

RAUNO NEITO

Learner characteristics and instructional activities associated with students' situational interest in coherent physics education



RAUNO NEITO

Learner characteristics and instructional
activities associated with students'
situational interest in coherent
physics education



UNIVERSITY OF TARTU

Press

1632

Institute of Physics, Faculty of Science and Technology, University of Tartu,
Estonia.

This dissertation was accepted for the commencement of the degree of Doctor of Philosophy (PhD) in Education on March 3, 2026 by the joint Doctoral Committee of the Institute of Education and Institute of Ecology and Earth Sciences, responsible for awarding doctoral degrees in education at the University of Tartu.

Supervisors: Kaido Reivelt, PhD
Institute of Physics, University of Tartu, Estonia

Professor Jari Lavonen, PhD
Department of Education, University of Helsinki, Finland

Elisa Vilhunen, PhD
Department of Education, University of Helsinki, Finland

Reviewers: Associate Professor Anna-Liisa Jõgi, PhD
School of Educational Sciences, Tallinn University, Estonia

Associate Professor Karin Täht, PhD
Institute of Mathematics and Statistics,
University of Tartu, Estonia

Opponent: Senior Lecturer Antti Lehtinen, PhD
Faculty of Mathematics and Science,
University of Jyväskylä, Finland

The public defence will take place on March 27, 2026 at 10:00 at the White Hall of the University of Tartu Museum, Lossi 25, Tartu.

The publication of this dissertation was financed by the Institute of Physics, University of Tartu and the European Union Horizon 2020 project SciCar (Addressing Attractiveness of Science Career Awareness) No. 952470.

ISSN 1406-9709 (print)
ISBN 978-9908-57-156-0 (print)
ISSN 2806-2426 (pdf)
ISBN 978-9908-57-155-3 (pdf)



Copyright © 2026 by Rauno Neito

University of Tartu Press
<http://www.tyk.ee/>



CONTENTS

List of original publications	8
List of abbreviations	9
1. Introduction	10
1.1. Aim and research questions	11
2. Theoretical background	13
2.1. Interest	13
2.2. Relevance	16
2.3. Effort	17
2.4. Challenge and skills	18
2.5. Instructional activities and coherent science instruction	20
3. Methodology	24
3.1. Participants	24
3.2. Measures	25
3.3. Procedure	27
3.4. Data analysis	28
3.5. Validity and reliability	30
3.6. Description of the teaching modules	31
3.7. Ethical considerations	32
4. Results	33
4.1. Background variables (RQ 1)	33
4.2. Situational variables (RQ 2)	35
4.3. Development of situational interest (RQ 3 and 4)	40
5. Discussion	41
5.1. Associations between background variables and situational interest	41
5.2. The complex nature of instructional activities	42
5.3. The effect of situation-specific learner characteristics	44
5.4. Previous situational interest and its development	45
6. Conclusion	46
6.1. Implications	47
6.2. Limitations	47
Bibliography	50
Appendix A. A detailed description of the learning module designed for Study 1	63

Acknowledgements	65
Sisukokkuvõte	67
Publications	73
Curriculum Vitae	138
Elulookirjeldus	140

LIST OF TABLES

1. Instructional activities used in the three studies	20
2. Instructional activities linked to science and engineering practices	22
3. Participants of the three studies	24
4. Items from the instruments used in Study 1	26
5. Items from the instruments used in Study 2	27
6. Items used in Study 3	27
7. Analysis methods and variables used in the studies	29
8. Multilevel model of situational interest in Study 1	33
9. Occasion-specific regression models for situational interest in Study 1	34
10. Multilevel models of situational interest in Study 2	35
11. Occasion-specific regression models for situational interest in Study 2	36
12. Multilevel model of situational interest in Study 3	37
13. Occasion-specific regression models for situational interest in Study 3	38
14. Development of the mean level of situational interest in all studies	39

LIST OF ORIGINAL PUBLICATIONS

- I Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2023). Predicting situational interest by individual interest and instructional activities in physics lessons: An experience sampling approach. *Journal of Baltic Science Education*, 22(6), 1063–1073. <https://doi.org/10.33225/jbse/23.22.1063>
- II Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2025). Students' situational interest and perceived relevance during designed coherent physics learning modules. *International Journal of Science Education*, Advance online publication. <https://doi.org/10.1080/09500693.2025.2488400>
- III Neito, R., Vilhunen, E., Lavonen, J., & Vesterinen, V.-M. (2025). The effect of instructional activities and collaborative tasks on interest and effort in a climate change education module. *Research in Science & Technological Education*, Advance online publication. <https://doi.org/10.1080/02635143.2025.2603291>

Author's contribution to the publications

- I: designing the questionnaires, collecting and analysing the data, writing the article as the main author.
- II: designing the questionnaires and the learning modules, collecting and analysing the data, writing the article as the main author.
- III: analysing the data, writing the article as the main author.

LIST OF ABBREVIATIONS

Acronyms

CSI – coherent science instruction

ESM – experience sampling method

SEP – science and engineering practices

1. INTRODUCTION

Students' interest in science has been steadily declining, with many learners reporting that science feels disconnected from their lives, overly abstract, or insufficiently engaging. A systematic literature review conducted by Potvin and Hasni (2014a) demonstrated that declining student interest in science is a global trend. Research consistently shows that this downturn typically begins at the start of lower secondary school – the very period when foundational scientific concepts are introduced (Hidi et al., 2004; Krapp & Prenzel, 2011; Potvin & Hasni, 2014b). Recent work by Steidtmann et al. (2023) further illustrates the robustness of this pattern: in their classlevel analysis of students progressing through lower secondary grades, interest in physics declined not only among students who were not studying physics during that period but also among those who were. This suggests that the decline is not merely a consequence of course exposure but reflects broader motivational dynamics affecting young learners.

But why does students' interest matter? First, interest is connected to other important aspects of learning, such as knowledge acquisition (Rotgans & Schmidt, 2011b) and conceptual change (H. Kang et al., 2010). Interest can positively influence the amount of effort students are willing to invest (Trautwein et al., 2015), which in turn affects students' academic achievement (Dunlosky et al., 2020). Therefore, interest is considered essential for learning (Harackiewicz et al., 2016; OECD, 2023; Renninger & Hidi, 2020). On a societal level, interest is an important factor when considering future career choices (Blotnicky et al., 2018; J. Kang et al., 2019). A number of problems, such as climate change or viral pandemics, require a deep understanding of science (J. Kang & Tolppanen, 2024; Sadler et al., 2025). This means at least some people need to be interested enough in science to choose a science career (Kearney, 2016). Arguably, it is even more important for policymakers and the citizens that elect them to have a basic grasp of science so that necessary steps are taken on a large scale to overcome such problems (Cologna et al., 2025). To achieve this, every citizen should have at least a little interest in science.

A number of factors have been proposed as an explanation for the declining interest. Science is perceived as more difficult and abstract than other school subjects, which could be related to decreased interest (Krapp & Prenzel, 2011; Logan & Skamp, 2008). Potvin and Hasni (2014b) suggest that a change in the variety of teaching practices, namely an increase in worksheet and exercise book assignments at the expense of discussions and projects, could be another cause. Teppo et al. (2021) found that varying teaching approaches is important for maintaining students' interest. Students perceive the science learned in school as not relevant or useful (Christidou, 2011; Lyons, 2006), while out-of-school science might be perceived as important (Potvin & Hasni, 2014b). Finally, the central factor connecting the aforementioned factors is the teacher. Steidtmann et al. (2023) found a positive relationship between students' interest in physics and their perception

of their teachers' teaching quality. Accordingly, teacher incompetence can have a negative effect on students' interest (Broeckelman-Post et al., 2016). Of course, the teachers' own motivation and enthusiasm towards their subject also affects their students' interest (M. Keller et al., 2017; D. Palmer, 2007).

Let us assume that a science teacher is enthusiastic and competent in teaching their subject. What can then be done by the teacher to address the other possible reasons for the decline in interest? How can the teacher plan their lessons so that the challenge of the learning tasks is adequate for the students' skill level? How much variety in teaching practices is enough, and which practices are more likely to trigger interest? What aspects do students consider irrelevant in science lessons? To answer these questions, a better understanding of what is happening to interest in lessons is required, namely, how learner characteristics and teaching practices affect students' interest in science (Lavonen et al., 2021; Renninger et al., 2019; Swarat et al., 2012) and how this interest develops during science lessons (Hecht et al., 2021; Rotgans & Schmidt, 2011b, 2017b). Through this improved understanding, teachers can better focus their efforts in planning interesting lessons for students.

1.1. Aim and research questions

The common aim of the three studies comprising my thesis was to find out which learner characteristics and teaching practices are associated with students' situational interest during physics teaching modules and to explain why some of these variables are more significant than others in various situations. The design allowed me to identify statistical associations rather than make strong causal predictions about situational interest. The variables included in the models were selected based on prior research and theoretical relevance, and the relative significance of each predictor was evaluated empirically through its estimated effects and confidence intervals.

I divided learner characteristics into background and situational variables. The background variables included students' gender, grade, individual interest, and perceived relevance of physics in general. These characteristics either did not change during the modules or changed little due to their relatively enduring nature (Hidi & Renninger, 2006; Priniski et al., 2018). The situational variables included students' perceptions of the relevance of the current activity, how much effort they allocated to it, how challenging it was for them, and how skilful they felt while engaged in the activity. The teaching practices I examined were the various instructional activities students engaged in, in relation to which we measured the situational variables. I did not study other aspects of teaching practices or teacher characteristics. The research questions of my thesis were as follows:

1. How are gender, grade, individual interest, and the perceived relevance of physics in general associated with students' situational interest?

2. How are instructional activities, their perceived relevance, and the effort, skills and challenges related to them associated with students' situational interest?
3. To what extent is subsequent situational interest associated with previous situational interest?
4. How does situational interest develop during physics teaching modules?

2. THEORETICAL BACKGROUND

2.1. Interest

The person–object theory of interest developed by Krapp conceptualises interest as a motivational construct understood as a connection between the person and an object (Krapp, 1993, 2002). This object can take forms such as written text, audiovisual material, people, animals, and activities (Renninger & Hidi, 2015a). According to the theory, interest has three components: affect, knowledge, and value (Hidi & Renninger, 2006; Schiefele, 1991). Although I did not examine the components separately, they provide the theoretical basis for the discussion. Interest is commonly divided into situational and individual interest (Hidi, 1990; Renninger & Hidi, 2015a). Situational interest is tied to a specific situation and can emerge and fade with the situation (Hidi et al., 2004). Situational interest may involve deep, effortless concentration accompanied by feelings of enjoyment or excitement (Krapp et al., 1992). It can be distinguished from individual interest by its stronger reliance on external factors (Krapp & Prenzel, 2011), which, for students, can be teachers or peers, as well as the content learned and the activities engaged in (Renninger et al., 2019). When situational interest is maintained beyond the end of the situation, it can develop into individual interest.

Individual interest is less affected by the environment than situational interest, but the person–environment interaction is still vital (Hidi, 1990). Individual interest is relatively stable, and objects of such interest (for example, a particular film or a science subject) are particularly significant to the interested person (Krapp, 1993). People with individual interest are likely to re-engage with this object of interest independently and can persevere even when the related activity is difficult or frustrating (Renninger & Hidi, 2020). The situation is confounded on whether individual interest directly supports learning or not. Previous studies (Ainley et al., 2002; Hidi et al., 2004; Schiefele, 1991) have supported this claim, while more recent studies (Romine et al., 2020; Rotgans & Schmidt, 2018) have suggested that situational interest acts as a mediator and is therefore more important in a classroom setting than individual interest.

The model of four-phase interest development established by Hidi and Renninger (2006) postulates that there are four phases of interest – two situational and two individual – and that a person’s interest passes through all these phases as it develops. The first stage is triggered situational interest, usually caused by incongruous, surprising, or intense environmental features (Renninger & Hidi, 2002). Triggered situational interest can fade quickly or, with support, evolve into maintained situational interest. Maintained situational interest is characterised by positive feelings towards and a wish to re-engage with the object of interest (Renninger & Hidi, 2020). With repeated re-engagement, it can develop into emerging individual interest, which is more self-generated than externally

supported and can make effortful activities seem effortless (Hidi et al., 2004). Finally, well-developed individual interest is characterised by resourcefulness and perseverance in the face of difficult tasks related to the object of interest. Hidi and Renninger (2006) have stressed that interest can also develop backwards, meaning that emerging individual interest can revert to maintained situational interest, for example. However, this model has been challenged by Rotgans and Schmidt (2018), who argued that there is always some pre-existing (individual) interest that subsequent interest will build upon. My studies examined situational interest. Although it comprises two phases, these were not distinguished during data collection; however, the framework proposed by Hidi and Renninger (2006) remains relevant for interpreting the results.

In parallel to the phases of interest, Häussler (1987) proposed that interest consists of three dimensions: interest in a topic or content, interest in the context in which that topic is presented, and interest in the activity associated with that topic. In his study about physics lessons, he found that most of the variance in students' responses to the interest item in the questionnaire was explained by the context dimension. In contrast, the other two dimensions had a smaller effect. In a subsequent study, Häussler et al. (1998) reconciled the dimensions framework with the situational and individual interest model by stating that the dimensions describe situational interest. Based on their studies, they stressed the importance of letting students engage in interesting activities and using contexts that are relevant to them (Häussler & Hoffmann, 2000). This dimensional conceptualisation of interest has more recently been used by Hammann et al. (2020), who studied the interactions between the three dimensions. They found that in content-context combinations, context was the driver of interest, but in content-activity combinations, content was the driver. The dimensionality framework is also useful for describing the effect of teaching practices within the scope of my thesis.

