High school students' situational engagement associated with scientific practices in designed science learning situations

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Abstract
This study seeks to understand how different scientific practices in high school science classrooms are associated with student situational engagement. In this study, situational engagement is conceptualized as the balance between skills, interest, and challenge when the reported experiences are all high. In this study, data on situational engagement were collected using the experience sampling method (ESM) from 142 students in southern Michigan (the United States), resulting 993 ESM responses, and 133 students in southern Finland, resulting 1,351 responses. In both countries, scientific practices related to developing models and constructing explanations were associated with higher student situational engagement than other practices. In southern Finland, using a model was also associated with a high level of student situational engagement. The results indicate that students may experience situational engagement more often in science classrooms that use models than those that do not employ such practices. Thus, scientific practices related to models should be used frequently in science
classrooms to situationally engage students while learning science.

**KEYWORDS**
experience sampling method, high school, scientific practices, student situational engagement

1 | INTRODUCTION

We need situationally engaged students in science classes for several reasons. Students who are situationally engaged are more likely to achieve better learning outcomes at school, benefit from their learning process (Finn & Zimmer, 2012, p. 97), and use effective learning strategies (Krapp, 2000). Furthermore, students who are situationally engaged are more likely to experience learning as rewarding and seek similar activities in the future (Marks, 2000). Overall, student engagement can be defined in many ways (Fredricks, Blumenfeld, & Paris, 2004; Pekrun & Linnenbrink-Garcia, 2012). The definition is partly determined by whether the perspective of inquiry is rooted in the microlevel (e.g., engagement in a task) or the macro-level (e.g., engagement for a group of learners; Sinatra, Hedly, & Lombardi, 2015). This study targets a micro-level phenomenon: student situational engagement.

Focusing on student situational engagement instead of general engagement is beneficial and justifiable because situational variables can be enhanced and triggered by new and innovative classroom activities (Singh, Granville, & Dika, *). Identifying the association between situational variables such as interest, which is a precondition for situational engagement, and specific classroom activities can inform teachers and teacher educators about how to encourage students to study science (Nakamura & Csikszentmihalyi, 2014, p. 92). For example, Organisation for Economic Co-operation and Development (OECD, 2016, p. 17) studies point out the low level of science-oriented students revealing that across OECD countries only 25% of students on average reported to look for science-related career. Despite calls for research, this topic has remained understudied.

In this study, student situational engagement refers to the relationship between students' evaluation of their skills, their interest in an ongoing task, and the challenge presented by that task (Schneider et al., 2016). The definition is based on Csikszentmihalyi’s (1990) theory of “flow” and its expanded version that includes situational interest (Krapp & Prenzel, 2011; Lavonen, Byman, Juuti, Meisalo, & Uitto, 2005). Although we have a specific definition for student situational engagement, it is in line with the common understanding of the concept “engagement.” In general, according to the U.S. National Academies of Sciences (2018), student engagement refers to the relationship between the learner and the learning activity. This relationship takes account of the characteristics of the activity, positive and negative reactions to the activity, the challenge met in the activity, and the level of the learner’s investments (Marks, 2000). In this study, situationally engaged students are closely related to active students. The definition is based on similar ideas as inquiry-based science learning, which introduces the idea that inquiry engages students in learning (Minner, Levy, & Century, 2010).

In the United States and Finland, teachers have faced problems in supporting students’ engagement and interest in science learning (OECD, 2007, 2016). One way to increase the level of student situational engagement in science learning is to use pedagogical approaches that challenge students and trigger their interest in science classrooms. Increasingly, the use of such scientific practices is being promoted globally in science teaching and learning (Berland et al., 2016; Hasni et al., 2016). This shift is also recognized in science curricula. The Finnish science curriculum (Finnish Ministry of Education and Culture [FMEC], 2013) emphasizes four learning competencies for students: designing and evaluating scientific inquiry, interpreting data, explaining phenomena, and using scientific concepts. In the Finnish curriculum, scientific practices are seen not just as supportive for learning but also as the core aim in science education. Similarly, in the United States, science standards emphasize the use of
scientific practices in science teaching. The Michigan K-12 Science Standards (Michigan Department of Education [MDE], 2015) have similar aims and performance expectations as the Next Generation Science Standards (NGSS; National Research Council [NRC], 2012), which aims to deepen learning through experiential approaches to science learning. In the Finnish science curriculum, asking questions, for example, is included as the general aim of physics and chemistry: “The objective of the teaching and learning in chemistry/physics is that the student is able to formulate questions about the phenomena he or she examines and to develop the questions further to serve as a basis for research, problem solving and other activities” (FMEC, 2013, p. 161, 166). In Michigan’s K-12 Science Standards, planning and conducting investigations is an aim under the course Forces and Interactions: “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. 27).

While many competencies can be categorized as scientific, and additionally various practices and activities can be used in science lessons (Ford, 2015), we focused on the following 10 scientific practices, which are common and emphasized in both standards: asking questions, developing models, using a model, planning an investigation, conducting an investigation, analyzing data, solving math problems, constructing an explanation, using evidence, and evaluating information. Previous research related to scientific practices has mainly described the qualities of scientific practices (Ford, 2015; Mody, 2015; Osborne, 2011, 2014) or discussed the use of specific practices in the classroom (Bell, Bricker, Tzou, Lee, & Van Horne, 2012; Evagorou, Erduran, & Mäntylä, 2015; Krajcik & Merritt, 2012). However, there is a need for research that examines how scientific practices are associated with students’ individual experiences, such as situational engagement, in real classroom situations. Accordingly, this novel research attempts to provide preliminary information about how different scientific practices used in science classrooms could increase the length of students’ situational engagement and thus enhance their learning in science. Given previous results, it is reasonable to presume that scientific practices are associated with student situational engagement. Different classroom activities, such as listening to a lecture and discussion, have been observed to be associated with student situational engagement in different ways (Inkinen et al., 2019; Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). While scientific practices can be assumed to be associated with student situational engagement in the same way as classroom activities, the interrelated nature of scientific practices can make the phenomena more complicated because multiple scientific practices can be used at the same time, whereas teachers typically use only one or two classroom activities at a time.

2 | SCIENTIFIC PRACTICES

Globally, the goal of science education has shifted from students’ knowing science content to students’ developing and using knowledge, along with scientific practices to understand the world (Berland et al., 2016). In this study, we focus on scientific practices classified into three categories (similar to the NRC, 2012 and Osborne’s, 2011, approach): (a) investigating, (b) developing explanations and solutions, and (c) evaluating information.

Investigation at school includes scientific practices that are similar to those real scientists employ while investigating scientific phenomena (Osborne, 2011). Investigation starts with a question that needs to be answered. Traditionally, questions have served different purposes in science classrooms. For example, teachers can use questions for formative and summative assessments while students can use questions to express their lack of knowledge of a specific subject (Reiser, Novak, Tipton, & Adams, 2017, p. 87). Asking questions can provide an opportunity to explore scientific concepts, understand what drives and fascinates scientists (Osborne, 2014), and develop scientific habits of mind (NRC, 2012). Furthermore, driving questions can be used to contextualize learning, anchor the said topic in real-world issues, and probing scientific inquiry (Krajcik et al., 1998).

