school	Biology 2 Chemistry 6 Physics 4
	Southern Michigan	281	Girls 32% Boys 31% Unknown 37%	1st high school	Biology 2 Chemistry 6 Physics 4
Study III	Southern Finland	133	Girls 59% Boys 41%	1st high school	Chemistry 6 Physics 6
	Southern Michigan	142	Girls 49% Boys 51%	1st high school	Chemistry 6 Physics 6

4.2.2 PROCEDURES

Data was collected via the Paco application, which is experience sampling software for Android smartphones. During the seven days of data collection in fall 2013 and 14 days in spring 2013 (Study I) the smartphones went off once in a science lesson as a signal to complete a short self-report questionnaire.

During the twelve days in spring 2015 and the school year 2015 – 2016 (Study II, Study III, respectively) the participants answered the ESM questionnaire three times in their science lessons. In all of the studies, the smartphones were programmed to emit a signal to all the students at the same time in their science lessons, and otherwise randomly during the day (from 8 am to 8 pm). Overall, the students received eight ESM questionnaires per day.

Before the data collection, the purpose of the study, the data collection procedure and the ethical aspects of the project were explained to the teachers and school principal, the guardians, and the students. It was emphasized that participation was voluntary, and that it was possible to cancel participation at any time. The students answered the ESM questionnaire anonymously, which was also explained to them. Before the data collection, the researchers labeled the smartphones by numbers and installed a gmail account on each one. For the first time, students' names were used to combine their background information with a specific smartphone. The smartphones were given to the students in the first lesson, when data collection started. The researchers in both countries stayed for the first lesson to ensure that all the students received the ESM questionnaire on their smartphones and were able to answer it. The smartphones were collected after data collection had ended. Students who participated actively were given a gift card as compensation in both countries.

4.2.3 DESIGNING THE LEARNING UNITS

Study III examined how the use of scientific practices was associated with student situational engagement. In both Finland and the US, science curricula that emphasize scientific practices had been recently taken into use when the data collection started. Even though the teachers were somewhat familiar with the scientific practices, it was assumed that additional support was needed to assist them to similarly implement scientific practices in their science lessons.

During the school year 2015–2016, one shared workshop was offered to the teachers from both countries. This workshop was held in the US, in February 2016, and lasted for a day. In addition, two more workshops were held in each country separately before the data collection. All the workshops were organized by the researchers. The main leader of the workshops was a collaborating professor (Joseph Krajcik) who had been working with scientific practices from the start together with a leading teacher (Deborah Peek-Brown). On the Finnish side, a professor (Jari Lavonen) and an associate professor (Kalle Juuti) were assistant leaders. In addition, two professors (Barbara Schneider and Katariina Salmela-Aro) gave introductions on social-emotional learning. The main aim of the shared workshop was to present how students could be helped to situationally engage in scientific practices. The teachers were given advice on how to let students explore a phenomenon and deepen their understanding by describing the phenomenon. They were also guided to include core ideas, concepts and models in their teaching. Because the data were collected as part of an international collaboration project, the aim was to deliver the teaching in as similar a way as possible.

After the workshops, several subject-specific meetings were arranged. In these meetings, the teachers collaboratively planned teaching units that they implemented in data collection. While working in these groups, the teachers received support from the researchers. The teaching unit was planned for six science lessons. Because the science teaching contexts in Southern Finland and the Southern Michigan differed from each other, the planning phase of the units was also different. In Southern Finland, some teachers collaborated with each other, while other teachers carried out the units more independently. In Southern Michigan, one teacher was responsible for leading the planning of each unit and other teachers implemented the units in their classrooms.

4.3 MEASURES

The questionnaires in each data collection session included a variety of measures beyond the scope of this dissertation, and below I describe only the measures relevant to the present study. The ESM questionnaire in Study I differed slightly from that in Studies II and III in the form of the questions. In the latter studies, the questions were presented in the past tense. This decision was made to clarify that the questions were related to the activity that the students were doing directly before they started answering the ESM questionnaire instead of any present activity which literally would have been the ESM questionnaire. The background questionnaire that students filled before or during the ESM data collection asked students their gender. The definition of gender comes from sociological studies, in which it refers to something that is constructed through cultural, psychological and social means, while sex is ascribed by biology (West & Zimmerman, 1987). The question related to gender was voluntary, and some of the students did not answer it.

4.3.1 MEASURES OF STUDENT SITUATIONAL ENGAGEMENT

Table 2 summarizes how situational engagement was operationalized in the different studies. The definitions of situational interest and situational skills were enhanced for Studies II and III after the comprehensive literature review. At the same time, the optimal learning moment model was expanded to include other situational emotions. This model is presented at the end of Section 1.1.

Situational interest

Study I measured students' situational interest using the questions "Is this activity interesting?" and "Do you enjoy what you are doing?". Cronbach's Alpha for sum was .81. Enjoyment was included in the measurement of situational interest because it has been closely associated with situational engagement (e.g. Csikszentmihalyi, 1990, p. 1) together with the challenge of the activity and students' high evaluation of their skills (Csikszentmihalyi, 2014, p. 182). Furthermore, situational interest in a task seems to occur when students enjoy performing the task (Krapp, 2002). All of the items were answered using a Likert scale ranging from 1 (not at all) to 4 (very much).

The definition of situational interest advanced in Studies II and III. Even though enjoyment and situational interest are related to each other, the decision was made to measure students' situational interest using only one question: "Were you interested in what you were doing?". The response options to this question were on a Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree).

Situational skills

In Study I, students' situational skills were measured as a sum, using five different questions. These questions were "Do you have skills in this activity?", "Are you succeeding?", "Do you feel capable?", "Do you feel in control?" and "Do you feel competent in this activity?". Cronbach's Alpha for the sum was .85. This definition of students' situational skills took into account different aspects of situational skills – students' self-evaluation of their success, capability, competence, and perception of control over what they were doing. The response options to all the questions were on a Likert scale with the extreme categories of 1 (not at all) and 4 (very much).

For Studies II and III, the definition of situational skills was brought closer in line with previous situational engagement studies using flow theory as their background theory. Students' situational skills were measured by asking "Did you feel skilled in what you were doing?", with Likert-scaled response categories of 1 (strongly disagree) and 4 (strongly agree).

Situational challenge

In Study I, situational challenge was measured using the question "Does the activity present a challenge?" with Likert-scaled extreme response categories of 1 (not at all) and 4 (very much). In Studies II and III, the question used to measure situational challenge was "Did you feel challenged by what you were doing?”. This question was answered on a Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree).