As situational interest is more susceptible to environmental factors than individual interest, it is reasonable to focus on it in school settings. Researchers and teachers seek to understand what triggers situational interest, for whom, and in which situations (Guo & Fryer, 2025; Renninger et al., 2019; Shubina et al., 2023). Of the three dimensions proposed by Häussler (1987), the importance of context has been emphasised by more recent studies (Broman et al., 2022; Hammann et al., 2020; Teppo et al., 2017). Habig et al. (2018) found that the effect of contexts also depends on the situation, meaning that a context that works well with one topic might be a poor choice for another topic. In addition, not all contexts that increase interest are more beneficial for learning (Golke & Wittwer, 2024). Content tends to be more engaging when it is concrete (Tapola et al., 2013) or when its social relevance is made explicit (Häussler et al., 1998). Certain topics, such as astronomy, warfare, and medicine, can also trigger student interest, though gender differences have been observed (Häussler & Hoffmann, 2000). Girls seem to be more interested in biology and medicine-related topics, whereas boys prefer physics and engineering-related topics (Christidou, 2006; J. Kang et al., 2019).

Swarat et al. (2012) argued that activities are stronger predictors of situational interest than content, although this has been disputed by Hammann et al. (2020). Nevertheless, studies have found that some activities have a positive effect on interest, while others may not have an effect or may even have a negative effect (Guo & Fryer, 2025). For example, hands-on and experimental activities have often been linked to higher interest (D. Cheung, 2018; Holstermann et al., 2010; D. Palmer et al., 2017). Renninger et al. (2019) found that instructional conversation between teachers and students can trigger interest, but only if the content is not too difficult and the scaffolding of the students is of high quality. The effect of group work on situational interest also seems to be complex and depends on the context and freedom of choice (Shubina et al., 2023; Tan et al., 2023; Vilhunen et al., 2025). Note-taking has been reported to decrease interest (Logan & Skamp, 2013). As with contexts, the effect of an activity depends on the situation. For example, Lavonen et al. (2021) conducted a study in Finnish and Chilean secondary school physics lessons to examine how activities predict situational interest. They found that writing and working in small groups were negative predictors of interest for Finnish students, whereas working in small groups was not a predictor and writing was a positive predictor for Chilean students.

The most important environmental factor for students in school is likely the teacher, who determines the combination of content, context, and activities. Teachers who are interested in their work positively affect their students (M. Keller et al., 2017), while indolence and incompetence in teachers are negative predictors of students' interest (Broeckelman-Post et al., 2016). Unclear instructions, repetition, and rushing by the teacher can also have a negative effect on students' interest (Logan & Skamp, 2013; Rotgans & Schmidt, 2011a). Hidi et al. (2004) emphasised that the methods teachers use to support their students' interest depend on whether the students are in the stage of triggered or maintained situational interest. This is also supported by Linnenbrink-Garcia et al. (2013) and Mitchell (1993), who found that activities such as group work or solving puzzles, as well as teacher approachability, have a positive effect on students' triggered situational interest, but not on maintained situational interest. However, positive predictors of the latter stage included involvement and perceived relevance, which had no significant effect on triggered situational interest.

In addition to the learner characteristics I focused on, there are others that can affect interest. One such characteristic is previous domain knowledge about the object of potential interest. Alexander et al. (1995) found that high previous domain knowledge correlated with high situational interest, whereas Rotgans and Schmidt (2014) found the opposite to be true, arguing that it is the knowledge gap that drives interest. Another characteristic with a somewhat disputed effect is individual interest. Tsai et al. (2008) observed that individual interest predicted situational interest, but Knogler et al. (2015) found that the two were unrelated. Harackiewicz et al. (2008) hypothesised that students with high individual

interest might skip the triggered and possibly even the maintained situational interest phases, transitioning straight to emerging individual interest. Rotgans and Schmidt (2018) proposed that individual interest can predict situational interest at the start of a lesson. However, the effect disappeared when students were presented with a situationally arousing problem. In contrast, they found that previous situational interest, rather than individual interest, predicted subsequent levels.

2.2. Relevance

Relevance is most closely associated with the value component of interest (Krapp, 1993), but distinguishing these from each other is difficult due to their considerable overlap (Stuckey et al., 2013). Contrary to interest theory, there is no generally agreed-upon definition for what relevance is (Priniski et al., 2018). A study by Stuckey et al. (2013) and another by Priniski et al. (2018) try to address the issue, but the authors of these studies have differing views, with the latter not referring to the former. Both studies are important in the context of this thesis, since the work by Priniski et al. is more clearly connected to interest theory, while Stuckey et al. position themselves to describe the meaning of relevance in science education. Therefore, I present a summary of both views.

The review conducted by Stuckey et al. (2013) revealed that “the term relevance can have different meanings, both intrinsic (felt by the student) and extrinsic (provided by the curriculum, parents, teachers and examinations)” (p. 12) and that it consists of three dimensions: individual, societal, and vocational (Eilks et al., 2014; Van Aalsvoort, 2004). The individual dimension is tied to people’s everyday lives and skills; the societal dimension concerns the link between the object of relevance (e.g. content or context) and society, and how that object contributes to societal development; and the vocational dimension is related to future career prospects. Stuckey et al. (2013) further expanded these dimensions by adding a time spectrum (present vs future) and a type spectrum (intrinsic vs extrinsic), noting that the dimensions can overlap. In addition, the importance of each dimension may vary across school stages (Newton, 1988).

While Stuckey and colleagues emphasised the multidimensionality of relevance, including its intrinsic and extrinsic nature and its consequences for a person’s life, Priniski et al. (2018) offered a much simpler definition: a personally meaningful connection to the individual (p. 12). They stated that relevance is a motivational construct conceptualised on a continuum of personal meaningfulness that can be divided into association, usefulness, and identification, which are not mutually exclusive. These types were linked to motivational theories, including interest theory (Hidi & Renninger, 2006), which highlights relevance as a key factor in the transition from situational to individual interest. Priniski and colleagues hypothesised that usefulness and identification are especially important for the development of individual interest. They also noted that while relevance can trigger interest, it is not a necessary component of situational interest. Stuckey et al.

(2013) also argued that interest and relevance are similar, but distinct constructs: a school subject like mathematics can be highly relevant for various reasons, but might not be interesting. While I agree with the viewpoint of Priniski et al. (2018), we used the definition presented by Stuckey et al. (2013) in Study 2 of my thesis; therefore, it will be the one followed here. However, I do not distinguish between intrinsic/extrinsic components or present/future orientations.

Intrinsic factors, such as interest in a subject, and extrinsic ones, such as its usefulness for future careers, are dominant in shaping students' subject choices in school (T.-A. Palmer et al., 2017). Unfortunately, science curricula have been criticised as collections of disconnected ideas that lack relevance for students (Christidou, 2011; Lyons, 2006; Osborne & Dillon, 2008). At the same time, few secondary students express an interest in science-related careers (Archer et al., 2020; Jenkins & Nelson, 2005). To address this perceived lack of relevance, teachers need to find ways to increase the perceived value of what is taught (Broman et al., 2022). According to J. M. Keller (1987), relevance does not have to originate from the content itself but can emerge from how it is taught. He proposed strategies for enhancing perceived relevance, including using analogies from students' past experiences and explicitly showing how topics build on existing skills or relate to future activities. These strategies were tested by Means et al. (1997), who found that they led to increased perceived relevance.

Since relevance encompasses multiple dimensions according to Stuckey et al. (2013), both the content and the context in which the content is taught can be perceived as relevant for different reasons. For example, Massolt and Borowski (2020) studied the perceived relevance of physics problems used with pre-service teachers. The participants found problems focusing on conceptual issues and requiring less mathematical skill to be more relevant, as secondary school physics rarely demands advanced mathematics. In contrast, the upper secondary students in the study by Broman et al. (2022) reported that problems embedded in personal contexts were most relevant, while those framed in vocational contexts were least relevant. The study also found that certain familiar "trigger words" (e.g. trans fats) increased the perceived relevance of materials, while unfamiliar terms decreased it. A similar effect has been reported regarding the titles of learning materials (Kotkas et al., 2016). As Priniski et al. argued, relevance depends on the individual, which is why variation in content, context, and activity is important to ensure that as many students as possible find a personally meaningful connection.

2.3. Effort

Like interest and relevance, effort carries various meanings, and its use in research has been inconsistent (Shenhav et al., 2017). To clarify the situation, Grund et al. (2024) reviewed the relevant literature and proposed that effort can be understood through three distinct conceptions: effort-by-complexity, effort-by-need frustration, and effort-by-allocation. The first refers to the difficulty of a task: complex

tasks require more effort to complete (Hoch et al., 2023). The second describes the mental strain a task can have, regardless of whether it is completed or not (Feldon et al., 2019). This form of effort is inherently negative and may hinder learning (Ryan & Deci, 2020). The third conception is linked to motivation and persistence, which originate from the person rather than the task (Muenks et al., 2016). If perceived effort were to be measured, the corresponding questions for each conception would be: how much effort do you have to invest?, how effortful or strenuous is it?, and how much effort are you willing to invest? (Grund et al., 2024). I used the latter conception: effort-by-allocation.

While effort-by-allocation is not directly linked to interest theory, it is connected to the expectancy–value theory (Eccles & Wigfield, 2020; Wigfield & Eccles, 2000). According to this theory, value is divided into attainment, intrinsic value, and utility value. Intrinsic value is seen as a counterpart to interest in the person–object theory (Krapp, 1999; Urhahne & Wijnia, 2023). Thus, interest and effort are related through motivational theories. Kehle and Urhahne (2025) stated that the two concepts are interrelated: while interest is more important at the beginning of tasks to facilitate learning, effort takes the lead as learning progresses. They found that invested effort mediated the effect of situational interest on test achievement. Similar links have previously been found by H. Kang et al. (2010) and Trautwein et al. (2015). Dietrich et al. (2017), whose research was grounded in the expectancy–value theory, found that motivation affects effort allocation, which in turn affects motivation in subsequent situations.

Similar to the effort-by-allocation conception, Paas (1992) defined *mental effort* as “the amount of (cognitive) capacity that is allocated to the instructional demands” (p. 429). The wording implies that it is the intention of the student, not the demand of the task at hand. It has even been suggested that measuring students’ invested effort in an activity can be a better estimate of their motivation than self-reports of motivation (S. H. Song & Keller, 2001). However, Kehle and Urhahne (2025) have supported the use of self-reporting, suggesting that using the experience sampling method is a more precise way to measure changes in motivation. Furthermore, they advocated the need to design learning tasks that are more relevant to students to better study the connection between interest and effort. Finally, Paas et al. (2005) stated that the amount of effort students allocate to learning tasks depends on the balance between their skills and the challenge; if a task is not challenging enough or is too challenging, the amount of allocated effort decreases.

2.4. Challenge and skills

Deci (1992) described interest from the self-determination theory point of view as “the affect that relates one’s self to activities that provide the type of novelty, challenge, or aesthetic appeal that one desires at that time” (p. 45). Despite my thesis being grounded in the person–object theory, the notion that interest is connected

to both activities and challenge is relevant. Based on the work by Deci, Chen et al. (2001) defined challenge as “the level of difficulty relative to a person’s ability” (p. 385), although Bricteux et al. (2017) argued that challenge should not be equated with difficulty; if difficulty is an obstacle that needs to be overcome, challenge is an opportunity for growth. Fulmer and Tulis (2013) also define challenge as task difficulty “that is matched to or slightly beyond one’s ability” (p. 11) and distinguish between two types: objective and perceived difficulty, of which the latter is influenced by students’ interest in the task, its relevance, and the amount of effort they are willing to allocate to it. This is the definition I will use in the thesis, focusing on the perceived difficulty.

Chen et al. (2001) found that challenge does not affect situational interest when students are engaged in physical activities, but there could be a significant association during conceptual tasks. Nuutila et al. (2021) observed that the relationship between challenge and situational interest depends on task characteristics and student expectancies and could be non-linear, whereas Fryer and Shum (2025) found that they were negative predictors of each other. Fulmer and Tulis (2013) also found that greater perceived difficulty was associated with lower situational interest. They stressed the importance of studying how interest develops during learning tasks and measuring perceived difficulty multiple times during lessons. Bricteux et al. (2017), focusing on the connection between interest and the skills–challenge balance in the context of flow theory (Csikszentmihalyi, 1990), found that interest moderates the relationship between the skills–challenge balance and flow. Without interest, flow is less likely, even if there is balance.

There are also examples of a positive relationship between interest and challenge, but only if certain criteria are met. Abuhamdeh and Csikszentmihalyi (2011) reported that perceived challenge was a strong predictor of enjoyment (of which interest in the activity was a part) when people were intrinsically motivated and the activity was goal-directed. If either condition was not fulfilled, perceived skills were a stronger predictor of enjoyment. Renninger et al. (2019) mentioned challenge as one of the possible triggers of interest that, alongside perceived relevance, depended on students’ awareness of the situation. They found that it worked as a trigger only if students felt a sense of accomplishment and if the challenge was adequate (i.e. balanced with skills and not too similar to a previous activity). This adequacy of challenge has also been reported by Tan et al. (2023). Adequate challenge can support the development of individual interest (Renninger & Hidi, 2015b).

Students’ skills have been examined as a factor related to interest in different educational contexts. Chen and Darst (2002) measured students’ individual and situational interest in physical education classes and found that students with high or low situational interest could be distinguished based on their motor skills and individual interest. Lee et al. (2023) observed that high reading skills were associated with a high level of situational interest and that situational interest developed differently for students with high and low reading skills. However, very little is

known about how skills predict situational interest in science education lessons. Perhaps the closest association between them in science education is within optimal learning moments, defined by Schneider et al. (2016) as situations in which students have high situational interest and feel challenged, but also perceive their skills to be adequate for the challenge. They defined skills as the “mastery of a set of specific tasks” (p. 402), which is the definition I am adhering to in my thesis. They hypothesised that triggering and maintaining interest in a topic for which a student has little previous knowledge and finite skills is difficult.