Questions can be seen as the engine that drives all scientific research, because, for example, they elicit active participation from students in the learning process and promote active collaboration between students and teachers (Osborne, 2014). Asking questions can increase student situational engagement as students construct
knowledge and work collaboratively with meaningful questions (Mestre, 2005), especially when the questions are asked and refined by the students themselves (Reiser et al., 2017, p. 88).

As pointed out in the Programme for International Student Assessment (PISA) framework, scientifically literate individuals know how to plan and conduct investigations (Osborne, 2014). The process starts with accounting for relevant variables, considering how these variables may be observed, measured, and controlled, and deciding how systematically the data will be collected and recorded (NRC, 2012; Windshitl, 2017, p. 136). Planning and carrying out investigations can be useful when students want to explain or understand the world by creating comprehensive explanations or models (Windshitl, 2017, p. 139). Investigations should not be restricted to laboratories, and students should have experience with investigations that range from those structured by teachers to those emerging from students’ own interest (Duschl & Bybee, 2014; NRC, 2012). Research indicates that conducting investigations is beneficial not only to students’ learning and understanding (Mercer, Dawes, Wegerif, & Sams, 2004) but also increasing students’ situational engagement levels (Duschl & Bybee, 2014).

Analyzing and interpreting data are essential activities for scientists, and for science learning (Osborne, 2011, 2014). While investigating, students analyze and interpret data that support their claims and reasoning, while explaining the phenomena at hand (Krajcik, 2015a). Data could be presented as tables, graphs, pictures, observations, maps, items, or facts (Rivet & Ingber, 2017, p. 159). While analyzing and interpreting data, it is important to work toward a goal and use a range of tools and multiple practices (Rivet & Ingber, 2017, p. 163).

Mathematics and computational thinking play an important role in data analysis and interpretation. They help scientists observe how much, how fast, or how frequently something happens (Wilkerson & Fenwick, 2017, p. 184). Mathematics and computational tools are central to science and engineering research (NRC, 2012) and guide the interpretation of measurements (Osborne, 2014). They are also used to build predictive models and for analyzing data (Wilkerson & Fenwick, 2017, p. 185). As a tool in science, mathematics can help students understand phenomena (NRC, 2012) and enhance their problem-solving skills (Schuchardt & Schunn, 2015).

Developing explanations and solutions involves building of models that are based on theory, formulation of hypotheses, and identification of solutions (Osborne, 2011). A large body of research related to scientific practices has focused on modeling and the use of models (Harrison & Treagust, 2000; Krajcik & Merritt, 2012; Krajcik et al., 1998). Modeling is an ambiguous concept that includes different activities (Schwarz et al., 2009). For example, models can be understood based on either how they are used (e.g., designing models or analyzing models) or which representational forms they take (e.g., tables, graphs, equations, words, or pictures; Passmore, Schwarz, & Mankowski, 2017, p. 114). Developing and using models involves meta-knowledge, which is understanding the nature and purposes of the models (Schwarz et al., 2009). Students can build or use models to understand how the world works, how it may change (Osborne, 2014; Passmore et al., 2017, p. 114), how to think and work scientifically (Harrison & Treagust, 2000), and how to generate new predictions that can be tested against new data about the phenomena (Krajcik et al., 1998).

In science classes, students often familiarize themselves with the final, canonical scientific model that scientists have developed over time, instead of constructing their own models (NRC, 2012). As a result, they usually see models as toys or miniatures of real-life objects, rarely realizing why scientists use multiple models to explain a phenomenon (Harrison & Treagust, 2000). By enabling students to develop and revise models to explain phenomena, schools can encourage students’ new ways of thinking as scientifically literate citizens (Krajcik & Merritt, 2012).

Studies on science learning have demonstrated the important role of cognitive tools such as different models (i.e., graphs), which help learners to see patterns in specific phenomena (Edelson & Reiser, 2006). Graphs, for example, are essential for modeling and simplifying numerical data, which allow the reader to access information quickly. Cognitive tools, such as new forms of computer software, allow learners to visualize complex data sets (Edelson & Reiser, 2006). Visual representations can be used to model phenomena that are not observable with the eye (i.e., microscopic and macroscopic) or do not exist in visual format but can be translated as such (Evagorou et al., 2015).
Constructing an explanation is closely related to developing and using models. Modeling, as a practice, can be divided into thinking about models (e.g., how to build a model or evaluate and revising model) and thinking with models (e.g., using and applying models; Passmore et al., 2017, p. 117). Many scientific explanations rely on the construction of models (Osborne, 2014) as these explanations are based on theories about how the world works and how models describe phenomena (Bybee, 2011; Krajcik & Merritt, 2012; Osborne, 2011). This is in line with a central aspect of science education, which is to engage students with standard scientific explanations of the world by helping them gain an understanding of the major ideas that science has developed (NRC, 2012), together with why and how something happens (McNeill, Berland, & Pelletier, 2017; Reiser, Berland, & Kenyon, 2012). Constructing explanations can be seen as a causal chain supported by evidence that leads to a claim (Reiser et al., 2012).

Evaluation is an indispensable part of students’ participation in scientific practices. As a category of scientific practices, evaluating involves using evidence for arguments and assessing information. The main aim of the practice is to discuss and critique either the data acquired from investigations or the claims built based on data (Osborne, 2011). Bybee (2011) argues that science cannot advance if scientists are unable to communicate their findings and learn from each other. To be able to share scientific ideas with others, it is important to know how to evaluate information. Evaluating and communicating information are thus vital to science education because they extend the knowledge of the world (NRC, 2012).

Situational engagement can be increased by giving students the opportunity to use evidence to build arguments (Berland & McNeill, 2010; Mestre, 2005). A good argument rests on the ground that is used as the evidence for a claim and a warrant, which is the assumption or principle that connects the ground and the claim (Toulmin, 2003, p. 95). In other words, argumentation is multidimensional process that includes defending, evaluating, critiquing, and revising ideas (Berland, McNeill, Pelletier, & Krajcik, 2017; Toulmin, 2003, p. 54). Scientific argumentation can provide new insights into phenomena and, thus, prove useful when students need external support for ideas that they are constructing or sharing with others (Berland et al., 2017). Additionally, learning to argue scientifically allows students to use their scientific knowledge to justify an explanation or identify the weaknesses in others’ arguments, which then further contributes to their knowledge and understanding (NRC, 2012). Usually, in science classrooms, students use unique information, such as opinions, or evidence to support their arguments. Forming and writing arguments can support the development of students’ understanding and engage them in the social science practice of debating and constructing knowledge (McNeill, 2009).