Table 2 *The differences in the definition of student situational engagement.*

Definition for situational engagement	Study I	Study II & III
Situational skills	Do you feel skills in this activity? Are you succeeding? Do you feel capable? Do you feel in control? Do you feel competent in this activity?	Do you feel skilled at what you were doing?
Situational interest	Is this activity interesting? Do you enjoy what you are doing?	Were you interested in what you were doing?
Situational challenge	Does the activity present a challenge?	Did you feel challenged by what you were doing?

4.3.2 MEASURES OF CLASSROOM ACTIVITIES

Study II focused on classroom activities. These activities were measured using a multiple-choice question: “What were you doing when signaled?” for which the response options were listening, discussing, writing, calculating, taking a quiz/test, working on a computer, working in a group, laboratory work, presenting, and other. The students were only able to select one option.

Listening applied to all the activities that involved students listening to either their teacher or other students. Discussing included activities in which the students talked with each other or as a group with a teacher. When students were working individually or as a group, they might have been writing, for example, taking notes, or calculating, taking a test or a quiz, or working on a computer. Working in a group was also given as an alternative if students were, for example, carrying out a larger project in a group. Presenting was kept as an option for an activity that involved students presenting their findings after a project to other students and/or their teacher. Laboratory work included activities that required students to be active investigators of a phenomenon in a formal or informal setting.

4.3.3 MEASURES OF SCIENTIFIC PRACTICES

Study III focused on scientific practices. These practices were measured using a multiple-choice question: “Which best describes what you were doing science when signaled?”. The questionnaire differed slightly during the school year 2015–2016 in that students had different response options in fall 2015 and spring 2016. I took only the options that were present in both versions into the analyses. These options were asking questions, developing a model, using a model, planning an investigation, conducting an investigation, analyzing data, solving math problems, constructing an explanation, using evidence to build an argument, evaluating information, and other. A closer description of the options can be seen in Study III (Inkinen et al., 2020).

4.4 DATA ANALYSES

The data were analyzed using the following statistical programs: IBM SPSS Statistics 22 (Study I), and STATA 14.1 (Study II, Study III). Descriptive statistics were obtained from the data by examining the means, standard deviations (Study I), and correlations of the study variables. The summary of the more specific main data analysis used in each of the original studies is presented in Table 3.

Table 3 *Summary of the main aims, participants, measures, and data analyses in each of the original study.*

Study	Main aim	Participants	Measures	Data analyses
Study I	To examine Finnish students’ situational engagement in exact and life science lessons, and how these experiences varied by gender and grade.	Southern Finland N = 135 9th: 31 girls, 37 boys 1st: 46 girls, 21 boys	Situational engagement Situations (exact/life science lessons) Gender Grade	MANOVA
Study II	To observe what degree are classroom activities associated with student situational engagement.	Southern Finland N = 247 Southern Michigan N = 281	Situational engagement Classroom activities	Three-level hierarchical logistic regression model

Study III	To examine how high school students perceived used of scientific practices are associated with student situational engagement.	Southern Finland N = 133 Southern Michigan N = 142	Situational engagement Scientific practices	Three-level hierarchical logistic regression model

4.4.1 A MULTIVARIATE ANALYSIS OF VARIANCES

Multivariate analyses of variance (MANOVA), such as analysis of variance (ANOVA), are examples of variable-oriented approaches (Laursen & Hoff, 2006). MANOVA can be seen as a generalized form or an extension of univariate ANOVA. Whereas in ANOVA statistical differences are examined between one continuous dependent variable and an independent variable, MANOVA extends this analysis by taking into account multiple continuous dependent variables and bundles them together into a weighted linear combination. MANOVA compares multivariate sample means when there are two or more dependent variables. In Study I, the preconditions of engagement – situational skills, interest and challenge – and situational engagement were the dependent variables whereas gender, grade and situation were the independent variables.

4.4.2 THREE-LEVEL HIERARCHICAL LOGISTIC REGRESSION MODELS

Hierarchical models were developed to illustrate the nature of organizations such as schools, because organizations as such consist of nested entities. For example, students are nested in classrooms and classrooms are nested in schools. Hierarchical regression models recognize that individuals within a particular group may be more similar than individuals in other groups, and this can be approached by modeling both individual and group-level residuals and recognizing the partial interdependence of individuals within the same group (Hofmann, 1997). There are also other hierarchical levels, such as groups in different activities and schools nested within cities. However, when performing an analysis, it is important to decide which hierarchical levels should be included.

It is clear that variables at one hierarchical level can influence variables at other hierarchical levels (Hofmann, 1997). Moreover, there will be correlations between the experiences of individuals as well as between groups of individuals (Gibbons & Hedeker, 1997). The hierarchical nature of the data is important to take into account when calculating standard errors (Raudenbush & Bryk, 2002). One of the primary advantages of hierarchical models is the investigation of relationships *within* a particular hierarchical level as well as the relationships *between* hierarchical levels (Hofmann, 1997).

In Studies II and III, three-level hierarchical logistic regression models were run with responses at level one nested within students at level two and within classrooms at level three. The outcome of the models was a binary indicator of whether a student was situationally engaged (1) or not (0). Classroom activities and scientific practices were also converted into binary indicators (1 = specific activity or practice used; 0 = all other activities or practices used) and models were run for each classroom activity or scientific practice at a time. The coefficients represented comparisons between the activity or practice examined in the model.

The hierarchical logistic regression models used were:

Level 1 - Responses

$$logit(\pi|tij) = \beta_{0ij} + \beta_{1ij}X_{tij}$$

Level 2 – Students

$$\beta_{0ij} = \gamma_{00j} + \upsilon_{0ij}$$

$$\beta_{1ij} = \gamma_{10j}$$

Level 3 – Classrooms

$$\gamma_{00j} = \delta_{000} + \eta_{00j}$$

$$\gamma_{10j} = \delta_{100}$$

where $\pi_{tij}$is a binary indicator of situational engagement for response *t* from student *i* in classroom *j* and X_{tij} is a binary variable indicating whether student *i* was participating in the activity category of interest at time *t*.

5 OVERVIEW OF ORIGINAL STUDIES

The overall aim of the dissertation is to examine which activities present in science classes are associated with a higher level of student situational engagement in Southern Finland and Southern Michigan. The research consisted of three empirical studies, which focused on investigating: 1) a sample of Finnish students' situational engagement in life and exact science lessons in particular, by focusing on gender and grade differences, 2) the association between student situational engagement and classroom activities in Southern Finland and Southern Michigan, and 3) the association between student situational engagement and scientific practices in Southern Finland and Southern Michigan. In this chapter, I present the main findings of each of the original studies. Further details are available in the original publications.