Table 1. Instructional activities used in the three studies

Study 1	Study 2	Study 3
Listening	Teacher–student interactions	Following the teacher’s presentation
Experimenting	Experiment-related activities	Working in groups
Answering worksheet questions	Solving problems	Working on an assignment
Watching a video	Calculation-related activities	Working with data
Not engaged in instructional activities	Not engaged in instructional activities	Brainstorming
		Seeking information

2.5. Instructional activities and coherent science instruction

In my thesis, the learner characteristics not mentioned in RQ 1 are all measured in relation to the activities students engage in during the designed teaching modules typically found in science lessons. Some of these activities (e.g. watching a video) are self-explanatory, while others (e.g. working with data) are more nuanced. All of these are referred to as *instructional activities*, understood as instructionally independent lesson segments that differ in purpose and activity format, and whose sequencing, role, and duration are planned and managed by teachers (Burns & Anderson, 1987; Vilhunen et al., 2021). While the term describes what students were doing, it also denotes the unit used to examine how teaching was structured. However, the term does not imply that the teaching modules designed for the three studies were based on a teacher-centred approach. Although there were situations where the teachers lectured, these were brief and typically occurred when a new topic was introduced. The purpose of using this term was to bridge the gap between the students and the theoretical framework of coherent science instruction, which is described in the following paragraph. The activities examined in the three studies are presented in Table 1.

The instructional activities were part of the physics teaching modules designed for all three studies. These modules were guided by the framework of *coherent science instruction* (CSI; Nordine et al., 2021). CSI is based on four characteristics: core ideas and scientific practices, rich phenomena, need-to-know, and

knowledge-in-use. First, CSI emphasises developing a small set of core ideas, which are realised through SEPs (Fortus & Krajcik, 2012). The second characteristic, rich phenomena, means that the content students learn should be situated in a context that is relevant to them (Hanuscin et al., 2016). This can be achieved by presenting problems that are in some way personally meaningful, such as local issues familiar to the students. Establishing the need-to-know is closely connected to this; it means making the relevance of what is being learned explicit (Schneider et al., 2020). While this is not always possible for every topic, at a minimum, the importance of a topic for understanding subsequent content should be communicated. Finally, knowledge-in-use ties the previous three elements together using core ideas and practices to make sense of rich phenomena and solve science-related problems while recognising the value of the knowledge and ideas involved (Sikorski & Hammer, 2017). Together, these four characteristics aim to bring coherence to science teaching and support students' interest in science.

Core ideas are essentially phrases that may not convey much information on their own but encapsulate the knowledge students are expected to acquire under a unifying theme (Krajcik et al., 2014). For example, conservation of energy and energy transfer is a core idea in physics that includes the understanding that energy transfers from hotter to colder bodies and that when the kinetic energy of an object changes, another form of energy must also change (Duncan et al., 2016). The core ideas of all studies are described in the methodology chapter. Science and engineering practices describe the activities scientists and engineers engage in during their work, such as developing and using models, planning and carrying out investigations, and engaging in argument from evidence (Osborne, 2014). While these terms may be familiar to students in the United States because they are part of their national science curriculum (National Research Council, 2012), this is not necessarily the case for students in Europe. This is why instructional activities were preferred over SEPs: the former uses terms more familiar to students in Estonia and Finland.

The following paragraphs describe the instructional activities used throughout the three studies. We chose these activities based on the person–object theory of interest and the framework of coherent science instruction. The person–object theory informed the selection and placement of activities by distinguishing between activities known to trigger situational interest (Renninger et al., 2019; Swarat et al., 2012). As per the characteristics of CSI, the activities were situated in surprising or relevant phenomena, and they were sequenced logically to support the students in making sense of the phenomena (Nordine et al., 2021). Activities were sequenced so as to connect conceptual explanations with hands-on experience and reflection so that students could integrate new ideas with prior knowledge. Conceptual explanations, enacted through activities such as teacher–student interactions or solving worksheet problems, established the need to know for the students: how to answer the driving questions of the modules and how to make sense of the experiment- and calculation-related activities. The activities were

also linked to several science and engineering practices (National Research Council, 2012). The SEPs corresponding to the instructional activities are presented in Table 2 with one exception. We did not include *watching a video* as the results of Study 1 showed that it was too specific and often included in the *teacher–student interactions* or *following the teacher’s presentation*.

Table 2. Instructional activities linked to science and engineering practices

Instructional activities	Science and engineering practices
Listening; teacher-student interactions; following the teacher’s presentation	Obtaining, evaluating, and communicating information; asking questions and defining problems
Experimenting; experiment-related activities	Planning and carrying out investigations; engaging in argument from evidence
Answering worksheet questions; solving problems; working on an assignment	Developing and using models
Working with data	Analysing and interpreting data
Calculation-related activities	Using mathematics and computational thinking
Working in groups; brainstorming	Constructing explanations and designing solutions

Listening, teacher–student interactions, and following the teacher’s presentation emphasise the importance of the teacher. In addition to listening, these interactions can involve students processing and organising information, making connections to previous knowledge, developing an understanding of a concept, or developing a skill (Tytler, 2007). The role of the teacher is to support students in this process by asking questions, participating in discussions, or responding to students’ questions. These activities were part of all three studies and were also the most frequently reported by students.

Experimenting and *experiment-related activities*, sometimes called hands-on activities or practical work by other researchers (Dillon, 2008), involve students “observing or manipulating the objects and materials they are studying” (Millar, 2004, p. 2). The word “related” implies that the activities both preceding and following the experiment itself are included, such as setting up the experiment, proposing a hypothesis, making a plan, and reflecting on the results. Whichever term is used, such activities are a common sight in science lessons, but their benefits for learning have been called into question. For example, Abrahams and Millar (2008) observed that most teachers prioritised the successful completion of the intended experiment and data collection procedure, leaving little time for discussion of the results. As a result, students remembered conducting the experiments but

failed to understand the scientific ideas behind them; a finding reinforced by a subsequent study (Abrahams & Reiss, 2012). K. K. C. Cheung and Sonkqayi (2025) found that although conducting experiments improved students' attitudes towards science, the clarity of the teacher's instructions negatively affected their cognitive domains of knowing and applying. I compared experiment-related activities with other instructional activities in Studies 1 and 2.

Working in (small) groups or *group work* refers to students collaborating to achieve a common goal or complete a specific task. This usually includes assigning roles and responsibilities, discussing, and evaluating their work (Hammar Chiriac, 2014). In a sense, group work is a special kind of instructional activity, as it may include other activities, such as seeking information, brainstorming, or working on assignments (Webb & Palincsar, 1996). The teacher's role includes forming the groups, defining the activity's aim, providing the necessary resources, and observing and supporting the students during the task (Slavin, 2014). Working in small groups was one of the primary activities in Study 3.

When students are *solving problems* or *working on an assignment*, they process information, make connections to previous knowledge, and develop their skills or their understanding of a phenomenon (Krajcik & Blumenfeld, 2005). This begins with reading the instructions and understanding the requirements and objectives of the assignment, followed by creating a plan to complete it. While doing so, students apply their existing knowledge and skills (Sothayapetch et al., 2013). These activities do not include experiment-related tasks, as they do not involve manipulating or observing physical objects. Instead, problems are presented on paper (i.e. a worksheet), on a slide, or verbally by the teacher. Solving problems was also featured in all three of my studies as one of the more frequently reported instructional activities.

Calculation-related activities and *working with data* can be seen as subcategories of the activities described above, but they require students to use mathematical and computational thinking skills (Çava et al., 2023). This includes organising data (e.g. in tables), manipulating it, and drawing conclusions, and may culminate in model-building (Lehrer & Schauble, 2004). Comparing two calculation-related activities with different designs was one of the highlights of Study 2.

Brainstorming involves thinking creatively to generate and explore ideas in an iterative and non-linear way. This is often done collaboratively: while students may initially generate ideas on their own, they later share, combine, and refine them to find the best solution for the task at hand (Mosely et al., 2018). Brainstorming was included as an instructional activity in the questionnaire of Study 3, but compared to the other activities, it was rarely reported.

Seeking information entails evaluating the reliability of sources and identifying relevant content by highlighting key points or taking notes (Wallace et al., 2000). This can be done individually or during group work. In Study 3, seeking information was reported alongside working in groups, albeit rarely.

3. METHODOLOGY

3.1. Participants

Participants of Studies 1 and 2 were Estonian lower secondary school students, and Study 3 participants were upper secondary school students. In all studies, the students were divided into groups, and the distribution of boys and girls was equal. In Study 2, the majority of students participated in both modules, but 34 students participated in only the first module, and 17 in only the second module, due to scheduling conflicts. Exact details on the number of participants, the groups, and their composition are presented in Table 3.

Table 3. Participants of the three studies

Study	Students	Groups	Composition
1	179	10	Five groups: mix of 8th- and 9th-grade students from different classes. Five groups: 8th- or 9th-grade students from the same classes.
2	129 in Module 1, 126 in Module 2	7	Mix of 8th- and 9th-grade students from different classes.
3	191	9	10th-grade students from the same classes.

The samples of the first two studies consisted of students who participated in a physics teaching programme run annually by the University of Tartu. The aim of this programme was to provide schools with an opportunity to enrich their students' physics knowledge by having an instructor from the university visit the schools and conduct an in-depth workshop once a month about a topic from the national curriculum. Much focus was placed on having the students conduct experiments, which they could not do during regular physics lessons due to a lack of equipment and/or time. The programme was meant for interested eighth- and ninth-grade students since teaching physics as a separate subject begins in the eighth grade. Most of the students volunteered to participate in the workshops, but a few smaller schools made participation mandatory for all students. Despite this, participation in the workshops was not tied to participation in my studies. All students in Studies 1 and 2 were taught by me. The sample of the third study was obtained as part of the project "Learning of the competencies of effective climate change mitigation and adaptation in the education system" (ClimComp) funded by the Research Council of Finland. The students came from a school that has a partnership with the University of Helsinki for such educational studies. Furthermore, these students were taught by four different teachers. Two teachers each had one group, one teacher had three groups, and the last teacher had four groups. Two groups had a substitute teacher for one lesson.

3.2. Measures

In all studies, the experience sampling method (ESM) was used to collect data about situational interest, perceived relevance, effort, skills, challenge, and instructional activities. The ESM involves collecting real-time self-reports from participants about the topic of interest, such as happiness or anxiety (Hektner et al., 2007). ESM questionnaires are typically brief and are administered multiple times during the study period (Eisele et al., 2021). The goal is to capture participants' feelings or experiences as they occur, thereby minimising recall bias. Additionally, repeated measurements allow researchers to explore how these constructs develop over time, such as how boredom fluctuates throughout the day.

ESM data can be collected in several ways, most commonly using smartphones or tablets that are specifically set up for this purpose (Dejonckheere & Erbas, 2021). The items typically use a Likert scale, although open-ended questions can also be included (Rintala et al., 2019). A key design choice concerns the sampling scheme, which can be random, semi-random, fixed, or event-based (Dejonckheere & Erbas, 2021). A random scheme prevents participants from anticipating when the next questionnaire will appear, thereby improving validity, but it may also increase participant burden and reduce compliance. Furthermore, questionnaires may appear at ill-timed moments for the participants or times that are irrelevant for the specific research (Vachon et al., 2019). A fixed scheme is essentially the opposite of a random scheme. A semi-random scheme addresses the shortcomings of the other two by offering moderate predictability: questionnaires appear within known timeframes, but not at fixed moments. This increases validity and compliance while reducing participant burden and is therefore often used by researchers. Finally, in event-based schemes, questionnaires are triggered by specific events (for example, after a nap), which is useful for examining the impact of particular occurrences (Himmelstein et al., 2019).

Study 1 focused on associating situational interest with individual interest and instructional activities. To measure individual interest, we administered a background questionnaire at the beginning of the teaching module, which included items about gender and grade, along with five statements about individual interest. The statements were modified versions of question ST094 in the "Students' View of Science" questionnaire of the 2015 PISA study (OECD, 2017), but instead of science in general, we asked about physics. To measure situational interest and the associated instructional activities, we used the ESM questionnaire, which consisted of two items. We measured situational interest with a Likert item and instructional activities with a multiple choice item. The scale of the Likert items in the background questionnaire ranged from *strongly disagree* to *strongly agree*, and in the ESM questionnaire, from *no interest* to *very high interest*. The Likert items in this and the following studies all used a 5-point scale. Items from both instruments and their types are presented in Table 4, and the choices for the

instructional activities are presented in Table 1. In addition to instructional activities, we included the option of “not engaging in an instructional activity” to give those students who were no longer focused on the module the chance to give an accurate report.

Table 4. Items from the instruments used in Study 1

Instrument	Item	Type
Background	“Usually I am having fun learning about physics topics.”	Likert
	“I like reading about physics.”	
	“I am happy when I’m dealing with physics.”	
	“I enjoy obtaining new knowledge in physics.”	
	“I am interested in learning about physics.”	
ESM	What is your gender?	multiple choice
	What grade are you in?	
	How interesting was the activity at hand?	Likert
	What was the activity?	multiple choice

In Study 2, we removed three items about individual interest but added an item about the perceived relevance of physics and a reverse-coded item about individual interest from the background questionnaire of the previous study. The reasoning behind this was that all of the removed items focused on the affective component of interest (*I am having fun...*, *I am happy...*, *I like...*), but interest also has a cognitive and value component. While the statement “*I enjoy obtaining new knowledge in physics*” is still focused on the affective component, the remaining statement “*I am interested in learning about physics*” and its negatively worded counterpart are more neutral and not biased towards the affective component. We also added two items about perceived relevance to the ESM questionnaire – one about the level of relevance and another about its dimensions: personal, societal, or vocational (Stuckey et al., 2013). To improve the validity of the items, I asked a few of the students in different groups to explain in their own words how they interpreted the questions. The students provided verbal feedback, which was not documented, but the most important feedback was that they made a distinction between interest and relevance. All items used in Study 2 are presented in Table 5. For the instructional activities, which have been modified since the previous study, see Table 1.

In Study 3, we did not use a background questionnaire. Instead, the main instrument was the ESM questionnaire, which included items about the instructional activities, situational interest, effort, challenge, and skills. While the effort-by-allocation conception implies intent for something about to happen, our question addressed students after they had completed an activity. However, the wording

of our question still implied willingness, without alluding to the complexity of the task or the frustration it could have caused. The Likert items were on a scale from *not at all* to *very much*, and the possible choices of instructional activities are visible in Table 1. The items of Study 3 are presented in Table 6.