The central idea behind using scientific practices in science classrooms is to involve students as active investigators who can solve problems based on their experiences (Krajcik, 2015b). Underlying this idea is the assumption that students are more situationally engaged and interested in science learning when they actually participate in science and use multiple ways to explore and understand the world rather than simply memorize or recite information (Krajcik, 2015b; Miller, Manz, Russ, Stroupe, & Berland, 2018; Mody, 2015). Further, the use of scientific practices helps students better understand difficult scientific concepts. Science teaching that focuses on scientific practices can also support students’ feelings that they can successfully learn and do science (Mody, 2015). Abilities that students learn through scientific practices can also be beneficial outside of the science classroom or even in other science-based contexts. Mody (2015), for example, explains how the skills and resources learned through scientific practices are beneficial in everyday life, by highlighting that students will eventually contend with uncertainty, in which they will need to express arguments clearly and back them up with evidence, and subject their own and others’ ideas to skeptical review. Using scientific practices can help students acquire the skills and resources needed to do so.

In science classrooms, when teachers make decisions about which practices to use in teaching, they must consider the various qualities of the practices, the outcomes they hope to achieve by using the practices, and how the practices fit with the classroom activities they have chosen. One goal a teacher may strive for is to increase students’ situational engagement. However, more research-based evidence is needed to determine how scientific practices are associated with student situational engagement. A systematic review by Potvin and Hasni (2014) found that different practices have a slight potential to increase, for example, students’ interest.
Student situational engagement is understood and measured within the classroom situation and, further, within its content area (Stodolsky, 1988, p. 1). In a classroom situation, three key elements can influence students' situational engagement: the students themselves, the teacher, and the content (Corso, Bundick, Quaglia, & Haywood, 2013). Students' backgrounds can influence their level of overall engagement; for example, their previous experiences may lead some students to be more interested and focused on science than others.

Teachers, on their part, play an important role in situationally engaging students in science classroom activities, such as scientific practices. Previous studies have shown that classroom activities, such as solving mathematical problems, discussing (Inkinen et al., 2019), and undertaking individual or group work (Shernoff et al., 2003), are associated with student situational engagement. Additionally, teachers can help their students explain phenomena, justify their claims, and debate the strengths of alternative explanations (McNeill, 2009). Situational engagement, therefore, is not just an isolated and mechanistic phase at the beginning of the lesson that appeals to students' curiosity but can be generated by employing scientific practices throughout a learning situation. These practices have the potential to guide students to situations, where they can employ their competencies in challenging and interesting ways. However, empirical evidence is limited on how students are situationally engaged in these practices in real science learning situations.

Situational engagement can be defined in many different ways. One approach is to define it as in flow theory, taking into account the continuum of the learning process. Flow is intrinsically rewarding and thus leads students to seek similar experiences in the future (Nakamura & Csikszentmihalyi, 2014, p. 92; Shernoff et al., 2003). In this study, we assume that when students are situationally engaged in scientific practices, they will seek similar activities in the future, which will encourage them to learn science.

In this study, situational engagement has been conceptualized as the times when students experienced a specific task as challenging and, at the same time, evaluated their interest in and the skills for the task as high (see Schneider et al., 2016). To be situationally engaged in a task, appropriate levels of skill or competence are needed to complete it (Brophy, 2004, p. 16). Students who are confident in their ability to perform a task usually believe that their investments in learning can help them overcome possible difficulties (Lavonen & Laaksonen, 2009). In an ideal situation, students are engaged in tackling tasks in a way that produces significant and understandable knowledge that aligns with learning goals (Lavonen, Krzywacki, Koistinen, Welzel-Breuer, & Erb, 2012). Hektner and Asakawa (2000) emphasized that people enjoy activities that they perceive they are skilled at and those that will strengthen their experiences of flow (Csikszentmihalyi, 1990).

Numerous studies have suggested that situational interest is a strong predictor of engagement (Osborne, Simon, & Collins, 2003; Singh et al., 2002) encouraging students to develop their science knowledge further, pursue careers in science, use scientific concepts in their lives (OECD, 2007, p. 39), and seek opportunities to reengage in science learning in the future (Ainley & Ainley, 2011). Situational interest originates between the task and the learner (Hidi & Renninger, 2006; Krapp & Prenzel, 2011), and can be changed and partially controlled by teachers (Cheung, 2018; Hidi & Renninger, 2004). It lasts only for a limited period (Krapp, 2007) and is triggered at the moment when a situation captures a person's attention and motivates them to focus on the task at hand (Brophy, 2004, p. 56; Hidi, Renninger, & Krapp, 2004, p. 97).

A situational challenge is defined as a desire to persist in working with an ongoing task (Eccles & Wigfield, 2002). A challenge can be seen as a positive state in which students' skills meet the demands of the task (Csikszentmihalyi, 1990). If the challenge of the ongoing task is too demanding for students, they are likely to become disengaged (Eccles & Wigfield, 2002). Previous studies have shown that people mostly enjoy what they are doing when their skills match the challenge of the task (Csikszentmihalyi & Schneider, 2000). In the context of students, providing them with appropriate challenges and opportunities to enhance their skills is the most important way to engage them in learning (Shernoff et al., 2003).
4 | RESEARCH QUESTIONS

The objective of this study was to uncover how students' perceived use of scientific practices is associated with student situational engagement in high school science classrooms in southern Michigan and southern Finland. Although the literature suggests that scientific practices may be engaging for students, more evidence is needed (e.g., Potvin & Hasni, 2014) to understand how different scientific practices—especially asking questions, planning and conducting an investigation, and using evidence to make an argument based on previous research (Duschl & Bybee, 2014; Mestre, 2005)—can support the development of student situational engagement.

5 | METHODS

This study is a part of a larger international collaboration aimed at understanding and supporting the development of student situational engagement. As a part of this collaboration, we collected the data during the 2015–2016 school year.

5.1 | Experience sampling method (ESM)

The ESM can be particularly enriching for education research, by enabling us to ask new and interesting questions, and offering insights into how education contexts shape learning (Zirkel, Garcia, & Murphy, 2015). With ESM, it is possible to collect information about students' personal experiences, such as feelings, thoughts, and emotions, which vary by situation (Hektner, Schmidt, & Csikszentmihalyi, 2007, p. 3). The idea of ESM is to get reliable information from individuals about personal changes over time, together with individual differences between individuals in the group (Bolger, Davis, & Rafaeli, 2003). Typically, ESM is used to assess experiences that are very sensitive to short-term changes. To track individual changes, repeated measures are obtained. Compared to paper questionnaires, the ESM improves the validity of the research, by diminishing the role of forgetfulness and retrospective remembering (Bolger et al., 2003).

5.2 | Participants

A group of high school teachers collaborated with researchers in southern Michigan and southern Finland with the aim of examining and developing high school students' situational engagement in science learning. The students were in grades 10–12, and their ages ranged from 14 to 17 years.