5.1 STUDY I

Linnansaari, J., Viljaranta, J., Lavonen, J., Schneider, B., & Salmela-Aro, K. (2015). Finnish students' engagement in science lessons. *NorDiNa: Nordisk tidsskrift i naturfagdidaktikk [Nordic Studies in Science Education], 11(2), 192–206*. https://doi.org/10.5617/nordina.2047

The main aim of Study I was to investigate students' situational engagement in science classes, distinguishing between the exact (chemistry and physics) and the life (biology) sciences. In other words, to shed light on a phenomenon – Finnish students' situational engagement – that had not been widely studied before. Another aim was to examine how students' situational engagement varied according to gender and grade. Based on the literature review two hypothesis were set. One hypothesis was that students' situational engagement would be higher among students who are in the 1st grade in high school compared to students who are in 9th grade. This hypothesis was made due to the selectivity of students. The data was collected from schools that included a comprehensive school (grades 1-9) and a high school (grades 10-12). These high schools were well-performing and able to select their students. Students who were in the 9th grade had not yet made the decision to continue to high school, vocational school or work-life. Thus, there were more variation between students in 9th grade than in 1st year of high school. Even though these schools had both a comprehensive school and a high school, students needed to apply to get into the high school. Another hypothesis was that girls' situational interest would be higher in life science lessons compared to exact science lessons – and with boys this would be vice versa.

The participants were 68 students (31 girls, 37 boys) from the 9th grade and 67 students (46 girls, 21 boys) from the 1st year of high school. Student situational engagement was measured using an ESM questionnaire that included questions on situational skills, interest and challenge. Five questions assessed the students' situational skills, focusing on their self-efficacy, control of the situation, feeling of competence necessary for the situation, evaluation of their success, and self-evaluation of skills. Situational interest was measured as a sum of situational interest and enjoyment. Situational challenge was measured using one question. The measure of student situational engagement was formed as the sum of skills, interest and challenge measured in situation. The students were also asked about their location when they answered the ESM questionnaire. Gender and grade information were elicited once before data collection started.

To estimate the students' overall level of situational engagement, the raw ESM scores were converted into z scores before conducting Pearson's correlations and MANOVA. Z scores allowed a better comparison of the groups of students. The standardized z scores were also added to the analysis because of their better sensitivity to the effect of context on students' quality of experiences, as in previous ESM research by Shernoff and colleagues (2003).

The results of student situational engagement revealed that boys as a group did not seem to be situational engaged in life science lessons nor girls as a group, especially in 9th grade, in exact science lessons. In exact science lessons, student situational engagement was higher among students in the 1st year of high school in both genders. In life science lessons, girls as a group experienced higher level of situational engagement in the 1st year of high school compared to students in 9th grade. Boys, on the other hand, experienced below an average level of situational engagement in both grades in life science lessons, but it was even lower among boys in the 1st year of high school. The results partly supported the hypothesis that students in 1st year of high school would experience higher level of situational engagement compared to 9th grade students in science lessons. The exception was life science lessons where boys as a group in 9th grade experienced higher level of situational engagement compared to boys in 1st year of high school.

There were no statistically significant differences between students' situational interest and life or exact science lessons. Instead, statistically significant differences were found between grade level and students' situational skills. The results revealed that girls as a group evaluated their situational skills as above average in 9th grade life science lessons and below average in exact science lessons. In the 1st year of high school, girls' situational skills turned to be below an average in life science lessons, and decreased even more in exact science lessons. However, boys' situational skills were slightly over an average in exact science lessons and slightly below average in life science lessons in both grades.

Overall, the findings of Study I show that when planning the content of science lessons, science educators and teachers should take into account ways in which to support students' situational skills, increase their situational interest and offer appropriate situational challenges. The results supported findings that girls had a higher level of situational engagement when participating in life science lessons and boys had higher situational engagement in exact science lessons. However, the focus was not on the content of the lessons, which would have had its own impact on the results.

5.2 STUDY II

Inkinen, J., Klager, C., Schneider, B., Juuti, K., Krajcik, J., Lavonen, J., & Salmela-Aro, K. (2019). Science classroom activities and student situational engagement. International *Journal of Science Education, 41(3), 316–329*. https://doi.org/10.1080/09500693.2018.1549372

The aim of Study I was to investigate students' situational engagement in exact and life science lessons. Study II deepened the acquired knowledge by examining how different classroom activities were associated with student situational engagement.

In Southern Finland, altogether 247 students participated in the study. The data were collected from 13 secondary science classes – two biology, four physics and six chemistry. In Southern Michigan, there were 281 students from 18 science classes – three biology, eight chemistry and seven physics classes. The data were collected using an ESM questionnaire. The students answered the ESM questionnaire three times during each of the science lessons. Data were collected from altogether 12 science lessons in both countries. The ESM questionnaire consisted of questions on student situational engagement and classroom activities. Student situational engagement was measured using questions directly related to situational skills, interest and challenge. The dichotomy variable of situational engagement was formed from these three questions. When students evaluated the value of situational skills, interest and challenge to be above average, they were considered to be situationally engaged. When one or more of these variables were below average, students were not situationally engaged. In addition to answering questions related to student situational engagement, students selected from a list the classroom activity that they were doing directly before answering the ESM questionnaire.

We used a series of three-level hierarchical logistic models with responses at level one nested within students at level two and within classrooms at level three. In Study II, student situational engagement occurred relatively infrequently in science classes in randomly selected situations in both Southern Finland and Southern Michigan. However, the level of student situational engagement was either lower or higher, depending on the classroom activities used. In both countries, one of the activities that students spent the majority of their time doing was listening. Listening was also the classroom activity that was related to students' low level of situational engagement. In Southern Michigan, students were more likely to be situationally engaged when discussing. In Southern Finland, students reported a higher level of student situational engagement when they were presenting material such as the outcome of an investigation or calculating.

The results indicate that all of the reported classroom activities were situationally engaging for some students. When interpreting the results, it should be noted that the students were presenting and calculating for only a small portion of class time. However, Study II offers evidence that the classroom activities teachers use are of importance for eliciting student situational engagement when we take into account individuals' variance. For example, the choice of letting students discuss a subject instead of listening to a lecture about it seems to be a reasonable strategy for enhancing student situational engagement.