Table 5. Items from the instruments used in Study 2

Instrument	Item	Type
Background	“I am interested in learning about physics.”	Likert
	“I enjoy obtaining new knowledge in physics.”	
	“Physics is relevant to me.”	
	“Learning about physics is not interesting for me.”	
ESM	What is your gender?	multiple choice
	What grade are you in?	
	“This activity was interesting for me.”	Likert
	“This activity was relevant to me.”	
	What was the activity you were currently engaged in?	multiple choice
	Why was (or wasn't) this activity relevant to you?	

3.3. Procedure

In Studies 1 and 2, students were given tablets to use during the teaching modules. The tablets contained the learning materials of the teaching modules, which were in the form of digital worksheets. The worksheets contained instructions to set up the experiments, provided opportunities to make notes of the results, and presented guiding questions to get students to think about what they were doing. Both the background and ESM questionnaires were administered through the tablets, and their visual style was identical to the other content on the worksheets.

Table 6. Items used in Study 3

Item	Type
Were you interested in what you were doing?	Likert
How much effort were you putting into the task?	
Did you feel skilled at what you were doing?	
Did you feel challenged by what you were doing?	
What were you doing before you started answering the questionnaire?	multiple choice

The teaching modules of Studies 1 and 2 consisted of three consecutive lessons,

and a single lesson usually lasted for 45 minutes. Thus, the modules were different from a regular lesson in length, but we deemed this beneficial for several reasons. First, if the ESM questionnaires had been administered within 45 minutes, the time between each questionnaire would have been very short, which would have been burdensome for the students and likely produced comparably small changes in situational interest. Second, the process of introducing a topic, conducting relevant experiments, and discussing them takes considerable time, and the longer format of the study allowed us to maintain a sensible pace for the students. Study 1 had a single teaching module and Study 2 had two modules.

The ESM questionnaire used in Study 1 was administered to the students three times. It utilised a modification of the semi-random sampling scheme, in which the time between the questionnaires was roughly 20 to 30 minutes, but every student received the questionnaire at a slightly different moment so as not to break the flow of the lesson. For example, if one student in a group needed to answer the questionnaire, then the others could continue with the experiment and later bring their classmate back up to speed. Unfortunately, this caused a situation where some students got their questionnaire during a break, which reduced the amount of data by 5%. Learning from this, we used the event-based sampling scheme in Study 2, and all students received their questionnaires at the same time. In addition to avoiding the problems of Study 1, this scheme was suitable for capturing specific instructional activities such as experiment- or calculation-related activities. The timing between the questionnaires was roughly 20 minutes. In both modules, the ESM questionnaire was presented to the students four times: twice during the theory-focused section, once after the experiment, and once after a calculation-related activity.

In Study 3, students were provided with smartphones to answer the ESM questionnaires, but the learning materials were not accessed through the phones. The study utilised one teaching module, which was divided into five 90-minute lessons. During each lesson, students answered the ESM questionnaire three times, meaning that the total number of questionnaires for each student was 15. This study utilised a fixed sampling scheme, which meant that students received a questionnaire every 20 minutes. The phones were programmed to signal the students when it was time to answer, but the teachers had the opportunity to finish what they were currently doing and then let the students answer. Another considerable difference from the previous studies was that students could choose to be engaged in multiple activities simultaneously (working in groups and brainstorming, for example).

3.4. Data analysis

Before analysing the data, I removed careless or incomplete answers. The main indicator for a careless answer was when a student had answered all items identically, even the reverse-coded one in Study 2. It was more difficult to judge whether such behaviour was a sign of carelessness in Study 3, since theoretically

the student could have felt that their interest or the other measured concepts did not change during the entire lesson. In such cases, I checked how the same student had answered in other lessons; if the same pattern was present in other lessons, I removed that student's data. A good indicator of carelessness was reports of instructional activities that could not have happened at that point; for example, reporting engaging in experiment-related activities if calculations were done instead. In Study 2, I treated the samples of both teaching modules separately; that is, I did not analyse changes in students' interest across modules or use data from the first module as input for analyses of the second.

The analysis methods used for each variable and their corresponding research questions are presented in Table 7. The individual interest used in the models of Studies 1 and 2 was the mean of the items measuring it, and the internal consistency of these items was high ($\alpha = .876$ in both studies). I used Kendall's Tau correlation both as an input to which variables should be included in the regression models and as a separate measure of their association with situational interest. I used ANOVA to first confirm whether there were differences between the mean levels of situational interest associated with instructional activities, and then Tukey's test as a post hoc analysis to find out which pairs differed.

Table 7. Analysis methods and variables used in the studies

Analysis method	Variables in relation to situational interest
Mann-Whitney U-test	gender, grade (RQ 1)
Kendall's Tau correlation	individual interest, subject relevance, activity relevance, effort, challenge, skills (RQ 1 and 2)
ANOVA and Tukey's test	instructional activities (RQ 2)
Mixed-effects model	individual interest, instructional activities, activity relevance, effort, challenge, skills (RQ 1 and 2)
Two-level structural model (Study 3)	instructional activities, effort (RQ 2)
Simple regression model	individual interest, activity relevance, effort, skills, challenge previous situational interest (RQ 1 – 3)
Descriptive statistics	development of situational interest (RQ 4)

To answer the second research question, I used two types of regression models. The first are multilevel regression models accounting for the nestedness of the data. Measures of interest and other situational variables were nested within students and students within groups. These models allowed me to answer the first two research questions. An additional multilevel model was used during Study 3 that modelled the connection between situational interest, effort, and instructional activities. The difference was that this model allowed for the covariance of interest

and effort, which provided a different result from ANOVA regarding instructional variables. To answer the third research question, I used simple linear regression to model the level of situational interest at each of the moments students answered the questionnaires, referred to in the models as occasions. These occasion-specific models included situational interest measured at the previous moment as well as the other variables used in the multilevel models, excluding instructional activities. The activities could not be included because the reported activities varied very little (the students reported the same activity or only a couple of activities). These models examined associations between earlier and later interest at the student level and did not model within-person change trajectories. I used the Akaike Information Criterion to determine which variables to include in the models. All analyses except the second multilevel model of Study 3 were conducted using R (R Core Team, 2022), whereas the second model was compiled using Mplus 8.6 (Muthén & Muthén, 2020). The descriptive statistics used to address the fourth research question were the mean situational interest levels at each measurement occasion. These captured the development across groups and modules rather than individual trajectories.

3.5. Validity and reliability

The number of items is likely the most contested topic of discussion regarding measurement. Due to its relatively intense nature, studies implementing the ESM often utilise single-item scales for the constructs of interest to minimise the participants' burden (Eisele et al., 2022). Renninger and Hidi (2011) noted that using single-item measures provides a basis for classifying interest relative to others (p. 176). However, in a later study, Renninger and Hidi (2015a) criticised scales consisting of only a few items for their inability to cover the many dimensions of interest, while others (Gogol et al., 2014; Hektner et al., 2007; Zirkel et al., 2015) defended them because they minimise disruption. Single-item scales are also in a difficult position regarding reliability and validity. Of the two, validity presents fewer problems, and the validity of a single item can be assessed through its correlation with other ESM and non-ESM items (Shrout & Lane, 2012). In addition, J. Song et al. (2023) found that single items can demonstrate adequate validity comparable to multi-item scales when they are carefully designed.

In ESM studies, reliability is conceptualised differently from traditional questionnaires that rely on multiple items per construct. Csikszentmihalyi and Larson (1987) have argued that the goal of ESM is to measure variability over time and within persons and thus, stability in the responses would defeat its purpose. Because ESM focuses on dynamic states rather than stable traits, reliability is evaluated at the withinperson level, not through internal consistency (Nezlek, 2017). However, many of the methods proposed to assess the within-person reliability assume that multiple items are used to measure a construct, and there is no widely accepted method for determining the reliability of single-item scales

(Eisele et al., 2021). Addressing this issue, Dejonckheere et al. (2022) investigated the use of single-item measures in ESM studies and the measurement error associated with them from a Classical Test Theory (CTT) perspective. Within this framework, reliability refers to the extent to which repeated assessments under comparable conditions yield consistent scores, while measurement error denotes random or systematic deviations of observed ratings from the underlying true score. The cause of these errors is said to be environmental factors out of the researchers' control. While noting that the measurement errors of the tested single-item measures were not trivial and should not be ignored, they also emphasised that such errors cannot easily be generalised to other single-item measures. Eisele et al. (2025) recently published an assessment tool that could be used to evaluate the quality of ESM items. Since methods for assessing the reliability of single-item ESM scales are still in their infancy, none of the studies in this thesis implemented any of the recommended approaches. However, since the focus of this thesis is on instructional activities, the items in all of the studies were worded to specifically refer to the activity at hand. This narrow wording reduces possible confusion and misinterpretation, therefore minimising measurement error as well. The validity of the items was assessed by utilising correlation analyses.

3.6. Description of the teaching modules

Study 1 took place in Estonia in the spring of 2022. The teaching module of this study focused on making sense of oscillations and followed the Estonian national curriculum. We chose this topic because it is often neglected by teachers in Estonia and offered numerous opportunities for students to conduct experiments. The driving question of the module was “Why is there a 660-tonne pendulum inside a skyscraper in Taipei?”, which was the rich phenomenon to be explored. The core ideas of this module were “Forces and motion”, “Types of interactions” and “Relationship between energy and forces”. The module began with a short introduction of period and frequency, during which I established the need-to-know for further activities. This was followed by putting the knowledge to use, which was accomplished by experimenting, calculating, and answering the worksheet questions in small groups. The lesson plan, core ideas, and science and engineering practices can be seen in Appendix A.

Study 2 took place in the spring of 2023 and had many similarities with the first study. The modules of this study focused on two important topics of thermodynamics: the transfer of thermal energy between bodies when their temperatures change and when their states of matter change. The driving questions of the modules were “Is a wooden house warmer during summer and colder during winter than a concrete house?” and “Can we heat a room by making ice cream?”. The core ideas of these modules were “Definitions of energy” and “Conservation of energy and energy transfer”. I intentionally designed the two modules to be similar to allow for comparison of the instructional activities. Both started with a

driving question, followed by learning the theory behind the phenomena that were going to be studied later on. At the end of both modules, students had a task that required calculating and an experiment for which they set hypotheses and later drew conclusions from. The teaching modules had the same length and format as the module designed for Study 1. A detailed description can be found in the appendix of Article II.

The teaching module of Study 3, designed as part of a collaboration between the participating teachers and researchers from the University of Helsinki, focused on the physics of climate change and followed the Finnish national curriculum. This collaborative approach was chosen because many science and physics teachers struggle with climate change topics and are unaware of suitable teaching methods (Feinstein & Kirchgasser, 2015; Stratton et al., 2015). At the same time, involving teachers gave the researchers a more accurate idea of what is viable to include in the module. The driving question of the module was “How can I support the city of Helsinki’s carbon neutrality goal for 2030?”, which was approved by the teachers as a rich phenomenon for the students to explore. The core ideas of the module were “Human impacts on Earth systems”, “Global climate change”, “Weather and climate”, “Natural resources”, and “Conservation of energy and energy transfer” (National Research Council, 2012). More specifically, the topics connected to these core ideas were the greenhouse effect, climate change mitigation, energy transformation in power plants, the production of waste, and recycling. Each lesson focused on one aspect of climate change. At the end of the module, the students had to create a concluding report about what they had learned, for which they were graded. The lesson plans are presented in the appendix of Article III. The teaching module was piloted in 2022 and 2023. Although I neither designed nor taught the materials in Study 3, I reviewed them and discussed their implementation with a participating teacher.

3.7. Ethical considerations

In all three studies, participating students were asked for their consent beforehand, and everyone had the option to opt out of the study without any negative consequences. Students could choose not to answer the questionnaires but still participate in the lessons like everyone else. The anonymity of the students was ensured because they used devices provided by us and not their personal devices, and only the gender and grade of the students were asked, which cannot be linked to any specific person. No sensitive data was collected from the students. The possible mental strain caused by the study was kept at a minimum by the shortness of the questionnaires. The first two studies did not need approval from an ethics board, although we acquired permission for the first study as a precaution. The project of Study 3 was approved by an ethics board, and the ethics declaration can be seen at the end of Article III.

4. RESULTS

4.1. Background variables (RQ 1)

The Mann-Whitney U-tests revealed no gender or grade differences in situational interest in Study 1, and only one occasion in Study 2 where ninth-grade students were more interested than eighth-grade students ($p = .03$). This occurred in Module 1 Occasion 3 during experiment-related activities. Occasions refer to the moments the students answered the ESM questionnaires. Although no gender differences emerged for situational interest, Study 2 Module 1 Occasions 1 and 2 showed differences in the perceived relevance ($p = .03$), favouring girls.

Table 8. Multilevel model of situational interest in Study 1

Predictors	β	SE	95% CI
Intercept (ref=idle)	1.24***	0.29	[0.53, 1.95]
Individual interest	0.56***	0.08	[0.40, 0.72]
Act: listening	0.41	0.26	[-0.10, 0.92]
Act: experimenting	0.60*	0.25	[0.11, 1.10]
Act: other	0.15	0.31	[-0.46, 0.76]
Act: watching a video	0.42	0.27	[-0.12, 0.95]
Act: answering worksheet questions	0.45	0.29	[-0.11, 1.01]
<i>Random effects</i>			
σ^2	.66		
$\tau_{00\text{ id}}$.35		
$\tau_{00\text{ group}}$.05		
ICC	.38		
N_{id}	144		
N_{group}	10		
Observations	345		
Marginal R ² /	.189/		
Conditional R ²	.496		

Note. $\tau_{00\text{id}}$ refers to the between-student variance and $\tau_{00\text{group}}$ to the between-group variance. The σ^2 indicates the within-student variance.