In southern Michigan, 142 students (69 girls and 73 boys) participated in the study, which resulted in 993 responses to an ESM questionnaire distributed during their science lessons. The students and teachers came from five public high schools. The students belonged to diverse, racial, ethnic, and socioeconomic groups. In terms of socioeconomic status, the schools ranged from <30% of students receiving subsidized lunch to more than 80% of the students. Among the students, 46% reported their race as White, 37% reported their race as other than White, and 17% did not report their race. Twelve (six female and six male) teachers participated in the study. Of the teachers, six taught physics, and six taught chemistry. All the teachers were certified in the science subject they taught. They ranged in experience from <1 year to more than 20 years, with 67% of the teachers having taught for at least 11 years.

In southern Finland, 133 students (79 girls and 54 boys) participated in the study. These participants accounted for 1,351 ESM responses in the science classrooms. Students and teachers came from three comprehensive high schools. Two of the schools were teacher training schools, and one had a special option for students to specialize in natural sciences. The majority of the students were born in Finland (94.9%) and spoke Finnish as their first language (86.8%). The other 5% of the students came from Russia, other European countries, Asia, and North America: in
which 11.8% had Finnish as a second language, and 3.7% were bilingual. Only students with high middle school grades were admitted into the three schools. A total of eight teachers (four females and four males) participated in the study. Four of them were chemistry teachers and the other four physics teachers. One male chemistry teacher happened to participate in the data collection twice, but in different semesters and with different students. All the teachers were certified in the science subject that they taught. They ranged in experience from 3 years to more than 20 years, with 50% of the teachers having at least 11 years’ experience.

5.3 | Teacher workshop

We organized a workshop for the teachers who participated in the data collection. In the workshop, a research–practice partnership (RPP) was formed to help teachers increase student situational engagement in their science classrooms by employing scientific practices. RPP is a long-term collaboration between practitioners (here teachers) and researchers that aims to investigate problems of practice and develop solutions for them (Coburn & Penuel, 2016). We considered RPP relevant because of the recent changes in the science curricula in southern Michigan and southern Finland. Although the changes in science curricula were nationwide, and at least some of the teachers had familiarized themselves with the scientific practices beforehand, we felt that additional support could be helpful when planning for data collection. In fact, RPP has been viewed as important and supportive to teachers’ professional learning (Coburn & Penuel, 2016).

The workshop consisted of collaborative meetings between researchers and other participating teachers during one academic year. The workshop included one meeting with teachers and researchers from both countries. In addition, several meetings were held in the teachers’ home countries, which focused on science teaching. During the workshop, we shared examples of science teaching that included scientific practices and emphasized the need for student collaboration.

The teachers designed teaching units in small collaborative groups, and as researchers, we visited these groups during the planning phase. The number of teaching units designed across both study locations ranged between 6 and 10 science lessons. The length of the lesson was approximately 75 min in southern Finland and 55 min in southern Michigan. Because science teaching practices and teachers’ professional development trajectories differed between southern Michigan and southern Finland, the planning phase of the units was also slightly different. In southern Finland, the teachers planned their teaching units more independently than those in southern Michigan. Further, the Finnish teachers taught different courses with varied student objectives because of the allocation of yearly lesson hours into intensive 5-week courses. In southern Michigan, one teacher was responsible for leading the planning of each unit, while the research team and other participating teachers offered their inputs. Finally, all the teachers implemented the units in their classrooms. In both countries, we were available to address questions and concerns throughout the planning and implementation processes.

This study focused only on science lessons in which teachers guided their students toward scientific practices. The units were formed to answer a main research question, such as, “When I am sitting by the pool, why do I feel colder when I am wet than when I am dry?” and “Why do some objects take the same amount of time to fall from the same height while others do not?” The main aim of the units was to familiarize the students with different chemistry or physics themes. For example, students had to describe movement with constant velocity and acceleration, and for this, they used models to describe why the movement changed or had acceleration.

Typically, investigations are conducted in laboratory settings, but school resources dictate whether a laboratory can be created in a regular classroom or if it has to be in a different room. Traditionally, investigations are organized by the teachers, who give students a worksheet to work on. The worksheet includes a description of the different phases of investigation. In the RPP workshop, however, we encouraged the teachers to let the students plan and conduct their own investigations. As a result, the teachers had to tolerate their students’ uncertainty. We advised teachers not to give students the right answers immediately, but to relocate responsibility to the students, for example, by encouraging them to develop models collaboratively.
Analyzing and interpreting data were incorporated into the investigation if the content warranted it. For example, if the investigation called for measurement of, say, speed in physics, the data derived from the investigation were followed by analysis and interpretation. Additionally, some analyses also involved solving of math problems. As with the investigations, we advised teachers to let the students assess the reliability of their results first. One option for the teachers was to encourage the students to work collaboratively in small groups when investigating and analyzing data.

Students were encouraged to develop and use models as a collaborative practice. Some of the teachers in southern Finland asked the students to use whiteboards in a small group when developing models. Students could also present their models to the whole classroom, which allowed them to discuss the models together. The development and use of models were not restricted to the use of whiteboards, however. Students were also encouraged to take notes on their worksheets in the notebooks. As a part of developing and using models, students could also construct explanations.

We included several elements in the workshop to emphasize modeling practices. Teachers were advised to guide their students toward constructing models, which were consistent with evidence and theories, to illustrate, explain, or predict phenomena. In addition, we instructed the teachers to encourage their students to communicate, compare, and evaluate the strengths of different models in accurately representing or predicting new phenomena. The teachers could, for example, promote the use of models among students for better explanatory and predictive power, derived from account for additional evidence or aspects of a phenomenon.

The use of models was also a suitable approach to let students evaluate information. We told teachers in the workshop that when some students explained the phenomenon to the whole classroom using a preliminary model, other students could be advised to simultaneously evaluate the information. Evaluating information can also involve focusing on scientific literature. We told the teachers that they could use multiple sources of information, such as videos and texts. Furthermore, the teachers could allow their students to use these sources of evidence, or other scientific literature, to develop arguments about their own investigations or prove why some claims were (or were not) correct.

5.4 Data collection procedure

Before the data collection, we introduced the process to the school principal, teachers, and students. Parental guardians were also informed of the process via a permission letter. Students were told that participation in the data collection was voluntary and that they could end their participation whenever they desired. The teachers adhered to the science curriculum for their lessons, although the planned teaching process during data collection differed from how they had previously taught the content. For data collection, lessons were planned in collaboration with the research team, which included professionals in science education. In addition, teachers were given all the support they needed during the data collection phase.

Data were collected via smartphones given to students during the first science lesson at the beginning of the data collection process. The smartphones were labeled beforehand, so that the answering process for the students was anonymous. Names of students were replaced with research-generated ID numbers to combine students' background information with their ESM data captured on the phones. Students were given an Android-based smartphone with a special application designed for collecting ESM data, via a questionnaire. The questionnaire remained unchanged throughout data collection, and the application was programmed to send the ESM questionnaire three times during a science lesson, to cover the entire lesson duration without overburdening the teachers or students.