5.3 STUDY III

Inkinen, J., Klager, C., Juuti, K., Schneider, B., Salmela-Aro, K., Krajcik, J., & Lavonen, J. (2020). High school students' situational engagement associated with scientific practices in designed science learning situations. *Science Education, 104(4), 667–692*. https://doi.org/10.1002/sce.21570

Study III examined the relationship between activities used in science classes and students' situational engagement by focusing on the scientific practices that are used to encourage students to actively participate in their science lessons. The main purpose of Study III was to investigate and understand how different scientific practices used in high school science classes are associated with student situational engagement, a topic that has not been studied before as such.

The participants consisted of 133 students from Southern Finland and 142 students from Southern Michigan. The data were collected from chemistry and physics lessons. Student situational engagement was measured in the same way as in Study II. The students were also asked to select the scientific practice they were using immediately before they answered the ESM questionnaire. As in Study II, Study III used three-level hierarchical logistic regression to examine the relationship between student situational engagement and the scientific practices reported by the students themselves in the ESM questionnaire. Pictures taken by the students were shown in Study III to contextualize what was happening in the science classes when the students reported the different uses of scientific practices. However, these pictures were not the focus of the research.

According to the situational engagement data, the constructing and refining models were related to higher levels of situational challenge and situational engagement. The results also revealed that student situational engagement was associated with the scientific practices of developing explanations and solutions. The scientific practices that belonged to this category were developing models, using models (only among the Finnish students) and constructing explanations.

Overall, the findings of Study III showed that the use of scientific practices in chemistry and physics can increase student situational engagement, especially when focusing on modeling. Teachers can support students' feelings of situational challenge, skills and interest in the ongoing task – or situational engagement – by letting them collaboratively use and develop models. Models can be used, for example, to simplify or visualize a phenomenon, or to spark situational interest in learning. However, to be able to efficiently use scientific practices in science classes, teachers should be supported in using these practices. In addition, if future results support the findings, teacher education – at least in Finland – should include instruction on how these practices can be used effectively in science classes.

6 DISCUSSION

The findings of the dissertation indicate that the level of student situational engagement can vary depending on the science classroom activities and scientific practices used in science lessons. In science lessons, the level of student situational engagement has been relatively low, which has encouraged to find new ways to situationally engaged students. The way in which situational engagement is conceptualized in this dissertation varies from previous research. However, it is supported by a strong theoretical background based on the flow-theory. This dissertation utilizes ESM as a research method, seeing situational engagement as a state and defining student engagement as a trait. Situational engagement – when approached through students' situational interest, skills and challenge – plays a powerful role in engaging students in learning. For example, students who believe in their skills in relation to the challenge of the task are more likely to become situationally engaged in learning and less likely to underachieve or drop out from school (Schunk & Mullen, 2012, p. 219).

6.1 MAIN FINDINGS

This section sums up findings from Studies I to III. I present (Study I) how student situational engagement varies according to gender and grade in the sample of Finnish science classes. Study I can be seen as an overview of a phenomenon before focusing on how different activities in science lessons are related to student situational engagement (Studies II and III). The findings of Study I and especially Study II and III are important for science teachers and science educators, because they provide information about activities that students are likely to also seek in the future (see Nakamura & Csikszentmihalyi, 2014, p. 92), and that lead to productive outcomes such as science learning (Schneider et al., 2016).

6.1.1 VARIATION IN STUDENT SITUATIONAL ENGAGEMENT ACCORDING TO GENDER AND GRADE

The first aim of this dissertation, and especially Study I, was to gain an overview of the level of student situational engagement and examine how it varies according to gender and grade, especially in exact and life science lessons. This research was only conducted in classrooms in Helsinki.

Consistent with prior research, we found that there were gender differences in the level of student situational engagement and situational skills.

The results of revealed that boys as a group seem to be situationally engaged in exact science lessons and girls as a group in life science lessons. The results are in line with previous research which has shown that girls have been attracted to life science and have more positive attitudes compared to boys (Britner, 2008; Uitto & Kärnä, 2014 p. 318). The level of student situational engagement also varied according to grade levels. In exact science lessons, student situational engagement was higher among students in the 1st year of high school in both genders. In life science lessons, girls situational engagement followed the same trend than in exact science lessons, but boys situational engagement in 1st year of high school were even lower than among boys in 9th grade. Previous research has shown that student engagement takes different forms throughout the school years, because students become deeply invested in learning after they have the intellectual capacity to self-regulate leraning (Fredricsk et al., 2004). Furthermore, students experience continued growth in intellectual capactities and competencies together with learning of fundamental skills and values as they grow older (Mahatmya et al., 2012, p. 47). A longitudinal study revealed that students with high engagement levels by the age of 10 seemed most likely to maintain these levels in the future, whereas students with moderate or low levels of engagement were more open to change (Wylie & Hodgen, 2012, p. 28). Because the data were collected in well-performing high schools, we can assume that students could have experienced higher levels of situational engagement also in previous grades.

The results also revealed statistically significant differences between situational skills and science subjects. Boys as a group experienced higher level of situational skills in exact science lessons compared to life science lessons – and girls vice versa. Based on the literature review by Osborne and colleagues (2003) girls do believe their capacities to succeed in science, but they do not pursue science. There is also evidence that women are represented in the life science fields to a much greater extent than in the physical science fields (Britner, 2008; Griffth, 2010). In schools, girls tend to perform better than boys in life sciences and experience more positive attitude dimensions towards it (Britner, 2008; Uitto & Kärnä, 2014, p. 318). Additionally, PISA report (OECD, 2018, p. 4) revealed that girls in Finland tend to perform better than boys also in physics. Surprisingly, there were no stastitically significant differences in situational interest and science subjects or grade levels, which was a hypothesis based on the literature review (Barnes, McInerey, & Marsh, 2005; Britner, 2008; Krapp & Prenzel, 2011)

Study I deduced that science educators and teachers should take into account ways to support students' situational skills, increase their situational interest and offer appropriate situational challenges. By supporting situational interest, skills and challenge it is possible to support student situational engagement, which will lead students to seek similar activities in the future (Nakamura & Csikszentmihalyi, 2014, p. 92). However, future research should control for the content and context of science lessons. For example, previous studies have shown that technology science topics could more interesting for boys than girls (Lavonen & Laaksonen, 2009) and that students are generally more interested in topics related to medicine and astronomy than to physics and chemistry as such (Lavonen et al., 2005a).

6.1.2 STUDENT SITUATIONAL ENGAGEMENT ASSOCIATED WITH CLASSROOM ACTIVITIES

The second aim of the dissertation was to examine how science classroom activities are associated with student situational engagement. Corso and colleagues (2013) claim that classroom activities can even be the most fruitful approach to understanding the variety of student situational engagement in science. By increasing the number of classroom activities that develop student situational interest, it is possible to provide a greater insight into the ways in which students can be helped to situationally engage with science classes (Ainley, 2012, p. 286; Ainley & Ainley, 2011). In addition, student situational engagement can be increased through classroom activities that offer situational challenges and are situationally interesting to students (Fredricks, 2011).