*** $p < .001$, ** $p < .01$, * $p < .05$

The Kendall's Tau correlation analysis showed that the perceived relevance of physics in general was not significantly correlated with any situational interest measure in Study 2, with one exception. The exception was Module 2 Occasion 3, where there was a weak correlation between the two variables ($\tau = .16$; $p = .049$). This occasion coincided with the lowest mean situational interest recorded in Study 2. At that point, the perceived relevance of the activity was strongly associated with situational interest, and its correlation with the relevance of physics in general was both significant and moderate. The relevance of physics in general was correlated to individual interest in both modules, and the correlations were moderate ($\tau = .38$ and $.30$; $p < .001$ for both). It was also correlated to the relevance of the activity in the first two occasions of Module 1 ($\tau = .17$ and

.20; $p = .04$ and $.01$) and the first three occasions of Module 2 ($\tau = .31, .22$ and $.26$; $p < .001$ for all three).

Table 9. Occasion-specific regression models for situational interest in Study 1

Predictors	β	SE	95% CI
Occasion 1			
Intercept	1.84***		[1.07, 2.61]
Individual int.	0.46***		[0.24, 0.69]
<i>Model summary</i>			
Observations	124		
R ² /	.122/		
R ² adjusted	.114		
Occasion 2			
Intercept	0.79*		[0.08, 1.50]
Individual int.	0.27*		[0.06, 0.49]
Previous sit. int.	0.55***		[0.39, 0.71]
<i>Model summary</i>			
Observations	110		
R ² /	.434/		
R ² adjusted	.424		
Occasion 3			
Intercept	0.57		[-0.26, 1.40]
Individual int.	0.60***		[0.34, 0.86]
Previous sit. int.	0.31**		[0.11, 0.51]
<i>Model summary</i>			
Observations	103		
R ² /	.369/		
R ² adjusted	.356		

Note. *** $p < .001$, ** $p < .01$, * $p < .05$

In contrast to the other background variables, individual interest was associated with situational interest on several occasions. Both the multilevel model (Table 8) and the occasion-specific models (Table 9) in Study 1 showed individual interest as a significant predictor. In the tables, I refer to the variables as *predictors*, but I do not imply a strong causal connection. In Study 2, the multilevel models (Table 10) showed that individual interest was associated with situational interest in Module 2, but not in Module 1. However, the occasion-specific models (Table 11) showed the same association only for Occasions 1 and 4 in Module 2. The significance of the association between individual and situational interest appeared to be connected to experiment-related activities and inversely related to goodness of fit for the occasion-specific models. Despite that, a correlation analysis showed that the link between individual interest and goodness of fit was insignificant, and a multilevel model including an interaction term between instructional activities and individual interest did not reveal a significant relationship.

Kendall's Tau correlation coefficients between individual and situational interest in Study 1 were all significant and moderate ($\tau_1 = .30$, $\tau_2 = .35$, $\tau_3 = .41$,

$p < .001$; Schober et al., 2018). In Study 2, the correlations were significant only in Module 1 Occasion 3, but in Module 2 Occasions 1 and 2, the correlations were either weak or moderate ($\tau = .18, p = .04$; $\tau = .21, p = .01$; $\tau = .28, p < .001$, respectively).

Table 10. Multilevel models of situational interest in Study 2

Predictors	Module 1			Module 2		
	β	<i>SE</i>	95% CI	β	<i>SE</i>	95% CI
Intercept (ref= Idle)	2.04***	0.31	[1.43, 2.65]	1.17***	0.30	[0.59, 1.76]
Individual interest	0.05	0.06	[-0.06, 0.17]	0.24***	0.06	[0.12, 0.35]
Relevance of the activity	0.40***	0.04	[0.32, 0.48]	0.33***	0.04	[0.25, 0.41]
Act: Exp	0.72***	0.16	[0.42, 1.03]	1.20***	0.16	[0.88, 1.52]
Act: T-S int	0.43**	0.15	[0.14, 0.71]	0.52**	0.16	[0.20, 0.84]
Act: Calc	0.54**	0.20	[0.16, 0.93]	0.23	0.19	[-0.15, 0.61]
Act: Solve	0.20	0.15	[-0.10, 0.51]	0.53**	0.18	[0.18, 0.87]
<i>Random effects</i>						
σ^2	.46			.63		
$\tau_{00 \text{ id}}$.15			.08		
$\tau_{00 \text{ school}}$.03			.06		
ICC	.28			.18		
N_{id}	118			116		
N_{school}	7			7		
Observations	417			449		
Marginal R^2 /	.236/			.317/		
Conditional R^2	.453			.438		

Note. *** $p < .001$, ** $p < .01$, * $p < .05$

4.2. Situational variables (RQ 2)

I measured the effect of instructional activities on situational interest mainly through ANOVA and Tukey’s test, but the results were also confirmed by the multilevel models to some extent. The reference category in all of the multilevel models was “not engaging in instructional activities”, indicated by *ref=Idle* in the tables. In Study 1, the mean levels of situational interest for the instructional activities did not differ statistically. However, both experimenting and listening were rated as significantly more interesting than not engaging in instructional activities. The multilevel model (Table 10) partially confirmed this, since listening was not significantly different from not engaging in instructional activities in the model.

In Study 2, the differences between the activities were the most definite. The results from Tukey’s test (see Table 3 in Article II) revealed that 60% of the activity pairs differed significantly in terms of situational interest; effect sizes were often medium or large (Cohen’s $d > .5$ or $d > .8$, respectively; Cohen, 1992). However, this included not engaging in any activity, and pairs containing this

option constituted half of the mentioned pairs. Furthermore, the pairs differed significantly in the two modules. In Module 1, the other instructional activities were significantly more interesting than not being engaged or solving worksheet problems, but there were insignificant differences between them. In Module 2, not being engaged was still the least interesting, but experiment-related activities were clearly more interesting than any other activity. This result was also confirmed by the multilevel models (Table 10).

Table 11. Occasion-specific regression models for situational interest in Study 2

Predictors	Module 1			Module 2		
	β	SE	95% CI	β	SE	95% CI
Occasion 1						
Intercept	2.87***	0.47	[1.94, 3.80]	2.35***	0.42	[1.50, 3.19]
Perceived rel.	0.17	0.09	[0.00, 0.35]	0.16*	0.08	[0.00, 0.32]
Individual int.	0.15	0.10	[-0.05, 0.35]	0.24**	0.09	[0.06, 0.42]
<i>Model summary</i>						
Observations	86			116		
R ² /	.080/			.100/		
R ² adjusted	.057			.084		
Occasion 2						
Intercept	0.78	0.57	[-0.34, 1.91]	-0.06	0.48	[-1.01, 0.90]
Perceived rel.	0.57***	0.10	[0.38, 0.76]	0.34***	0.09	[0.17, 0.51]
Previous sit. int	0.31**	0.10	[0.11, 0.52]	0.51***	0.10	[0.31, 0.71]
Individual int.	-0.03	0.10	[-0.22, 0.17]	0.13	0.10	[-0.07, 0.34]
<i>Model summary</i>						
Observations	86			116		
R ² /	.387/			.402/		
R ² adjusted	.365			.386		
Occasion 3						
Intercept	1.41*	0.55	[0.32, 2.50]	1.04*	0.49	[0.06, 2.01]
Perceived rel.	0.35***	0.08	[0.19, 0.51]	0.54***	0.10	[0.33, 0.75]
Previous sit. int.	0.22**	0.09	[0.04, 0.39]	0.16	0.08	[-0.01, 0.32]
Individual int.	0.18	0.09	[0.00, 0.36]	-0.02	0.10	[-0.23, 0.19]
<i>Model summary</i>						
Observations	90			109		
R ² /	.267/			.280/		
R ² adjusted	.242			.260		
Occasion 4						
Intercept	-0.09	0.55	[-1.19, 1.01]	3.12***	0.37	[2.39, 3.85]
Perceived rel.	0.46***	0.09	[0.29, 0.63]	0.22***	0.05	[0.12, 0.33]
Previous sit. int.	0.48***	0.10	[0.28, 0.69]	0.03	0.06	[-0.09, 0.15]
Individual int.	0.10	0.09	[-0.09, 0.30]	0.15*	0.07	[0.01, 0.28]
<i>Model summary</i>						
Observations	78			105		
R ² /	.489/			.193/		
R ² adjusted	.468			.169		

Note. *** $p < .001$, ** $p < .01$, * $p < .05$

In Study 3, the multilevel model including the covariance of interest and effort (see Table 1 in Article III) showed that three instructional activities had a significant effect on situational interest. However, this analysis was run with the initial data, where each student could report multiple activities per measure. The ANOVA conducted on data where only a single activity had been reported (1737 out of 2253 data points) did not reveal any significant differences in situational interest when used for the whole module, but it did reveal one difference in Lesson 5 when comparing the activities within lessons. The significant difference was seen between brainstorming and following the teacher’s presentation with the former being more interesting (Cohen’s $d = .79$, $p = .02$). Instructional activities had a more significant effect on perceived levels of effort and challenge. As a result, I did not include instructional activities in subsequent models of situational interest because, according to the Akaike information criterion, the models would have been worse with them included.

Table 12. Multilevel model of situational interest in Study 3

Predictors	β	SE	95% CI
Intercept	1.05***	0.11	[0.83, 1.27]
Challenge	0.07***	0.02	[0.03, 0.11]
Effort	0.12***	0.02	[0.12, 0.20]
Skills	0.46***	0.02	[0.42, 0.50]
<i>Random effects</i>			
σ^2	.51		
$\tau_{00 \text{ id}}$.22		
$\tau_{00 \text{ group}}$.03		
$\tau_{00 \text{ lesson}}$.01		
ICC	.34		
N_{id}	206		
N_{group}	9		
N_{lesson}	5		
Observations	1737		
Marginal R^2 /	.312/		
Conditional R^2	/.543		

Note. *** $p < .001$, ** $p < .01$, * $p < .05$

Except for Occasion 1 Module 1, the perceived relevance of the instructional activity was associated with situational interest (see Table 11). Still, its significance in the module was lower in Occasion 1 Module 2. The data collected about the perceived dimensions of relevance explained how the activities were considered relevant. The analysis showed that the vocational dimension was the least chosen option, with the most chosen option alternating between the individual and the societal dimensions (see Table 4 in Article II). The individual dimension was more frequently reported during Module 1 Occasion 2 and Module 2 Occasion 4, whereas the societal dimension dominated during Module 1 Occasion 4 and the first three occasions of Module 2. The correlation analyses showed that

situational interest was significantly correlated to perceived relevance on all occasions; correlation coefficients ranged from $\tau = .24$ to $\tau = .50$ in Module 1 and from $\tau = .19$ to $\tau = .47$ in Module 2.

Table 13. Occasion-specific regression models for situational interest in Study 3

Predictors	Occasion 1			Occasion 2			Occasion 3		
	β	SE	95% CI	SE	95% CI	SE	95% CI		
Lesson 1									
(Intercept)	1.19***	0.31	[0.59, 1.79]	0.32	0.31 [-0.30, 0.93]	0.14	0.26	[-0.38, 0.66]	
Effort	0.29***	0.07	[0.14, 0.43]	0.17*	0.08 [0.02, 0.33]	0.15*	0.07	[0.00, 0.30]	
Skills	0.42***	0.07	[0.28, 0.56]	0.34***	0.07 [0.20, 0.48]	0.33***	0.06	[0.20, 0.46]	
Challenge	0.01	0.08	[-0.14, 0.16]	0.18*	0.08 [0.03, 0.34]	0.09	0.07	[-0.05, 0.24]	
Pr. sit. int.	-	-	-	0.33***	0.08 [0.16, 0.49]	0.47***	0.07	[0.33, 0.62]	
Obs.	140			117		118			
R ² /	.297/			.451/		.604/			
R ² adjusted	.282			.432		.590			
Lesson 2									
(Intercept)	0.58*	0.29	[0.01, 1.15]	0.26	0.27 [-0.27, 0.79]	0.09	0.30	[-0.50, 0.69]	
Effort	-0.04	0.08	[-0.21, 0.13]	0.15	0.08 [-0.01, 0.31]	0.19*	0.09	[0.02, 0.36]	
Skills	0.58***	0.07	[0.44, 0.73]	0.40***	0.07 [0.27, 0.54]	0.29***	0.08	[0.13, 0.45]	
Challenge	0.33***	0.08	[0.16, 0.49]	-0.01	0.07 [-0.15, 0.12]	0.06	0.09	[-0.12, 0.24]	
Pr. sit. int.	-	-	-	0.41***	0.07 [0.28, 0.55]	0.46***	0.08	[0.30, 0.62]	
Obs.	132			103		99			
R ² /	.379/			.588/		.558/			
R ² adjusted	.365			.571		.539			
Lesson 3									
(Intercept)	0.45	0.29	[-0.13, 1.02]	0.14	0.30 [-0.46, 0.74]	0.13	0.30	[-0.48, 0.73]	
Effort	0.18	0.09	[-0.00, 0.36]	0.12	0.09 [-0.06, 0.29]	0.26**	0.09	[0.08, 0.44]	
Skills	0.57***	0.07	[0.43, 0.70]	0.31***	0.09 [0.14, 0.49]	0.57***	0.08	[0.40, 0.73]	
Challenge	0.15	0.09	[-0.02, 0.33]	0.16*	0.08 [0.00, 0.32]	0.01	0.09	[-0.17, 0.19]	
Pr. sit. int.	-	-	-	0.44***	0.09 [0.26, 0.62]	0.21*	0.08	[0.04, 0.37]	
Obs.	127			97		76			
R ² /	.402/			.538/		.652/			
R ² adjusted	.387			.518		.633			
Lesson 4									
(Intercept)	0.57	0.30	[-0.03, 1.16]	0.20	0.32 [-0.44, 0.83]	0.30	0.44	[-0.59, 1.18]	
Effort	0.26**	0.09	[0.08, 0.44]	0.30***	0.08 [0.14, 0.47]	-0.05	0.11	[-0.26, 0.16]	
Skills	0.52***	0.09	[0.35, 0.69]	0.31**	0.09 [0.13, 0.49]	0.55***	0.11	[0.34, 0.76]	
Challenge	0.09	0.08	[-0.08, 0.25]	0.11	0.08 [-0.05, 0.28]	0.15	0.11	[-0.06, 0.37]	
Pr. sit. int.	-	-	-	0.27**	0.10 [0.08, 0.46]	0.28**	0.10	[0.07, 0.48]	
Obs.	109			78		66			
R ² /	.438/			.557/		.512/			
R ² adjusted	.422			.533		.480			
Lesson 5									
(Intercept)	0.01	0.32	[-0.61, 0.64]	-0.03	0.49 [-1.02, 0.96]	0.57	0.46	[-0.36, 1.49]	
Effort	0.24*	0.10	[0.04, 0.44]	-0.04	0.12 [-0.29, 0.21]	0.36*	0.14	[0.07, 0.65]	
Skills	0.58***	0.08	[0.41, 0.75]	0.42**	0.14 [0.14, 0.71]	0.33*	0.13	[0.06, 0.59]	
Challenge	0.15	0.09	[-0.03, 0.33]	0.11	0.11 [-0.11, 0.33]	-0.16	0.11	[-0.38, 0.06]	
Pr. sit. int.	-	-	-	0.60***	0.14 [0.33, 0.87]	0.22	0.11	[-0.01, 0.45]	
Obs.	101			43		42			
R ² /	.461/			.593/		.520/			
R ² adjusted	.444			.550		.468			

Note. *** $p < .001$, ** $p < .01$, * $p < .05$

Of the three new concepts examined in Study 3, challenge was the least associated with interest. While challenge was associated with situational interest in the multilevel model (Table 12), in the occasion-specific models (Table 13), there was a weak association on only three of the 15 occasions. There was no clear trend for how challenge developed. Effort had a stronger association with situational interest than challenge in the multilevel model and was associated with situational interest on nine of the 15 occasions. In most cases, the association was weaker than that between other variables and situational interest. Except for Lesson 1, the mean values of effort changed little during Occasions 1 and 2 but increased during Occasion 3. The strongest association was between skills and situational interest in both the multilevel models and the occasion-specific models. Like challenge, there was no clear trend in the development of the mean values of skills.