The ESM questionnaire was written in English and then translated into Finnish. The Finnish version went through an iterative process, with active collaboration from both countries to ensure that the Finnish version was properly translated. The ESM questionnaires were piloted in both countries to ensure that the meanings of the questions were comparable.
At the beginning of the data collection, we visited the science classrooms to introduce the data collection process to the students and teachers. We briefly introduced the background of the research and explained that it was a collaboration research between two countries. The students were then introduced to the aim of the project and the expectations from the participants. We also assured them that participation was voluntary and that their smartphone responses would remain anonymous. Because ID numbers were the only way to match students’ answers to their backgrounds, we clarified that any changes to the smartphones had to be properly written down and brought to our attention. The students were also instructed to answer only their own ESM questionnaires.

After this short introduction, we demonstrated the filling of an ESM questionnaire to the students and familiarized them with notification alerts for participating in the study. We also went through the ESM questions and their meanings. Additionally, because scientific practices could be difficult for the students to distinguish, the teachers were given the option of saying what they were doing out loud, when the students were answering the ESM questionnaire.

5.5 Measuring student situational engagement and scientific practices via ESM

Student situational engagement (see also Schneider et al., 2016) was measured using the following three questions: “Did you feel skilled at what you were doing?,” “Were you interested in what you were doing?,” and “Did you feel challenged by what you were doing?” Students responded to these statements on a 4-point Likert scale with the following response categories: 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree. Students were considered situationally engaged if their responses were agree or strongly agree to all the three questions. A binary variable of 1 or 0 was attached to positive and negative responses, respectively.

On the same ESM questionnaire, students were asked to identify the scientific practice that they had used: “Which best describes what you were doing in science when signaled?” They were given the following answers to choose from: (a) asking questions, (b) developing a model, (c) using a model, (d) planning an investigation, (e) conducting an investigation, (f) analyzing data, (g) solving math problems, (h) constructing an explanation, (i) using evidence to make an argument, (j) evaluating information, and (k) other. These options were recoded as dichotomous variables for the analysis (1 = scientific practice was reported, 0 = scientific practice was not reported). The option of other was included on the ESM questionnaire for the times students were doing activities unrelated to scientific practices.

The ESM questionnaire also guided the students to take a picture of what they were doing, in the following words: “Take a picture of the main thing you are doing.” In addition, students were asked an open-ended question “What were you learning about in science when signaled?”

5.6 Analysis strategy

To better contextualize what was happening in science classrooms when the students answered the ESM questionnaire, students’ pictures were analyzed using data-driven content analysis. Students captured 429 pictures (43.20% of answers) in southern Michigan and 1,046 (77.40% of answers) in southern Finland. Pictures assigned to the “other” category in response to the question “Which best describes what you were doing in science when signaled?” were omitted from the analysis. In the pictures, we focused on students’ descriptions of the lesson content and primary targets, which refer to objects that were captured, such as worksheets, which was the most commonly covered item. For example, if there was a worksheet and computer on a student’s desk, but the picture covered only a small part of the computer, the worksheet was treated as the primary target of the picture. Pictures were used to show what students were doing or wanted to capture during different scientific practices.

The pictures that the students took were unambiguous and clear, and they were grouped into eight categories: “book,” “computer,” “laboratory work,” “overall picture of the classroom,” “teacher presentation,” “whiteboard,”
“worksheet,” and “other.” In the pictures labeled “book,” students had captured either photos of the cover of a book or pages of an open book. In the pictures labeled “computer,” the computer was either switched off or the screen showed school work. Some pictures of smartphones were also categorized as “computer.” Pictures in which the computer was being used for other purposes, such as playing games, were categorized as “other.” Pictures under the “laboratory work” category depicted either laboratory tool(s) or classmates doing laboratory work. The category “overall picture of the classroom” contained pictures of the whole classroom, with different students doing classroom activities and their teacher, or even an empty classroom. For pictures labeled “teacher presentation,” students had photographed a teacher, a PowerPoint presentation, a blackboard, a teacher’s desk, or demonstration tools. Some teachers had purchased whiteboards for their students, and the pictures in which students were using these whiteboards were labeled “whiteboard.” Pictures were labeled as “worksheet” if they contained images of a worksheet or a notebook. In southern Finland, most of the pictures in the “other” category had shots of the classroom ceiling or their own or others’ heads. In southern Michigan, pictures in the “other” category mainly featured others’ heads, the floor, or a blank table surface. To show what students were actually doing when they reported different scientific practices, we examined the caption of the students’ pictures. We also examined students’ responses to the open-ended question “What were you learning about in science when signaled?”

Descriptive statistics were used to determine the time students reported spending on different scientific practices. We also examined how student situational engagement varied in relation to the scientific practices reported. To examine how different scientific practices were associated with student situational engagement in southern Michigan and southern Finland, three-level, logistic regression models were run. In all of the logistic regression models, scientific practices were compared one by one to the situations when other scientific practices, including the category “other” were used in science classrooms. The outcome of the models was a binary indicator of student situational engagement (0 = not engaged, 1 = engaged).

Level 1—Responses

\[
\text{logit}(\pi_{ij}) = \beta_{0ij} + \beta_{1ij}X_{tij},
\]

Level 2—Students

\[
\beta_{0ij} = \gamma_{00j} + \nu_{0ij}, \quad \beta_{1ij} = \gamma_{10j},
\]

Level 3—Classrooms

\[
\gamma_{00j} = \delta_{000} + \eta_{00j}, \quad \gamma_{10j} = \delta_{100},
\]

where \( \pi_{ij} \) is a binary indicator of student 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 at time \( t \). For the analysis, Stata version 14.2 by StataCorp was used.

6 | RESULTS

Based on students’ open-ended answers, there were several topics in both countries that students worked with during the data collection. In chemistry and physics lessons in southern Finland, there was more variation in science
content. However, in physics lessons in southern Michigan, the topic in different classrooms was magnetism. Table 1 shows the topics that students focused on in their science lessons, along with examples from the students themselves.

### 6.1 Student situational engagement

Table 2 reveals how much time students reported using each of the scientific practices when they were prompted to answer an ESM questionnaire. The table also shows how much time students reported being situationally engaged when the scientific practices were used in their science classrooms.

In southern Michigan, the students were involved in four main scientific practices in their science lessons: developing models, conducting an investigation, analyzing data, and using a model. In terms of the classifications proposed by Osborne (2011) and NRC (2012), investigations accounted for 43% of the time, and developing explanations and solutions for around 33% of the time. In southern Finland, too, students reported four main scientific practices, three of which were the same as those in southern Michigan: conducting an investigation, developing models, and analyzing data. The exception was evaluating information, which accounted for 10% of the Finnish students’ time. In southern Finland, investigations accounted for 39% of student time and developing explanation and solutions for almost 26%.