Study II revealed that students experience situational engagement in science classes quite infrequently in Southern Finland and Southern Michigan. This concern is the engine behind studies that try to determine ways in which to support student situational engagement in science lessons. Study II showed that listening can reduce opportunities for students to become situationally engaged. This result has also been substantiated in previous results. For example, an ESM study by Schmidt and colleagues (2018) of 244 high school students in the US revealed that listening to a lecture was associated with students' low level of engagement. Another ESM study by Shernoff and colleagues (2003) of 526 high school students in the US supported this finding. However, listening to a lecture can be a desired classroom activity when a teacher introduces new information to students or demonstrates how the information can be used to solve problems or perform tasks (Lavonen et al., 2005b). Instead, when teachers lecture about a topic already familiar to students, students might feel less situationally challenged and this may reduce the level of their situational engagement (Shernoff et al., 2000, p. 145).

The classroom activities that increased student situational engagement differed between Southern Finland and Southern Michigan students. In Southern Michigan, students' situational engagement was higher when students had opportunities to participate in either group discussion, small group discussion or discussion in pairs. This is in line with previous research that has revealed that several classroom activities, such as discussion, are particularly motivating and engaging for students (Forsthuber et al., 2011, p.

126; Yazzie-Mintz, & McCormick, 2012). For example, research focusing on 42 754 students in the US supported the finding that discussion was related to students' high level of engagement. According to our definition, situational engagement consists of high levels of situational skills, interest and challenge. Usually, students who actively participate in discussions know something about the topic, so they evaluate their situational skills as high. Regardless of whether or not students participate in discussions, they can be situationally interested in the subject or the topic. Furthermore, discussions are usually guided by questions. These questions can be based on students' interest or concern about topics that the students have not been able to answer themselves. This can lead to the experience of a challenging situation.

Finnish students' situational engagement seemed to be higher when they either used calculation to solve problems in science classes or presented their findings to others. Mathematics and calculation are essential for science learning because many science problems can be solved using mathematics. For example, calculation helps demonstrate and model different phenomena and examine causations. According to the definition of situational engagement, calculation is a classroom activity in which students are situationally interested and have adequate situational skills to succeed. Properly chosen mathematical problems often provide situational challenge as well. In high schools in Southern Finland, mathematics is a compulsory subject for students, and mathematics courses usually start before or at the same time as science courses. This might help students gain the skills necessary for solving problems in science lessons. The calculations used in science are also usually applied and related to verbal assignments, which might offer adequate challenges for students to become situationally engaged.

Another classroom activity that increased the level of student situational engagement in Finland was presentation. Presentation in this study stood for classroom activities in which students presented material, such as an outcome of an investigation, to each other. This could be done in small groups or by individuals. This activity increases situational engagement through the levels of situational interest, skills and challenge. We can assume that because the students were presenting their own work, they were situationally interested in the subject and had the proper situational skills to do the task. Moreover, as an activity, presenting might be exciting to some of the students and thus increase their level of situational challenge.

To sum up the findings of Study II, students tend to be situationally engaged when they actively participate in their science classes. It is important that teachers carefully familiarize themselves with the results of using different classroom activities in their science lessons. For example, even though it would be easier for teachers to use lecturing as the main classroom activity, it would be more beneficial for the students if they worked collaboratively to become familiar with different scientific phenomena. Of course, school as a framework defines the resources available for teaching. For example, only a certain amount of classroom time is available for different contents, which limits the use of classroom activities. Even though Study II revealed only a few classroom activities related to student situational engagement, these activities should not be used alone. Science classes have students who prefer different classroom activities and learn in different ways. The use of different classroom activities in science lessons avoids situations in which these activities are directed towards only some of the students by giving all the students the opportunity to be able to learn, enjoy and become situationally engaged in science lessons (Fairbrother, 2000, p. 7; Lavonen et al., 2007; Lavonen et al., 2005b).

6.1.3 STUDENT SITUATIONAL ENGAGEMENT ASSOCIATED WITH SCIENTIFIC PRACTICES

Study II concluded that student situational engagement could be increased by giving students possibilities to actively participate in science lessons. The purpose of Study III was to deepen the results of Study II by examining how scientific practices that support students' active participation to think and act like scientists (Ford, 2015; Krajcik & Merritt, 2012) are associated with student situational engagement. Researchers have suggested that student engagement in science learning could be increased and improved by curricula changes (Singh et al., 2002). These changes reflect the challenges that science education currently faces in terms of how science teaching and learning could be made more appropriate for the modern world (Osborne & Dillon, 2008). Curricula changes have recently been made in Finland and the US that highlight the use of scientific practices in science classes to increase the number of situationally engaged students.

In both countries, developing explanations and solutions increased the level of student situational engagement. The importance of scientific practices that belong to this category has also been found in previous research focusing on modeling in science classes (e.g. Harrison, & Treagust, 2000; Kenyon et al., 2011; Matthews, 2007; Schwarz, & White, 2005). The use of models in science classes has many benefits for students. For example, based on the results of 4456 students in the US, models are positively related to engagement, self-concept, enjoyment, and instrumental motivation together with the general and personal value of science (Grabau, & Ma, 2017). The fact that models help students understand the nature of science makes its role central to science teaching in school (Forsthuber et al., 2011, p. 27; Henze, Van Driel, & Verloop, 2007; Schwarz, & White, 2005). Models can be used to, for example, explain phenomena (Krajcik & Merritt, 2012), express and externalize thinking, create theories (Schwarz & White, 2005), and make predictions (Kenyon et al., 2011). Models also increase student situational engagement by socializing students to learn through verbalization of thinking, which guides behavior in an activity (Brophy, 2004).

Developing models and constructing explanations can be used to represent scientific phenomena that are too complex or difficult to understand and observe directly (Krajcik & Czerniak, 2014; Schwarz et al., 2009). In other words, working with models can offer students situational challenges that increase their opportunities to become situationally engaged. In an ideal situation, models are developed, and explanations are constructed in connection to contents that are interesting for students and related to their previous experiences. In addition, the diversity of models (Harrison & Treagust, 2000; Osborne, 2014; Schwarz et al., 2009) can increase the opportunities for different students to become situationally interested. Teachers were encouraged in the workshops to let their students develop and use models, and construct explanations by themselves or in groups. Because the students were active participants in the learning process and worked collaboratively, they might also have felt situationally skilled in these moments.