Correlation analyses showed that challenge was significantly correlated with situational interest on eight of the 15 occasions, whereas effort and skills were significantly correlated on all occasions. Correlations were weak ($\tau = .16$ to $\tau = .23$) between situational interest and challenge; weak ($\tau < .26$) on four occasions and moderate ($\tau < .49$) on all other occasions between situational interest and effort; and moderate on four occasions and strong ($\tau < .71$) on all other occasions between situational interest and skills.

Table 14. Development of the mean level of situational interest in all studies

Occasion 1	Occasion 2	Occasion 3	Occasion 4
Study 1			
3.42 [3.24, 3.61]	3.63 [3.43, 3.82]	3.69 [3.48, 3.9]	-
Study 2			
Module 1			
4.08 [3.93, 4.22]	3.92 [3.74, 4.10]	4.23 [4.06, 4.40]	3.98 [3.79, 4.17]
Module 2			
3.83 [3.67, 3.98]	3.60 [3.40, 3.80]	3.46 [3.28, 3.64]	4.66 [4.55, 4.78]
Study 3			
Lesson 1			
3.07 [2.91, 3.25]	3.19 [3.00, 3.37]	3.15 [2.96, 3.34]	-
Lesson 2			
2.83 [2.63, 3.02]	2.86 [2.67, 3.04]	2.97 [2.78, 3.16]	-
Lesson 3			
2.80 [2.60, 2.99]	2.91 [2.72, 3.11]	3.02 [2.79, 3.25]	-
Lesson 4			
2.90 [2.69, 3.11]	2.87 [2.66, 3.09]	2.80 [2.60, 3.00]	-
Lesson 5			
2.62 [2.40, 2.84]	2.75 [2.46, 3.04]	2.99 [2.75, 3.23]	-

4.3. Development of situational interest (RQ 3 and 4)

Subsequent situational interest was associated with the previous values on almost all occasions in all studies (see the tables of the occasion-specific models). The only exceptions were Study 2 Module 2 Occasions 3 and 4, and Study 3 Lesson 5 Occasion 3. The development of situational interest during the teaching modules was described by the occasion-specific models and the mean values of situational interest for each occasion. I obtained the mean values through descriptive statistics, presented in Table 14. The mean values of interest observed different trends in all studies. In Study 1, situational interest increased, whereas in Study 2 it decreased until the experiment-related activities, at which point it increased again. In Study 3, the level of situational interest showed no clear trend. There was a significant difference between the means of Occasions 1 and 3 in Study 1. In Study 2 Module 2, only the means of Occasions 2 and 3 were not significantly different. In Study 2 Module 1, and all lessons of Study 3, the means did not differ significantly.

5. DISCUSSION

The conducted analyses implied that individual interest was the only background variable, which was relatively consistently related to situational interest (RQ 1). The effect of instructional activities on situational interest was modest compared to the effects of the learner characteristics measured in tandem with the activities. Of these learner characteristics, challenge was the least associated with situational interest. Relevance and effort were associated with situational interest on most occasions, and skills on all occasions (RQ 2). Previous situational interest influenced subsequent levels across nearly all measurement occasions (RQ 3). The mean levels of situational interest observed different trends in all the studies: growth in Study 1, decline interrupted by experiment-related activities in Study 2, and fluctuation in Study 3 (RQ 4).

5.1. Associations between background variables and situational interest

Our findings suggest that Estonian students do not exhibit an interest-related gender gap, as reported in other studies (Carreño et al., 2022; Häussler et al., 1998; Hoffmann, 2002). This aligns with the PISA 2015 report (OECD, 2016), which showed no significant gender differences in students' enjoyment of learning science in Estonia and Finland, in contrast to larger disparities in countries such as Germany, the UK, and the US. While situational interest did not differ by gender, the finding that girls reported higher perceived relevance at specific points in a teaching module invites closer consideration. The first occasion is unlikely to be explained by exposure to specific content, as it emerged early in the module. The second occasion, however, emerged when emphasising the real-world applications of specific heat capacity in detecting cancer—an example aligned with earlier findings that girls are more drawn to topics related to medicine (Baram-Tsabari & Yarden, 2008; Christidou, 2006).

The absence of notable grade-level differences in situational interest is consistent with two possible explanations. First, the decline in interest is more pronounced across larger age gaps (e.g. sixth versus ninth grade) than between the eighth and ninth grades examined here (Potvin & Hasni, 2014b; Steidtmann et al., 2023). Second, the teaching module topics in both studies were likely novel to students in both grades (D. Palmer et al., 2016): oscillations are often omitted or superficially covered in eighth-grade physics due to time constraints, and most ninth-grade participants in Study 2 had not yet encountered the thermodynamics content presented. In the only case in which ninth-grade students showed higher situational interest, the experiment involved was more labour- and thought-intensive than other instructional activities. For these students, the activity may have been more relevant, being more clearly connected to their current curriculum, whereas eighth-grade students may have viewed it as less relevant given that

the topic would not be addressed that year (Eccles & Wigfield, 2002). This interpretation points to perceived relevance as a potential explanatory factor rather than an independent effect.

The absence of a consistent association between situational interest and the perceived relevance of physics in general could imply that students who do not perceive physics to be relevant can still be situationally interested in physics lessons. From a theoretical perspective, perceiving physics as relevant may support the development of individual interest and the perception that activities in physics lessons are relevant (Priniski et al., 2018). However, the direction of this relationship cannot be inferred from my study design.

It is unsurprising that individual interest was associated with situational interest, given their theoretical connection (Hidi & Renninger, 2006) and the findings of previous studies (Harackiewicz et al., 2008; Tsai et al., 2008). The results here, however, are only partly consistent with previous results, which found that individual interest predicts situational interest at the start of a lesson and in the absence of a situationally arousing event (Rotgans & Schmidt, 2018). Like with the absence of grade-level differences, it is possible that the novelty of the situation (a different teacher, participating in a study, using tablets) had such an effect on students that their differences in levels of individual interest were insignificant. The instability of early estimates may also reflect this heightened novelty. In addition to novelty, other unmeasured variables, such as autonomy or self-efficacy, may have had a stronger association with situational interest, potentially reducing the effect of individual interest if included.

Still, reconciling my results with the second finding of Rotgans and Schmidt is difficult, as I expect that experiment-related activities were the most situationally arousing activities students could engage in. Although a consistent association between individual interest and experiment-related activities was not confirmed, it is plausible that students with higher individual interest in physics have had more positive prior experiences with experiments, making them more engaged in subsequent ones. Prior research suggests that students with more experience in experiment-related activities often report higher interest in them (Holstermann et al., 2010), though this was not true for all the studied activities. Similarly, parents of children with a strong interest in science have suggested that this interest often stems from conducting experiments (D. Cheung, 2018).

5.2. The complex nature of instructional activities

The findings concerning instructional activities are challenging to interpret. It appears that the effect of instructional activities is minor compared to the situation-specific learner characteristics, while many studies have found that instructional activities can influence situational interest (Logan & Skamp, 2013; D. Palmer et al., 2017; Renninger et al., 2019). The samples were not large enough to detect very small effects, suggesting that any such differences were modest. This does

not mean that the choice of activity is irrelevant; rather, the studies' contexts need closer examination.

In Study 1, students worked within a relatively uniform instructional setting in which experiments, listening, and answering worksheet questions were closely intertwined. Although these were different activities, the overall setting hardly changed. Thus, it makes sense that the only clear difference was between engaging and not engaging in instructional activities. Disengagement was more likely linked to factors such as low relevance (Kotkas et al., 2016; Zayac et al., 2021) or low challenge (van Tilburg & Igou, 2012) than to the activity type.

In Study 2, the modules had clearer sections of theory, calculations, and experimenting. The lower situational interest associated with solving worksheet problems in Module 1 is less straightforward to explain. This was a recurring activity, and students may have experienced too much of it at once and too little variance in the problems (D. Palmer, 2009). Meanwhile, the experiment-related activities of Module 2 are easy to explain, since they were in stark contrast to the rest of the module. The experiment used novel instruments, was very interactive and provided a reward, (frozen juice) at the end; qualities associated with increased interest (Guo & Fryer, 2025; Renninger et al., 2019). Given the contrast between the experiment and the previous instructional activities, it would have been surprising if the experiment did not stand out.

The climate change module resembled Study 1's oscillations module, as activities were often intertwined rather than strictly sequential. Such overlap may have diluted measurable differences in interest. Nevertheless, students appeared capable of distinguishing among activities, as reflected in differences in perceived effort and challenge. A similar pattern was observed in Study 1, where the activities varied, but the lesson setting changed little. Although the overall setting remained relatively stable in Study 2, thermodynamics and atomic-level phenomena are considerably more abstract and less familiar than pendulums or climate change (Kesidou & Duit, 1993), which may have made the sections feel more distinct. The only clearly differentiated activity contrast in Study 3 can be explained similarly to the experiment-related effect in Study 2 Module 2: the contrast between the activities was stark, reflecting a shift in setting from a teacher-led discussion to complete student autonomy (Renninger et al., 2019).

In conclusion, it appears that choosing a specific instructional activity with the goal of increasing students' situational interest may not be a particularly effective strategy. Rather, instructional activities appear to function as the means through which interest is connected to learner characteristics and through which the students experience the content and context of the learning material. Thus, it may be more beneficial for teachers to focus on refining the activities they already use in lessons: enhancing their relevance and making them appropriately challenging for the students. At the same time, varying instructional activities remains important for maintaining students' situational interest and helping it develop into individual interest (Mirlohi & Herman, 2024; D. Palmer, 2009; Tan et al., 2023).

5.3. The effect of situation-specific learner characteristics

It appears that the perceived relevance of an activity might not be as important as the other learner characteristics in supporting situational interest at the beginnings of teaching modules. However, to confirm this hypothesis, perceived relevance should be measured in tandem with the other characteristics, as well as other possible factors such as novelty and autonomy. In addition to the modules' beginnings, one situation stood out from the others during the teaching modules that merits discussion: Module 2 Occasion 3. There was a strong association between perceived relevance and situational interest, but the content on this occasion seemed to offer limited affective stimulation (Renninger & Hidi, 2011). The learning tasks on this occasion relied primarily on definitions, explanations, and straightforward calculations, lacking the visual or conceptual elements present earlier in the module. In this context, perceived relevance appeared to primarily support the value component of situational interest (Krapp, 1993). This illustrates the value of a core feature of coherent science instruction: establishing a need-to-know (Hanuscin et al., 2016). Many essential aspects of science cannot be made engaging through visuals or narrative, yet they are critical for future learning. Making their importance clear can maintain student engagement until the learning goals are achieved. Overall, the association between situational interest and perceived relevance was in line with previous findings (Linnenbrink-Garcia et al., 2013; Priniski et al., 2018; Renninger et al., 2019). Still, due to the considerable overlap of interest and relevance (Renninger & Hidi, 2011; Stuckey et al., 2013) and the single-item approach of the study, it cannot be ruled out that if situational interest had been operationalised as a compound construct consisting of separate items for the affect, knowledge and value components, as suggested by Potvin et al. (2022), the association with perceived relevance would have been diminished.

The few occasions where challenge was associated with situational interest were characterised by teacher-guided structures and relatively limited task demands. These situations may have differentiated students more in their experience of challenge, with some students possibly perceiving too little of it (Tan et al., 2023). However, these occasions did not otherwise differ systematically from the remaining lessons, limiting stronger conclusions. Abuhamdeh and Csikszentmihalyi (2011) hypothesised that the significance of challenge might not be detected if the full range of activities is examined, as we did. It is very possible that we failed to register any significant influences of challenge due to not meeting some criteria (Nuutila et al., 2021; Renninger et al., 2019).

No consistent pattern emerged that would explain the occasions where effort was not associated with situational interest. Although increases in effort coincided with higher situational interest in some lessons, this pattern was not replicated consistently across modules. One possible explanation is that the relation between situational interest and effort-by-allocation is non-linear, although this is an assumption given the lack of evidence. In addition, it should be kept in mind that

while I included effort in the models as a predictor of interest, a causal relationship cannot be inferred (J. Song et al., 2019). Still, understanding how situational interest and effort allocation affect each other is valuable for both teachers and researchers (Dietrich et al., 2017).