Student situational engagement varied depending on the scientific practice used in the countries. The scientific practice that showed the lowest level of student situational engagement was investigations. In southern Michigan, students reported being situationally engaged for 10% of the time when they were conducting an investigation. In southern Finland, evaluating information, planning an investigation, and conducting an investigation were the practices associated with <20% student situational engagement. Student situational engagement was the highest when students were using evidence to make an argument in southern Michigan and using a model and constructing an explanation in southern Finland.

Logistic regression models were used to determine how scientific practices were associated with student situational engagement. Table 3 shows the results for southern Michigan and southern Finland.

In both countries, scientific practices related to models seemed to increase students’ chances of being situationally engaged. In southern Michigan, students were 2.15 times more likely to be situationally engaged when they were developing models compared to when they were doing some other activity in the science lesson. In southern Finland, when students were developing models (odds ratio [OR] = 1.82) or using a model (OR = 2.36), they were more likely to be situationally engaged. Additionally, when students in Finland were constructing an explanation, they were 1.96 times more likely to be situationally engaged.

### 6.2 Content of the science lessons via students’ pictures

When observing students’ pictures, it is important to keep in mind that they reflected only those subjects or targets that the students wanted to reveal. Because scientific practices tend to overlap and several practices may be employed at the same time, students could have been doing different things while reporting the same scientific practice or they could have captured the same target when reporting different scientific practices. For example, when planning investigations, students could have asked for the teacher’s help, and the teacher could have shown them something on the blackboard. Such a picture would be categorized as “teacher presentation.” Alternatively, students could have been planning their investigations using a worksheet or whiteboard (which would be categorized as “worksheet” or “whiteboard”), or they could have been searching information in a book related to the topic (which would be categorized as “book”). Another example of the interconnection between different scientific practices is that students could have used, for example, a worksheet for different purposes throughout the
**TABLE 1** The content of science lessons in southern Michigan and southern Finland derived from students’ open-ended answers

| Topic | Southern Michigan | Southern Finland |
|-------|------------------|------------------|
| Structures and properties of matter (Chemistry) | Molecules, Models, Destruction of models | Molecules, Models, Structural formula, Isometry, Spectroscopy, Dispersion force, Orbitals, Hydrogen bond, Strong and weak bonds |
| Liquids (Chemistry) | Temperature and properties of liquids, Structure and property of liquids, Does water make you colder? | Solvation, H₂O, Capillary action, Liquids |
| Chemical reactions (Chemistry) | Chemical reactions, Burning Mg, Combination of two subjects, Mass change, What happens to substances in a chemical reaction | Modeling of galvanic cell, Electrolysis, Daniell cell, Electrochemistry |
| Electrochemistry (Chemistry) | | |
| Electricity and magnetism (Physics) | Magnets, Magnetic force, Magnetic fields, Electromagnetism, Revision of the magnetic model, Attraction and repulsion of magnets, Electric motors, Magnetism and velocity, Trains and magnets | |
| Thermodynamics (Physics) | State of the gases at the microlevel, State equations of gases, Thermal expansion, Specific heat capacity, Charles law, Velocity and pressure | |
| Mechanics (Physics) | Kinetic energy, Mechanical energy | (Continues) |
scientific practices. For example, while investigating, students may have taken notes of what they planned to do or were doing at that moment. Additionally, a worksheet could be used to draft models or for writing explanations of why something happened.

The content students captured with their pictures varied. However, the variation was greater among students from southern Finland where the concept of scientific practices was less familiar. In southern Michigan, regardless of scientific practice, students mostly took pictures of their worksheets. In southern Finland, students' pictures

| TABLE 1 | (Continued) |
|----------|-------------|
| Topic | Southern Michigan | Southern Finland |
| Waves (Physics) | | |
| Beat of a sound | Decibels | |

Note: $N = 378$ observations from 142 students in 12 classrooms in southern Michigan and $N = 924$ observations from 133 students in nine classrooms in southern Finland.

*Topics are named after theoretical content analysis of students’ answers.

| TABLE 2 | Summary statistics for southern Michigan and southern Finland |
|----------|-------------------------------------------------------------|
| Scientific practices | Southern Michigan* | Southern Finland |
| | Activity (% of the lesson) | Situationally engaged (% of answers) | Activity (% of the lesson) | Situationally engaged (% of answers) |
| Investigation | | | | |
| (1) Asking questions | 8.77 | 23.31 | 3.48 | 21.28 |
| (2) Planning an investigation | 3.96 | 18.33 | 5.63 | 18.42 |
| (3) Conducting an investigation | 14.52 | 10.45 | 13.77 | 19.35 |
| (4) Analyzing data | 13.45 | 17.16 | 10.81 | 23.97 |
| (5) Solving math problems | 2.38 | 27.78 | 5.33 | 20.83 |
| Developing explanations and solutions | | | | |
| (6) Developing models | 14.84 | 24.89 | 13.18 | 29.78 |
| (7) Using a model | 12.40 | 21.28 | 5.26 | 39.44 |
| (8) Constructing an explanation | 6.00 | 25.27 | 7.33 | 33.33 |
| Evaluating | | | | |
| (9) Using evidence to make arguments | 2.11 | 37.50 | 1.41 | 21.05 |
| (10) Evaluating information | 9.04 | 17.52 | 10.07 | 16.91 |
| Other | 12.53 | 14.21 | 23.76 | 15.26 |
| Overall | 12.53 | 14.21 | 23.76 | 15.26 |

Note: $N = 993$ observations from 142 students in 12 classrooms in southern Michigan and $N = 1,351$ observations from 133 students in nine classrooms in southern Finland.

*The original total percent of the answers were 156%. The scale was adjusted to 100%.
mainly belonged to three categories: worksheet, whiteboard, and teacher presentation. The contents of students’ pictures taken during scientific practices are listed in Table 4. Table 4 also contains short summaries of how teachers were guided in the workshop to better evaluate the content of the pictures.

The bounded nature of scientific practices was evident in the pictures. However, the presence of one to three targets was also common among students’ pictures practices. Figures 1–3 show the picture contents segregated according to the scientific practices reported. Figure 1 contains pictures from students in southern Michigan and Figures 2 and 3 from southern Finland.

7 | DISCUSSION

The findings of the present research offer new insight into the activities that could be used in science classrooms to better situationally engage students in studying science subjects. The research supports previous findings that students can benefit from the use of the scientific practices in science lessons. For example, by including scientific practices in science learning, students can become more powerfully involved as active investigators, who solve problems based on their experiences (Krajcik, 2015b; Miller et al., 2018; Mody, 2015). Further, students may develop more interest in science learning when performing scientific practices because they are exposed to the multiple ways in which scientists explore and understand the world (Shernoff et al., 2003). The novelty of this study is also supported by Potvin’s and Hasni’s systematic review (2014), which asserted that only a small number of studies had examined science classroom activities and students’ reactions toward them.