Studies II and III both support the finding that student situational engagement can be increased in science lessons by allowing students to actively participate in lessons. This shift towards actively participating students who construct knowledge by themselves may be new not only to students, but also to teachers. To be able to improve teaching, teachers need additional support when adapting and transforming new practices (Osborne & Dillon, 2008 p. 22).

6.2 THEORETICAL CONSIDERATIONS

This study basically has two theoretical viewpoints. The first focuses on the operationalization of the concept of situational engagement. Student engagement has been studied for a long time – thus it is conceptualized in many different ways (see Eccles & Wang, 2012; Fredricks, 2011; Fredricks et al., 2004; Reschly & Christenson, 2012). Previous research has mainly focused on students' general engagement instead of situational engagement, using cross-sectional and longitudinal surveys (Tuominen-Soini & Salmela-Aro, 2014). However, when engagement is more narrowly defined, such as situational engagement, the value of the study and unique contribution to the research is clearer than when focusing on the broader concept (Eccles & Wang, 2012).

The definition of situational engagement builds on the balance between situational challenge, situational skills (see Csikszentmihalyi 1990; 1997; 2014) and situational interest (Brophy, 2004, p. 221) which, in fact, commonly occurs in the school context. One crucial outcome of students' learning is the development of their skills and knowledge, which allows encountering new challenges (Csikszentmihalyi, 2014, p. 28 – 29). The focus on student situational engagement expands our understanding of how to get students more involved in school, to learn better at school (Csikszentmihalyi, 2014) and to experience similar experiences in the future (Nakamura, & Csikszentmihalyi, 2014, p. 130; Shernoff et al., 2003). The fact that students might seek similar, situationally engaging experiences in the future is a key factor for science education, because it may increase the number of science-oriented students. Thus, this dissertation can be interpreted as a first step towards increasing the number of science-oriented students by focusing on activities in science classes that will increase the number of moments when students are situationally engaged.

The second viewpoint relates to the use of innovative data collection tools that enable capturing students' situational experiences. Previous research has mainly observed student engagement using questionnaires, observations or interviews. However, these methods only enable retrospective observation of student engagement. They may increase the possibility of memory cognitive biases or prevent the observation of students' momentary thoughts, feelings and actions (Barrett & Barrett, 2001; Zirkel et al., 2015). Student engagement as a trait is also something that is difficult to enhance and modify by, for example, classroom activities (Singh et al., 2002). Innovative methods, such as ESM, can help capture situational experiences of different subtypes of student engagement, which will lead to a more integrated picture of engagement (Eccles & Wang, 2012).

6.3 EDUCATIONAL IMPLICATIONS

The findings of the dissertation support the idea that different classroom activities and scientific practices associate differently with student situational engagement. The information that activities that teachers use can increase the level of student situational engagement is important for teachers and teacher educators for several reasons. If schools and classrooms fail to provide developmentally appropriate educational environments for students, they fail to motivate students' interest and engagement, which may produce cynicism and lead to alienation from school (Upadyaya & Salmela-Aro, 2013). According to Pianta and colleagues (2012, p. 369), even though students might have remarkably high degrees of engagement within school settings, this rarely occurs in classrooms. A low level of student situational engagement can lead students to feel unmotivated and uninvolved in school life (Appleton et al., 2008), which over time can lead to school failure (Gettinger & Walter, 2012, p. 654; Finn & Zimmer, 2012, p. 98; Reschly & Christenson, 2012, p. 4).

Classroom activities that encourage students to participate actively in science lessons seem to be related to their higher level of situational engagement. In this dissertation, I assume that discussion, working in a group, laboratory work, and presenting are classroom activities that require students to be active. As Shernoff and colleagues (2000, p. 149) have pointed out, passive classroom activities seem to provide fewer and weaker opportunities for students to be situationally engaged. They explain this by saying that science learning is, in fact, a matter of doing. Based on the results of this dissertation, teachers should consider how much classroom time they spend on lecturing. There are times – for example, when a teacher is presenting new and difficult material to students – when activities that involve students listening is justifiable (Lavonen et al., 2005b), but otherwise listening is associated with lower levels of student situational engagement (Schmidt et al., 2018; Shernoff et al., 2003). Previous research (Forsthuber et al., 2011, p. 126; Yazzie-Mintz, & McCormick, 2012) has supported the use of discussion in lessons. When focusing on only Finnish students, the dissertation shed light on the interesting phenomenon that presenting and calculating were related to students' higher level of situational engagement.

The present research supports the implementation of scientific practices in science classes. Especially when students were involved in activities that included developing explanations and solutions, their situational engagement was higher than during other activities. This finding is rational because as an activity, modeling plays a central role in understanding science (Forsthuber et al., 2011, p. 27; Henze et al., 2007; Schwarz, & White, 2005). Our results suggest that science teachers should especially use activities related to models in their science lessons. However, previous research has shown that teachers require additional support for effectively executing activities related to modeling, which have greater benefits for cognitive and affective domains (Grabau & Ma, 2017).

Pianta and colleagues (2012, p. 369) state that too often science classes fail to capitalize on student interests and goals. It is important that the classroom activities that teachers use in their science classes have a clear goal and purpose. Students come from different backgrounds to science learning situations and prefer different learning styles. Even though our results are promising, there is a need for replicative research. Especially in Finland, there is a lack of studies on science classroom activities (Lavonen & Laaksonen, 2009). The results of the dissertation show that the types of method that teachers use in science classes matter. Thus, these results could be taken account in teacher education in Finland. For example, these results could be used as an argument for why lesson plans should be carefully considered and structured. Lessons plans have been an important part of teacher pedagogical studies in Finland, but teacher training students do not always understand why.

6.4 METHODOLOGICAL REFLECTIONS

In the dissertation, the data were collected using ESM, which enabled the gathering of situational data from students. However, Study I did not fully take advantage of this; it converted the raw ESM scores into z scores. This allowed greater sensitivity to the effect of the context on students' quality of experience (Shernoff et al., 2003), comparing the results between different groups of students when the scales of all variables had no absolute interpretation (Bergman & Magnusson, 1997).

In terms of statistical analyses, Study I used MANOVA to compare the differences between students' situational engagement levels in exact and life science lessons according to gender and grade. The major criticism of MANOVA, especially when used to analyze ESM data, is that it will only show differences between groups of students and not take into account individual variances. The use of MANOVA requires potentially subjective assumptions from the variables. In Studies II and III the statistical methods were improved; three-level hierarchical logistic regression models were used to examine how classroom activities and scientific practices were associated with student situational engagement. In the models, students' responses (level one) were nested within students (level two) and within classrooms (level three). Several models were run to compare one classroom activity or scientific practice at a time to other activities taking place in science lessons. In Study III, we formulated new dichotomous variables for each of the scientific practices even though two or more scientific practices were usually present at the same time.