Across the teaching modules, perceived skills showed a strong and consistent association with situational interest. However, I did not specifically compare the interest levels of students with high perceived skills versus low perceived skills. While on the majority of occasions, the significance of skills was very high, one occasion showed a weaker association, coinciding with the highest perceived challenge level in the module. This pattern raises the possibility that some students may have entered a state of flow, in which linear relations between skills, prior interest, and situational interest may no longer apply (Bricteux et al., 2017; Schneider et al., 2016). To test this hypothesis, time-series models could be used to better analyse how situational interest, challenge, and skills change over time and when the skills–challenge balance is appropriate for the emergence of flow. Overall, these findings extend earlier work by suggesting that the skills-interest relationship may be continuous across classroom situations, rather than being limited to specific moments (Chen & Darst, 2002; Lee et al., 2023). In addition, the observed relationship suggests that skills should be taken into account in future studies focusing on situational interest.

5.4. Previous situational interest and its development

The association between previous and subsequent situational interest is consistent with previous findings (Rotgans & Schmidt, 2011a). The exceptions observed at the end of Studies 2 and 3 may be explained by their distinct nature. In these situations, heightened autonomy and novelty may have been sufficient to elevate situational interest regardless of its prior level (Renninger et al., 2019). In contrast, the third exception observed in Study 2 suggests a different mechanism: students felt interested only when they perceived the activity to be relevant, despite previous interest levels. Taken together, these occasions may represent affective or value-related extremes that temporarily disrupt the otherwise stable dependence of situational interest at its prior level.

Regarding the development of situational interest, the results of Study 2 were most in line with previous findings (Rotgans & Schmidt, 2017b), whereas the results of Studies 1 and 3 conflicted with them. It is possible that the teaching modules in those studies managed to consistently maintain the situational interest of the students, whereas Study 2 did not (Renninger & Hidi, 2011). This suggests that situational interest may be more stable across lessons when instructional activities are perceived as coherent, and more variable when students encounter sharper contrasts between activities. However, these trends do not reflect development at the individual level, which may differ considerably from the general patterns.

6. CONCLUSION

The aim of my thesis was to examine how the factors that teachers can influence are associated with situational interest in physics classrooms. To address this, three studies were designed within the framework of coherent science instruction, using the experience sampling method with lower and upper secondary students in Estonia and Finland. The aim was divided into four research questions, focusing on background and situational learner characteristics, instructional activities, the dependence of subsequent situational interest on previous levels of it, and the development of situational interest.

Studies 1 and 2 showed that gender, grade, and the perceived relevance of physics as a subject had little, if any, association with Estonian students' situational interest in physics lessons, whereas individual interest was associated with situational interest in numerous situations. The insignificance of gender aligned with PISA findings, the effects of grade could be explained by novelty, and the weak role of perceived relevance of physics in general is explained by its indirect connection with situational interest. Unlike previous studies, where individual interest quickly lost its importance once lessons began, it remained influential at the end of two teaching modules and throughout Study 1. I hypothesised a possible link between individual interest and experiment-related activities; although not supported by my data, this has been suggested in other studies.

Findings about instructional activities were mixed: only Study 2 showed consistent differences in situational interest, and strong contrasts such as engaging versus not engaging yielded some significant differences in Study 1 as well. Overall, instructional activities seemed to exert, at most, an indirect influence on situational interest, though varying them is still important. Challenge was largely insignificant, likely because the study did not create suitable conditions to detect an effect. Effort was associated with situational interest on most but not all occasions, hinting at a possible non-linear relationship between effort and situational interest. Both the perceived relevance of activities and skills were consistently associated with situational interest. Relevance seemed to be less important at the beginnings of lessons. Findings on skills echoed earlier studies, but one occasion suggested that skills' association with situational interest may weaken when students enter a state of flow.

As in previous studies, situational interest was consistently associated with its previous levels. The few exceptions may reflect occasions where either the affective or value component of situational interest dominated, which might not follow the usual developmental pattern during lessons. The development of situational interest showed a stable or upwards trend in Studies 1 and 3, and a downwards trend in Study 2 – the only case aligning with earlier findings. Although only a hypothesis, this could suggest that Studies 1 and 3 were more successful in sustaining students' situational interest across modules.

6.1. Implications

The theoretical implications of my thesis concern situational interest in classroom settings. While the link between relevance and interest was already established, my thesis adds insights into how effort, challenge, and skills affect situational interest. The effects of effort and challenge were less clear, but the importance of skills was evident and should be considered in research on situational interest in science lessons. The development of situational interest in classrooms has received little attention so far, and my results both support and challenge earlier findings, thereby complementing existing knowledge. I emphasised the role of previous situational interest in its association with subsequent levels, but also showed occasions where it has little effect. Moreover, I demonstrated that situational interest does not necessarily decline as students' knowledge gaps are filled. Finally, individual interest should not be seen as important only until students encounter a sufficiently engaging problem, since it can continue to support situational interest throughout a lesson.

The practical implications of my thesis relate to the designed teaching modules. The modules and their structure offered concrete examples of the coherent science instruction framework in practice: how to establish a need-to-know and what kinds of rich phenomena can be used for exploration. The modules of Study 2 provided numerous examples of how to make the relevance of topics explicit through the HIKU sections in the appendix of Article II, which may serve as inspiration for other teachers. In addition, I showed that some instructional activities, such as calculations in Study 2 Module 2, benefit more than others from being made explicitly relevant, such as the subsequent experiment-related activity. Since teachers' time and resources are limited, these findings suggest what should be prioritised when selecting and designing instructional activities. Both the theoretical and practical implications could be of particular use in teacher education, as teachers in training are likely more susceptible to new ideas than teachers who already have developed their own way of teaching. The HIKU sections and examples of coherent science instruction may give novice teachers a concrete starting point when planning their lessons, while the theoretical implications highlight that situational interest is shaped by more than the activities themselves.

6.2. Limitations

The studies have a number of limitations regarding the samples and data collection, limiting generalisability. The samples of Studies 1 and 2 involved students with various levels of academic achievement and interest in physics, but the programme from which we obtained our sample was voluntary and aimed at students interested in physics. This likely meant that students already interested in physics were more represented than those who were not. A similar situation occurred with the sample of Study 3. The Finnish students were from schools known for higher

academic achievement, and the teachers involved in designing and teaching the teaching modules were also likely more motivated than the average teacher. In addition, Estonian and Finnish students are culturally very similar and show similar attitudes towards science (OECD, 2016). This was helpful when comparing the studies, but it also means that results from students in China, Germany, or the US would probably differ. A small discrepancy between the studies was the age of the students, which limited comparability. However, this was not a major problem considering that Studies 1 and 2, involving eighth- and ninth-grade students, took place in spring, while Study 3, involving tenth-grade students, mostly took place in autumn. Regarding the development of situational interest, the results should be interpreted with caution, as comparisons of mean scores across measurement occasions describe changes in group-level averages rather than within-person development.

Some of the methods I used are parametric (ANOVA, Tukey's test, linear regression), and some are not (Mann-Whitney U-test, Kendall's Tau correlation). Likert items are in essence ordinal, meaning that the response levels have a specific order, but equal distancing between these levels is debatable and depends on using an odd- or even-numbered scale (Joshi et al., 2015). In a strict sense, non-parametric methods should be used for ordinal and nominal data, but Norman (2010) argued that parametric tests are robust against violations of the assumptions made about the data used in parametric tests. He states that using either option is not wrong, but using non-parametric tests leads to a loss of information due to their overly conservative nature. I also tried using t-tests and Pearson correlation but ended up with largely the same results. Thus, my approach is somewhat of a mix of the two schools of thought, which is not necessarily a perfect approach but it was carried over into the following studies. This can be considered as a weak point of the thesis, although, as stated, it has not led to false positive results but rather more conservative ones.

The validity and reliability of the instruments were likely the biggest limitation of my thesis. As Potvin et al. (2022) pointed out, situational interest scales with one or a few items are unlikely to capture all possible dimensions of situational interest. The same applies to the other variables. However, the experience sampling method limits how many items can be included to measure the constructs as close to the situation of interest as possible. It could be argued that adding a few more items for situational interest would not significantly increase the burden on respondents. Yet the burden escalates quickly if multiple constructs are measured simultaneously, as in Study 3. The results showed that including the other constructs was crucial for identifying what affected situational interest in different situations. I could assess the validity of my items to some extent through correlations with other variables, but I could not assess their reliability, as the necessary tools are still being developed (Dejonckheere et al., 2022; Eisele et al., 2025). These issues should be kept in mind when interpreting the results.

Future studies on situational interest should aim to include the significant variables identified in my thesis (previous situational interest, individual interest, relevance of the activity, challenge, effort, and skills) within a single model to observe their combined effect. This approach could make some situations that were otherwise difficult to explain, such as Study 2 Module 2 Occasion 4, easier to interpret. It could also clarify the beginnings of lessons, since model fit indices on the first occasions of Study 3 were considerably better than those of Studies 1 and 2. Coupled with knowledge of the content, context, and instructional activities used on the measured occasions, such a combined model would have great potential for describing what is happening in students' minds during science lessons. A more precise model would also allow instructional activities to be analysed in greater detail to determine which components exert the strongest influence on situational interest or other variables. Finally, studies utilising the experience sampling method should consider applying the emerging tools for assessing the reliability of items to strengthen their findings.

BIBLIOGRAPHY

- Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education*, 30(14), 1945–1969. <https://doi.org/10.1080/09500690701749305>
- Abrahams, I., & Reiss, M. J. (2012). Practical work: Its effectiveness in primary and secondary schools in England. *Journal of Research in Science Teaching*, 49(8), 1035–1055. <https://doi.org/10.1002/tea.21036>
- Abuhamdeh, S., & Csikszentmihalyi, M. (2011). The importance of challenge for the enjoyment of intrinsically motivated, goal-directed activities. *Personality and Social Psychology Bulletin*. <https://doi.org/10.1177/0146167211427147>
- Ainley, M., Hidi, S. E., & Berndorff, D. (2002). Interest, learning, and the psychological processes that mediate their relationship. *Journal of Educational Psychology*, 94(3), 545–561. <https://doi.org/10.1037/0022-0663.94.3.545>
- Alexander, P. A., Jetton, T. L., & Kulikowich, J. M. (1995). Interrelationship of knowledge, interest, and recall: Assessing a model of domain learning. *Journal of Educational Psychology*, 87(4), 559–575. <https://doi.org/10.1037/0022-0663.87.4.559>
- Archer, L., Moote, J., & MacLeod, E. (2020). Learning that physics is not for me: Pedagogic work and the cultivation of habitus among advanced level physics students. *Journal of the Learning Sciences*, 29(3), 347–384. <https://doi.org/10.1080/10508406.2019.1707679>
- Baram-Tsabari, A., & Yarden, A. (2008). Girls biology, boys physics: Evidence from freechoice science learning settings. *Research in Science & Technological Education*, 26(1), 75–92. <https://doi.org/10.1080/02635140701847538>
- Blotnicky, K. A., Franz-Odenaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM Education*, 5(1), 22. <https://doi.org/10.1186/s40594-018-0118-3>
- Bricteux, C., Navarro, J., Ceja, L., & Fuerst, G. (2017). Interest as a moderator in the relationship between challenge/skills balance and flow at work: An analysis at within-individual level. *Journal of Happiness Studies*, 18(3), 861–880. <https://doi.org/10.1007/s10902-016-9755-8>
- Broeckelman-Post, M. A., Tacconelli, A., Guzmán, J., Rios, M., Calero, B., & Latif, F. (2016). Teacher misbehavior and its effects on student interest and engagement. *Communication Education*, 65(2), 204–212. <https://doi.org/10.1080/03634523.2015.1058962>
- Broman, K., Bernholt, S., & Christensson, C. (2022). Relevant or interesting according to upper secondary students? Affective aspects of context-based chemistry problems. *Research in Science & Technological Education*, 40(4), 478–498. <https://doi.org/10.1080/02635143.2020.1824177>
- Burns, R. B., & Anderson, L. W. (1987). The activity structure of lesson segments. *Curriculum Inquiry*, 17(1), 31–53. <https://doi.org/10.1080/03626784.1987.11075276>
- Carreño, M. J., Castro-Alonso, J. C., & Gallardo, M. J. (2022). Interest in physics after experimental activities with a mobile application: Gender differences. *International Journal of Science and Mathematics Education*, 20(8), 1841–1857. <https://doi.org/10.1007/s10763-021-10228-4>