Another aspect that makes this study novel is the use of ESM, which allows researchers to receive topical information from students in science classrooms. The use of ESM data and measurement of situational engagement in learning situations have supported our hypothesis that scientific practices can be used to engage students in science learning. Even though the research topic is understudied, some studies have discussed the positive effects
| Scientific practices          | Teacher workshop       | Worksheet | Whiteboard | Teacher presentation | Laboratory work | Book | Computer | Overall picture | Other |
|------------------------------|------------------------|-----------|------------|----------------------|-----------------|------|----------|-----------------|-------|
| Investigating                |                        |           |            |                      |                 |      |          |                 |       |
| Asking questions             | Students plan and conduct own investigations in laboratory or more formal settings. Main idea was to let students to observe why something happens and deepen understanding. | 60.00     | 0          | 14.00               | 8.00            | 0    | 0        | 4.00            | 14.00 |
| Southern Michigan (N = 51)   |                        |           |            |                      |                 |      |          |                 |       |
| Southern Finland (N = 51)    |                        | 19.61     | 19.61      | 19.61               | 11.76           | 9.80 | 7.84     | 0               | 11.76 |
| Planning an investigation    |                        |           |            |                      |                 |      |          |                 |       |
| Southern Michigan (N = 87)   |                        | 65.52     | 1.15       | 4.60                | 16.10           | 0    | 9.52     | 2.30            | 14.29 |
| Southern Finland (N = 274)   |                        | 35.38     | 23.08      | 10.77               | 12.31           | 3.08 | 6.15     | 1.54            | 7.69  |
| Conducting an investigation  |                        |           |            |                      |                 |      |          |                 |       |
| Southern Michigan (N = 61)   |                        | 39.68     | 0          | 1.59                | 30.16           | 0    | 9.52     | 4.76            | 14.29 |
| Southern Finland (N = 66)    |                        | 35.38     | 23.08      | 10.77               | 12.31           | 3.08 | 6.15     | 1.54            | 7.69  |
| Analyzing data               |                        |           |            |                      |                 |      |          |                 |       |
| Southern Michigan (N = 23)   |                        | 65.22     | 0          | 13.04               | 4.35            | 0    | 4.35     | 0               | 13.04 |
| Southern Finland (N = 88)    |                        | 18.18     | 9.10       | 28.41               | 22.73           | 4.55 | 9.10     | 1.14            | 6.81  |
| Solving math problems        |                        |           |            |                      |                 |      |          |                 |       |
| Southern Michigan (N = 73)   |                        | 45.21     | 0          | 1.37                | 39.73           | 0    | 4.11     | 1.37            | 8.22  |
| Southern Finland (N = 182)   |                        | 13.74     | 16.48      | 8.24                | 40.11           | 3.30 | 12.64    | 1.65            | 3.85  |
| Developing explanations and solutions | Students develop and use conceptual models. The aim was to understand a phenomenon. | 60.00     | 0          | 2.67                | 13.33           | 0    | 10.67    | 2.67            | 10.67 |
| Developing models            |                        |           |            |                      |                 |      |          |                 |       |
| Southern Michigan (N = 75)   |                        | 60.00     | 0          | 2.67                | 13.33           | 0    | 10.67    | 2.67            | 10.67 |
| Southern Finland (N = 141)   |                        | 18.49     | 19.18      | 32.88               | 6.16            | 9.59 | 4.79     | 4.79            | 4.11  |
| Using a model                |                        |           |            |                      |                 |      |          |                 |       |
| Southern Michigan (N = 16)   |                        | 75.00     | 0          | 0                   | 12.50           | 0    | 0        | 6.25            | 6.25  |
| Southern Finland (N = 48)    |                        | 29.17     | 6.25       | 22.92               | 6.25            | 25.00| 2.08     | 2.08            | 6.25  |
| Constructing explanations    |                        |           |            |                      |                 |      |          |                 |       |
| Southern Michigan (N = 15)   |                        | 80.00     | 0          | 6.67                | 6.67            | 0    | 0        | 0               | 6.67  |
| Southern Finland (N = 65)    |                        | 21.54     | 26.15      | 16.92               | 10.77           | 10.77| 1.54     | 4.62            | 7.69  |
| Scientific practices      | Teacher workshop | Worksheet | Whiteboard | Teacher presentation | Laboratory work | Book | Computer | Overall picture | Other |
|--------------------------|------------------|-----------|------------|---------------------|-----------------|------|----------|-----------------|-------|
| Evaluating              |                  |           |            |                     |                 |      |          |                 |       |
| Using evidence          | Teachers were encouraged to use, e.g., scientific literature, videos, texts. | 0         | 0          | 0                   | 100             | 0    | 0        | 0               | 0     |
| Southern Michigan (N = 1) |                  |           |            |                     |                 |      |          |                 |       |
| Southern Finland (N = 11) |                  | 36.36     | 27.27      | 0                   | 18.18           | 0    | 0        | 0               | 18.18 |
| Evaluating information  |                  |           |            |                     |                 |      |          |                 |       |
| Southern Michigan (N = 27) |                  | 33.33     | 0          | 18.52               | 18.52           | 0    | 0        | 3.70            | 25.93 |
| Southern Finland (N = 120) |                  | 17.50     | 14.17      | 30.83               | 5.00            | 13.33| 4.17     | 5.00            | 10.00 |

Note: The numbers related to the content of the students’ pictures are reported in percentage.
of different activities, such as scientific practices, on increasing student situational engagement in real science classrooms (cf. Singh et al., 2002). Our results, therefore, offer teachers and teacher educators new strategies for increasing the number of science-oriented students.

Our results suggest that students are more situationally engaged when they are doing certain scientific practices. According to the descriptive statistics, in southern Michigan, students reported being engaged 16% of the time, on average. Students' situational engagement was below average when they were conducting investigations. However, these students reported above-average situational engagement when they were using evidence to make arguments. Other practices that elicited above average level of situational engagement were solving math problems, developing models, and constructing an explanation. In southern Finland, students' situational engagement was below than

FIGURE 1  Content that was captured the most in pictures when different scientific practices were reported in Southern Michigan. Only one picture was associated with using evidence to make arguments so it was left out of the figure.
FIGURE 2  Content that was pictured the most when different scientific practices were reported in southern Finland—Part I
FIGURE 3  Content that was pictured the most when different scientific practices were reported in southern Finland—Part II
average level (22%) when they were evaluating information or planning and conducting investigations. In contrast, their situational engagement level was higher when they were using a model or constructing an explanation.