In Studies II and III, three-level hierarchical logistic regression models were run without first grouping students on the basis of their background characteristics. By doing so, some of the individual varieties might have been lost. To obtain more precise information on student situational engagement, students could first be grouped according to their characteristics or previous experiences by using latent profile analysis (LPA) or cluster analysis.

6.5 GENERAL LIMITATIONS AND FUTURE DIRECTIONS

The present research has limitations that also have implications for future research. Concerning the *participants of the studies*, Studies I, II and III were carried out in Southern Finland and Southern Michigan, which makes generalizing the results impossible. In all of the studies, the sample sizes (Study I: 135 Finnish students; Study II: 247 Southern Finland students, 281 Southern Michigan students; Study III: 133 Southern Finland students, 142 Southern Michigan students) were rather small. The research was conducted in three schools in Southern Finland and seven schools in Southern Michigan. The Finnish schools were all categorized as high performing schools based on the results of the students. Two of the schools were also teacher training schools and one was specialized in natural sciences. In Southern Michigan, even though there was more variance between the schools than in Southern Finland, the sample was not representative. In the US, there are huge differences not only between schools in the same state, but also between schools in different states. Thus, the results of the studies can only shed light on and suggest different patterns behind student situational engagement.

Another limitation concerns the *context and content* of the study. For example, in Study I, we divided science subjects into exact (chemistry and physics) and life (biology) sciences. Previous research has also divided these subjects into life and physical sciences (Britner, 2008; Greenfield, 1997) or life and hard sciences (Krapp, & Prenzel, 2011), but using only two categories leads to limitations. For example, because students' attitudes towards chemistry are not as uniform as those towards physics, the combination of these subjects can distort the results. In Studies I, II and III, we did not include the content of the lessons in the analyses; we explored all the science subjects in a similar way – by expecting students' attitudes towards the content to be permanent in these subjects. However, previous research has found that students indeed react differently to different content even within the same science subject, such as physics (e.g. Forsthuber et al., 2011, p. 80; Lavonen et al., 2005a; Lavonen & Laaksonen, 2009). In future studies, relating the information to the content of the science lessons and the comparison of different contents within a science subject would provide important information about the factors that truly lie behind student situational engagement.

The *operationalization* of situational engagement leaves some ambiguity in terms of the interpretation of the results. In the dissertation, student situational engagement was conceptualized as students' experiences of high situational interest, skills and challenge. Even though the definition has not been widely used, it is backed by strong empirical evidence. For example, previous research has shown that situational interest energizes and directs students' interaction with classroom activities (Ainley, 2012, p. 286), and it focuses attention on the ongoing task (Brophy, 2004, p. 221; Hidi, Renninger, & Krapp, 2004, p. 94). Situational skills, on the other hand, reflect students' cognitive performance (Snow, 1994), and develop incrementally as knowledge increases (Brophy, 2004, p. 221). A situational challenge can be seen as the engine that pushes situational skills and situational interest to new levels of capacity (Schneider et al., 2016). In addition, the relationship between situational skills, interest and challenge is crucial (Fredricks, 2011; Gettinger & Walter, 2012; Osborne et al., 2003; Schneider et al., 2016).

In terms of *variables*, some issues should be discussed. First, the present research relied on only self-report measures which could have caused the results to be distorted by common method variance. To obtain a more reliable conception of student situational engagement, other data collection methods, such as observing students' behavior in real science classroom situations or interviewing students, could also have been used to support the findings. Furthermore, students pre-existing experiences of science subjects could have been examined before the actual ESM data collection by using a background questionnaire. Another limitation of self-report measurement is that it is only sensitive to the experiences that the students are able to consciously report and what the person decides to communicate about their inner states (Hektner et al., 2007). Several factors might influence how students evaluate their experiences. Even though the students were told that the answering process was anonymous, they may still have answered the ESM questionnaire dishonestly – either consciously or unconsciously. Another option is that students have given socially desirable answers. For example, they might think it is more desirable to answer that they are interested in science lessons. Students can also evaluate their skills as lower than they really are on the basis of stereotypical ideas of science success. They may also grade their experiences in different ways (Hektner et al., 2007). Thus, we cannot know exactly how students' answers should be compared when they answer the question "Is this activity interesting?" with either "much" or "very much".

Furthermore, the *research design and procedures* may add limitations to the research. For example, ESM itself has several issues that should be taken into account before conducting an ESM study. Experience sampling has notable challenges related to participants, situations, measurements and data analytics (Scollon et al., 2003). The first challenge related to participants is the question: Who participates in the ESM study? (Barrett & Barrett, 2001; Scollon et al., 2003). ESM studies as such are burdensome for participants, which already limits the number of students willing to participate. In the present study, the teachers who participated were already familiar to the researchers, and the students who participated were assessed beforehand as being suitable for the research. In addition, the students' own motivation to participate in the study is crucial (Scollon et al., 2003). In the present study, when introducing the data collection procedure, the researchers tried to increase student motivation to participate by highlighting the international context of the data collection. Another problem, as some of the teachers pointed out during the data collection, ESM may not be the best possible data collection method for students who have concentration problems.

The ecological strength of ESM is being able to gather data in a full range of situations (Scollon et al., 2003). However, to avoid burdening the participants, it is also important to select these situations carefully. In this research, the focus was on the students' answers during science lessons, but the data were collected throughout the week, also in other situations. This might have lowered the students' response rate because the data collection was more burdensome than if it had only been collected during science lessons. After data collection, the students gave feedback on the situations in which they had to answer the ESM questionnaire. They reported that, for example, during their free time, they did not always hear the signal, and this lowered their response rate. They had also encountered situations in which answering the ESM questionnaire was not allowed, such as during a concert or in a movie theater. Based on the feedback received, it seems that ESM is best suited for the school context; for example, during science lessons.

Throughout the data collection, collaboration between the researchers and teachers was active. The teachers' wishes and concerns were also taken into account as much as possible. For example, the number of times that the ESM questionnaire had to be filled in during science lessons was changed between Study I and Study II, based on the feedback of the teachers. In Study I, which was at the beginning of the international project, the data were collected only once during a science lesson. After the data collection, meetings were held in both countries during which the data collection procedure was discussed. Teachers in both countries mentioned the concern that one measurement during a science lesson was not enough to cover all the classroom activities used in the lesson. This feedback was taken into account and the research design was modified for future data collection times. Because of this, in Studies II and III, students answered the ESM questionnaire three times during a science lesson. During Study I, the data collection lasted two weeks, including both weekends. The students' response rates, however, revealed that two weeks was too long to keep answering the ESM questionnaires. There was a distinct decline in the students' response rate, which was focused on the weekends. For Studies II and III, the answering schedule was changed so that students answered the ESM questionnaire on ten to twelve weekdays, which were the days they had science lessons. This change increased the students' response rates.

There were also some technological challenges related to the use of smartphones. In some of the phones the time changed if the smartphone was switched off for even a short period of time. This was problematic, because the ESM questionnaires were delivered to the phones on the basis of the time on the phone. Furthermore, some students reported that sometimes the application stopped working for no reason. This problem was solved if the smartphone was turned off, but then the student missed the opportunity to answer that specific ESM questionnaire. The students could also accidentally add or remove the ESM questionnaires from their phones if they were not careful enough.

Because the data collection procedure was new to both the researchers and the teachers, feedback was frequently collected from the teachers and the students. Their experiences of the ESM data collection were rather positive based on the feedback I received after collecting the smartphones. Some students even reported that answering the ESM questionnaire helped them reflect on and regulate their own learning. For example, when answering the ESM questionnaire, they realized that their thoughts were somewhere other than on the learning process, and they directed their focus back to the science learning. However, in addition to the benefits, using ESM also had limitations. For example, the students reported that the ESM questionnaire was too long. Because this study was part of an international project, the ESM questionnaire included other questions in addition to those related to student situational engagement, classroom activities and scientific practices. Because the data collected also concerned situations other than science lessons, answering the ESM questionnaire might have felt longer than if it had only focused on science lessons. Because we wanted the answering process to be easy for the students, we used the same ESM questionnaire throughout the data collection process.

Typically, when the students became familiar with the ESM questionnaire, the answering process took less than two minutes. However, the teachers gave us feedback that the actual response time was longer, because it included the time from the first alarm sound to when the students returned to their work. Even though the students received the ESM questionnaire at the same time, there was some variance. The ESM questionnaire was related to the time on the smartphone, and it was almost impossible for this to be exactly the same on all of the phones. Because the data collection was quite burdensome, the teachers chose students they knew would manage to finish this kind of task for the study. For example, one teacher explained that the disturbance the answering process caused would not be suitable in a class that contained one or more students with concentration difficulties.

Despite the limitations of the present study, it also presented *openings* for future research. Previous research has shown that students' and teachers' engagement levels are related to each other (Csikszentmihalyi, 2014, p. 177; Skinner, & Pitzer, 2012, p. 26). In other words, teachers who are engaged in teaching science can transmit this state of mind to their students. On the other hand, if the majority of the students are not engaged in science learning, this state of mind can transfer to the teacher and might prevent them finding ways to support student situational engagement. In addition, students' situational engagement could be examined in relation to that of their peers (Fredricks, 2011; Velayutham, & Aldridge, 2013) – for example by focusing on the feeling of science classroom belonging (Juvonen et al., 2012). Research focusing on the relationship between students' and teachers' or students' mutual engagement could be conducted using background and ESM questionnaires.

In this study we did not group the students before data analysis. However, LPA or cluster analysis could have provided more information on how students with different backgrounds become situationally engaged when the teacher uses different classroom activities or scientific practices. Especially among high school students, previous experiences have already had an impact on who the student is, how they relate to, for example, science learning, and how they act. When we analyzed the data without surveying the students' backgrounds, we also dismissed part of the students' uniqueness – thus the results describe a more overall situation.

Previous research has addressed how early adolescence is an important time for forming student engagement, attitudes and interest (Osborne, & Dillon, 2008; Osborne et al., 2003; Wylie, & Hodgen, 2012). Thus, a longitudinal study that examines students from the age of 10 until they enter vocational or high schools would provide information on the development of situational engagement. The special focus could be on school transitions. In Study I, we compared student situational engagement between students who were in the 9th grade and those who were in the 1st year of high school. The results of longitudinal studies could be used to further examine how to support student situational engagement in order to increase the number of students who pursue science careers.

6.6 CONCLUSIONS

The dissertation produces new insights into student situational engagement in their science lessons – a topic that has previously been understudied. By focusing on student situational engagement instead of general engagement, we can learn a great deal about what kind of learning situations or activities really engage students. This dissertation – especially Study III – was topical due to the changes in science curricula in Finland and the US. These curricular changes were one example of how these countries have reacted to the international concern of declining numbers of science-oriented students. The dissertation supports the idea that when students actively participate in their science lessons, they are also situationally engaged when working. This was especially true when students developed explanations and solutions.

To conclude, the present dissertation indicates that research should focus more on student situational engagement, especially conceptualizing it through students' self-evaluation of their situational skills, interest and challenge of the task. How teachers structure their science lessons for students plays an important role. It is important to use different classroom activities and scientific practices, keeping in mind a clear focus and goal. The time should be effectively used to support students' active participation instead of allowing students to "take the easy way out" by giving them the correct answers straight away. This might be an ambiguous goal for teachers and teacher educators and might require workshops or changes in science education that support teachers' own professional growth.

The dissertation, which is part of an international collaboration project funded by the Academy of Finland and National Science Foundation, has turned out to be beneficial from the teacher education point of view. The research was planned together with professors and researchers of the University of Helsinki and Michigan State University. In addition, collaboration with teachers and students was active. The meetings with researchers and teachers in both countries were regular and held either on-site or via skype. This had an important impact on the research and its development. The collaboration between the two countries was also important for the researchers and teachers because it allowed interactive learning from each other. During my doctoral study years, I was also able to spend several weeks in the US and learn more about their school culture.

In the light of the results, it is possible to highlight several aspects of science education: what, how and why science subject teaching should be conducted, by ensuring and improving the opportunities of students to experience situational engagement in learning situations. The use of smartphones has made the collection of situational engagement easy and interesting for students. In the future, the results of this dissertation can be used to support student teachers at university or in teacher training schools. For example, in courses on teaching practices, teacher training students could be advised to use scientific practices as part of their chemistry or physics lessons at least in

Finland. In addition, the results can be used to highlight the importance of well-structured lesson plans. This dissertation supports the idea that a well-structured lesson plan has a clear goal and a clear structure. It includes several classroom activities or scientific practices, because different activities situationally engage different students. Based on the literature review and the results of this dissertation, listening as an activity is related to a lower level of student situational engagement and, thus, it should not be used in science lessons without a clear purpose. This dissertation also provides indications that different methods that activate students learning could be used in science lessons to get situationally engaged students.

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