These results become more interesting when we consider the multilevel nature of the ESM data. In both countries, scientific practices related to developing explanations and solutions increased student situational engagement. In other words, despite being in different countries, classrooms, and exposed to different content, the students, overall, seemed to report more situational engagement when they were developing models and constructing explanations than when doing other practices. Additionally, students in southern Finland reported being situationally engaged more often when using a model. These results differ from previous findings, where student engagement levels were reported to be higher when they were asking questions, using evidence to make arguments (Mestre, 2005) and doing investigations (Duschl & Bybee, 2014). The deviation from past results could be attributed to how these activities were observed and measured in science classrooms. In this study, we adopted the definition for scientific practices used, for example, in the NGSS (NRC, 2012) and in the Finnish science curriculum (FMEC, 2013). However, similar scientific practices can be defined in different ways (e.g., Duschl & Bybee, 2014; Mestre, 2005).

As mentioned above, developing and using models are important scientific practices, because they help students understand the world (Osborne, 2014) by providing an explanation for why something behaves as it does and allow students to generate new predictions (Schwarz et al., 2009). Models can also be seen as a way to simplify and visualize phenomena that are familiar to students in their everyday life. In accordance with the definition of situational engagement, models are a way to spark students’ interest. In a traditional science classroom, students are introduced to scientific models instead of being asked to construct their own (NRC, 2012). In this study, we encouraged the teachers to use conceptual models in their science lessons. During the workshop, teachers were advised to encourage their students to construct models that are consistent with evidence or theories related to the science lesson. The use of models was promoted to explain or predict phenomena. The situational engagement data collected in this study show that constructing and refining models can increase the experienced levels of challenge and lead to situational engagement. With proper guidance and trust, students can create models by themselves, within the framework of their knowledge. By letting students collaboratively use and develop models, a teacher can support students’ skill, need for challenge, and interest—or situational engagement—in the ongoing task.

Taking into account the fact that the results are derived from a few science classrooms in southern Finland and southern Michigan, we present some recommendations for science education. The results indicate that the use of scientific practices, especially related to modeling, in physics and chemistry education can increase student situational engagement. Further, given the benefits for student situational engagement, scientific practices—especially those related to developing explanations and solutions—should be included in science teaching. By giving students opportunities to actively participate in science lessons, say, by allowing them to develop their own or collaborative models, it is possible to increase their levels of interest, skills, and challenge. However, this finding must be confirmed through additional research. While the number of scientific practices used in science lessons is increasing in both southern Michigan and southern Finland, this study provides information about which scientific practices could be emphasized more. When we are able to confirm these results with a larger sample size in the future, we will have more reliable information about which scientific practices should be emphasized, and whether teachers need additional help in planning their science lessons.

8 | LIMITATIONS

This study had several limitations. First, the student and classroom samples were purposive, rather than generalizable to the populations of either country. Moreover, conclusions should not be drawn about the differences between the two countries. However, the similarities between the countries are noteworthy, including the finding that scientific practices related to models were associated with student situational engagement in both countries.
Another limitation is that the scientific practices used in science lessons were reported only by the students. Before data collection, researchers in both countries explained to the students and teachers the different scientific practice options on the ESM questionnaire and their meanings. Students were directed to use the category of “other” when no scientific practice seemed appropriate. Further, teachers were also given the option of saying out loud which scientific practice was being used in the classroom. However, we cannot be certain that students understood scientific practices in the same way as other students, teachers, or researchers. Moreover, we do not have information about how teachers enacted the practices except that they all participated in the same workshop where they received information about scientific practices. In this study, we restricted ourselves to examining scientific practices in general. We did not observe, for example, what kind of models the students were working with. This is definitely something that could be pursued in future research.

Scientific practices as such also make the situation more complicated, because usually, they are linked together when used in science classrooms. Further, in science classrooms, teachers also use different classroom activities when exposing students to different scientific practices. Because multiple scientific practices were present in each lesson, students working at different paces may have answered the ESM questionnaire at different phases of the unit. Thus, the teachers could have stated a practice that did not accurately reflect what each student was doing at the time. In addition, we cannot know whether all students had the same understanding of the different options. However, in the workshops conducted for teachers before the data collection process, we went through the different scientific practices, and the units that teachers taught were planned at these meetings.

It would be helpful if future research can support these findings with video recordings or teacher lesson plans. This would result in more reliable examination of what actually happened in the science classrooms when the students used different scientific practices. In the logistic regression models, we compared each scientific practice to all the other practices and “other” activities. In the future, however, similar research should be undertaken by comparing scientific practices in lessons to science classroom activities that are unrelated to scientific practices.

Because data were collected using smartphones three times during each science lesson, the collection process itself may have disrupted students’ learning. However, we visited the schools during and after the data collection, the teachers and students reported that their learning was not disrupted or disrupted only at the beginning of data collection. The ESM questionnaire remained consistent throughout the data collection, and students were often able to complete it in <2 min. The teachers were also authorized to tell their students to either keep the smartphones on silent mode or wait before answering, if necessary. Some technical problems occurred with the data collection but only with a minimal number of students.

8.1 | Future work

Science instruction has experienced a shift toward increased use of scientific practices in science classroom. Nevertheless, there is a lack of research evidence on how scientific practices are related to students’ experiences such as situational engagement. The present study gives promising results that scientific practices, in fact, are related to students’ situational engagement. Given the dearth of literature and our results, more research, involving larger sample sizes, should be conducted on how scientific practices are associated with student situational engagement. The topic warrants more academic attention because there are several benefits to engaging students in learning science. For example, engaged students have better learning outcomes, and their learning process is more efficient (Finn & Zimmer, 2012, p. 98). Furthermore, engaged students are likely to seek similar situationally engaging experiences while learning science in the future (Marks, 2000; Nakamura & Csikszentmihalyi, 2014, p. 92).

The present results lend support to the suggestion that scientific practices should be used in science teaching to promote situational engagement among students and to help them to learn. The use of such practices in science classrooms could be observed in different countries, after taking account of cultural differences. Such research may...
explain why there are differences in how students situationally engage in scientific practices in different countries. Another potential avenue is to examine differences in student situational engagement by grade level and gender.

It would also be interesting to explore how scientific practices are associated with students' skills, interest, and need for challenge. Future research could focus, for example, only on situational interest related to scientific practices. Studies can also investigate causal relationships, such as, how students' situational interest develops over time. Another option would be to examine why different scientific practices increase or decrease students' levels of situational engagement. Future studies could, for example, focus on one specific scientific practice from a situational engagement viewpoint. Focusing only on one or two scientific practices would allow a deeper examination of how and why these practices situationally engage students.

Qualitative data such as interviews or video recordings could be used to collect information about what makes different scientific practices situationally engaging. This would allow for room for examining the content of the science lessons. Such a study may also provide useful insights into what makes a unit interesting for students, how the difficulty of the units is associated with student situational engagement, or how students' expertise is related to their situational engagement with a unit. Scholars can also explore students' other situational feelings. For example, if students are not situationally engaged in doing scientific practices, are they bored?

If future results support the findings of the current study, teacher education—at least in Finland—should include instruction on how these practices can be used effectively in the science classroom. Furthermore, because the shift toward the use of scientific practices in science teaching is recent, we also highlight the importance of workshops for teachers.

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