- Çava, B., Çava, P., & Yılmaz, Y. Ö. (2023). Problem-Solving in science and technology education. In B. Akpan, B. Çava, & T. Kennedy (Eds.), *Contemporary issues in science and technology education* (pp. 253–265). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-24259-5_18
- Chen, A., & Darst, P. W. (2002). Individual and situational interest: The role of gender and skill. *Contemporary Educational Psychology*, 27(2), 250–269. <https://doi.org/10.1006/ceps.2001.1093>
- Chen, A., Darst, P. W., & Pangrazi, R. P. (2001). An examination of situational interest and its sources. *British Journal of Educational Psychology*, 71(3), 383–400. <https://doi.org/10.1348/000709901158578>
- Cheung, D. (2018). The key factors affecting students individual interest in school science lessons. *International Journal of Science Education*, 40(1), 1–23. <https://doi.org/10.1080/09500693.2017.1362711>
- Cheung, K. K. C., & Sonkqayi, G. (2025). Students science achievement in cognitive domains: Effects of practical work and clarity of instruction. *Research in Science & Technological Education*, 43(1), 191–208. <https://doi.org/10.1080/02635143.2023.2261014>
- Christidou, V. (2006). Greek students sciencerelated interests and experiences: Gender differences and correlations. *International Journal of Science Education*, 28(10), 1181–1199. <https://doi.org/10.1080/09500690500439389>
- Christidou, V. (2011). Interest, attitudes and images related to science: Combining students voices with the voices of school science, teachers, and popular science. *International Journal of Environmental and Science Education*, 6(2), 141–159. <http://files.eric.ed.gov/fulltext/EJ944846.pdf>
- Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112(1), 155–159. <https://doi.org/10.1037/0033-2909.112.1.155>
- Cologna, V., Mede, N. G., Berger, S., Besley, J., Brick, C., Joubert, M., Maibach, E. W., Mihelj, S., Oreskes, N., Schäfer, M. S., van der Linden, S., Abdul Aziz, N. I., Abdulsalam, S., Shamsi, N. A., Aczel, B., Adinugroho, I., Alabrese, E., Aldoh, A., Alfano, M., ... Zwaan, R. A. (2025). Trust in scientists and their role in society across 68 countries. *Nature Human Behaviour*, 9(4), 713–730. <https://doi.org/10.1038/s41562-024-02090-5>
- Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper & Row. https://www.researchgate.net/publication/224927532_Flow_The_Psychology_of_Optimal_Experience
- Csikszentmihalyi, M., & Larson, R. (1987). Validity and reliability of the experience-sampling method. *The Journal of Nervous and Mental Disease*, 175(9), 526. https://journals.lww.com/jonmd/abstract/1987/09000/validity_and_reliability_of_the.4.aspx
- Deci, E. L. (1992). The relation of interest to the motivation of behavior: A self-determination theory perspective. In K. A. Renninger, S. E. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 43–69). Psychology Press.
- Dejonckheere, E., Demeyer, F., Geusens, B., Piot, M., Tuerlinckx, F., Verdonck, S., & Mestdagh, M. (2022). Assessing the reliability of single-item momentary affective measurements in experience sampling. *Psychological Assessment*, 34(12), 1138–1154. <https://doi.org/10.1037/pas0001178>
- Dejonckheere, E., & Erbas, Y. (2021). Designing an experience sampling study. In I. Myin-Germeyns & P. Kuppens (Eds.), *The open handbook of experience sampling methodology: A step-by-step to designing, conducting, and analyzing ESM studies*

- (pp. 33–70). Center for Research on Experience Sampling Ambulatory Methods Leuven. <https://research.tilburguniversity.edu/en/publications/designing-an-experience-sampling-study>
- Dietrich, J., Viljaranta, J., Moeller, J., & Kracke, B. (2017). Situational expectancies and task values: Associations with students' effort. *Learning and Instruction, 47*, 53–64. <https://doi.org/10.1016/j.learninstruc.2016.10.009>
- Dillon, J. (2008). *A review of the research on practical work in school science* (A report commissioned by the Royal Society). Kings College. https://www.academia.edu/35007091/A_Review_of_the_Research_on_Practical_Work_in_School_Science
- Duncan, R. G., Krajcik, J. S., & Rivet, A. E. (2016). *Disciplinary core ideas: Reshaping teaching and learning*. National Science Teachers Association Press.
- Dunlosky, J., Badali, S., Rivers, M. L., & Rawson, K. A. (2020). The role of effort in understanding educational achievement: Objective effort as an explanatory construct versus effort as a student perception. *Educational Psychology Review, 32*(4), 1163–1175. <https://doi.org/10.1007/s10648-020-09577-3>
- Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*(1), 109–132. <https://doi.org/10.1146/annurev.psych.53.100901.135153>
- Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, 61*, 101859. <https://doi.org/10.1016/j.cedpsych.2020.101859>
- Eilks, I., Nielsen, J. A., & Hofstein, A. (2014). Learning about the role and function of science in public debate as an essential component of scientific literacy. In C. Bruguière, A. Tiberghien, & P. Clément (Eds.), *Topics and trends in current science education: 9th ESERA conference selected contributions* (pp. 85–100). Springer Netherlands. https://doi.org/10.1007/978-94-007-7281-6_6
- Eisele, G., Hiekkaranta, A., Kunkels, Y. K., Rot, M. a. h., van Ballegooijen, W., Bartels, S. L., Bastiaansen, J. A., Beymer, P. N., Bylsma, L. M., Carpenter, R. W., Ellison, W. D., Fisher, A. J., Forkmann, T., Frumkin, M. R., Fulford, D., Naragon-Gainey, K., Greene, T., Heininga, V. E., Jones, A., ... Kirtley, O. J. (2025). ESM-Q: A consensus-based quality assessment tool for experience sampling method items. *Behavior Research Methods, 57*(4), 124. <https://doi.org/10.3758/s13428-025-02626-1>
- Eisele, G., Kasanova, Z., & Houben, M. (2021). Questionnaire design and evaluation. In I. Myin-Germeys & P. Kuppens (Eds.), *The open handbook of experience sampling methodology: A step-by-step to designing, conducting, and analyzing ESM studies* (pp. 71–90). Center for Research on Experience Sampling Ambulatory Methods Leuven.
- Eisele, G., Vachon, H., Lafit, G., Kuppens, P., Houben, M., Myin-Germeys, I., & Viechtbauer, W. (2022). The effects of sampling frequency and questionnaire length on perceived burden, compliance, and careless responding in experience sampling data in a student population. *Assessment, 29*(2), 136–151. <https://doi.org/10.1177/1073191120957102>
- Feinstein, N. W., & Kirchgasser, K. L. (2015). Sustainability in science education? How the next generation science standards approach sustainability, and why it matters. *Science Education, 99*(1), 121–144. <https://doi.org/10.1002/sce.21137>

- Feldon, D. F., Callan, G., Juth, S., & Jeong, S. (2019). Cognitive load as motivational cost. *Educational Psychology Review*, *31*(2), 319–337. <https://doi.org/10.1007/s10648-019-09464-6>
- Fortus, D., & Krajcik, J. S. (2012). Curriculum coherence and learning progressions. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 783–798). Springer. https://doi.org/10.1007/978-1-4020-9041-7_52
- Fryer, L. K., & Shum, A. (2025). Math task experiences and motivation to learn more: How prior knowledge and interest interact with Task-Interest & Task-Difficulty perceptions and feed a desire to reengage. *British Educational Research Journal*, *51*(1), 49–72. <https://doi.org/10.1002/berj.4057>
- Fulmer, S. M., & Tulis, M. (2013). Changes in interest and affect during a difficult reading task: Relationships with perceived difficulty and reading fluency. *Learning and Instruction*, *27*, 11–20. <https://doi.org/10.1016/j.learninstruc.2013.02.001>
- Gogol, K., Brunner, M., Goetz, T., Martin, R., Ugen, S., Keller, U., Fischbach, A., & Preckel, F. (2014). My questionnaire is too long! The assessments of motivational-affective constructs with three-item and single-item measures. *Contemporary Educational Psychology*, *39*(3), 188–205. <https://doi.org/10.1016/j.cedpsych.2014.04.002>
- Golke, S., & Wittwer, J. (2024). Informative narratives increase students situational interest in science topics. *Learning and Instruction*, *93*(101973), 101973. <https://doi.org/10.1016/j.learninstruc.2024.101973>
- Grund, A., Fries, S., Nückles, M., Renkl, A., & Roelle, J. (2024). When is learning effortful? Scrutinizing the concept of mental effort in cognitively oriented research from a motivational perspective. *Educational Psychology Review*, *36*(1), 1–24. <https://doi.org/10.1007/s10648-024-09852-7>
- Guo, Z., & Fryer, L. K. (2025). What really elicits learners situational interest in learning activities: A scoping review of six most commonly researched types of situational interest sources in educational settings. *Current Psychology*, *44*(1), 587–601. <https://doi.org/10.1007/s12144-024-07176-x>
- Habig, S., Blankenburg, J., van Vorst, H., Fechner, S., Parchmann, I., & Sumfleth, E. (2018). Context characteristics and their effects on students situational interest in chemistry. *International Journal of Science Education*, *40*(10), 1154–1175. <https://doi.org/10.1080/09500693.2018.1470349>
- Hammann, M., Jördens, J., & Büschgens, D. (2020). Students situational interest in cultivated plants: The importance of contextualisation and topic selection. *International Journal of Science Education*, *42*(16), 2765–2799. <https://doi.org/10.1080/09500693.2020.1836430>
- Hammar Chiriatic, E. (2014). Group work as an incentive for learning students' experiences of group work. *Frontiers in Psychology*, *5*, 558. <https://doi.org/10.3389/fpsyg.2014.00558>
- Hanuscin, D., Lipsitz, K., Cisterna-Albuquerque, D., Arnone, K. A., van Garderen, D., de Araujo, Z., & Lee, E. J. (2016). Developing coherent conceptual storylines: Two elementary challenges. *Journal of Science Teacher Education*, *27*(4), 393–414. <https://doi.org/10.1007/s10972-016-9467-2>

- Harackiewicz, J. M., Durik, A. M., Barron, K. E., Linnenbrink-Garcia, L., & Tauer, J. M. (2008). The role of achievement goals in the development of interest: Reciprocal relations between achievement goals, interest, and performance. *Journal of Educational Psychology, 100*(1), 105–122. <https://doi.org/10.1037/0022-0663.100.1.105>
- Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest matters: The importance of promoting interest in education. *Policy Insights from the Behavioral and Brain Sciences, 3*(2), 220–227. <https://doi.org/10.1177/2372732216655542>
- Häussler, P. (1987). Measuring students interest in physics design and results of a cross-sectional study in the Federal Republic of Germany. *International Journal of Science Education, 9*(1), 79–92. <https://doi.org/10.1080/0950069870090109>
- Häussler, P., Hoffman, L., Langeheine, R., Rost, J., & Sievers, K. (1998). A typology of students interest in physics and the distribution of gender and age within each type. *International Journal of Science Education, 20*(2), 223–238. <https://doi.org/10.1080/0950069980200207>
- Häussler, P., & Hoffmann, L. (2000). A curricular frame for physics education: Development, comparison with students' interests, and impact on students' achievement and self-concept. *Science Education, 84*(6), 689–705. [https://doi.org/10.1002/1098-237X\(200011\)84:6<689::AID-SCE1>3.0.CO;2-L](https://doi.org/10.1002/1098-237X(200011)84:6<689::AID-SCE1>3.0.CO;2-L)
- Hecht, C. A., Grande, M. R., & Harackiewicz, J. M. (2021). The role of utility value in promoting interest development. *Motivation Science, 7*(1), 1–20. <https://doi.org/10.1037/mot0000182>
- Hektner, J. M., Schmidt, J. A., & Csikszentmihalyi, M. (2007). *Experience sampling method: Measuring the quality of everyday life*. Sage.
- Hidi, S. E. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*(4), 549–571. <https://doi.org/10.3102/00346543060004549>
- Hidi, S. E. (2006). Interest: A unique motivational variable. *Educational Research Review, 1*(2), 69–82. <https://doi.org/10.1016/j.edurev.2006.09.001>
- Hidi, S. E., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4
- Hidi, S. E., Renninger, K. A., & Krapp, A. (2004). Interest, a motivational variable that combines affective and cognitive functioning. In Y. Dai & R. J. Sternberg (Eds.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 89–115). Lawrence Erlbaum Associates. <https://www.taylorfrancis.com/books/9781135624491/chapters/10.4324/9781410610515-11>
- Himmelstein, P. H., Woods, W. C., & Wright, A. G. C. (2019). A comparison of signal- and event-contingent ambulatory assessment of interpersonal behavior and affect in social situations. *Psychological Assessment, 31*(7), 952–960. <https://doi.org/10.1037/pas0000718>
- Hoch, E., Sidi, Y., Ackerman, R., Hoogerheide, V., & Scheiter, K. (2023). Comparing mental effort, difficulty, and confidence appraisals in problem-solving: A metacognitive perspective. *Educational Psychology Review, 35*(2), 61. <https://doi.org/10.1007/s10648-023-09779-5>
- Hoffmann, L. (2002). Promoting girls' interest and achievement in physics classes for beginners. *Learning and Instruction, 12*(4), 447–465. [https://doi.org/10.1016/S0959-4752\(01\)00010-X](https://doi.org/10.1016/S0959-4752(01)00010-X)
- Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-on activities and their influence on students interest. *Research in Science Education, 40*(5), 743–757. <https://doi.org/10.1007/s11165-009-9142-0>

- Jenkins, E. W., & Nelson, N. W. (2005). Important but not for me: Students attitudes towards secondary school science in England. *Research in Science & Technological Education*, 23(1), 41–57. <https://doi.org/10.1080/02635140500068435>
- Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology*, 7(4), 8. <https://doi.org/10.9734/BJAST/2015/14975>
- Kang, H., Scharmman, L. C., Kang, S., & Noh, T. (2010). Cognitive conflict and situational interest as factors influencing conceptual change. *International Journal of Environmental and Science Education*, 5(4), 383–405. <https://digitalcommons.unl.edu/teachlearnfacpub/379/>
- Kang, J., Hense, J., Scheersoi, A., & Keinonen, T. (2019). Gender study on the relationships between science interest and future career perspectives. *International Journal of Science Education*, 41(1), 80–101. <https://doi.org/10.1080/09500693.2018.1534021>
- Kang, J., & Tolppanen, S. (2024). Exploring the role of science education as a catalyst for students willingness to take climate action. *International Journal of Science Education*, Advance online publication. <https://doi.org/10.1080/09500693.2024.2393461>
- Kearney, C. (2016). *Efforts to increase students interest in pursuing mathematics, science, and technology studies and careers. National measures taken by 30 countries* (2015 report). European Schoolnet, Brussels. https://www.educationandemployers.org/wp-content/uploads/2014/06/efforts_to_increase_interest_stem_full_report.pdf
- Kehle, L., & Urhahne, D. (2025). Interest and effort in learning and performance. *British Journal of Educational Psychology*, Advance online publication. <https://doi.org/10.1111/bjep.70040>
- Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*, 10(3), 2–10. <https://doi.org/10.1007/BF02905780>
- Keller, M., Neumann, K., & Fischer, H. E. (2017). The impact of physics teachers pedagogical content knowledge and motivation on students achievement and interest. *Journal of Research in Science Teaching*, 54(5), 586–614. <https://doi.org/10.1002/tea.21378>
- Kesidou, S., & Duit, R. (1993). Students' conceptions of the second law of thermodynamics an interpretive study. *Journal of Research in Science Teaching*, 30(1), 85–106. <https://doi.org/10.1002/tea.3660300107>
- Knogler, M., Harackiewicz, J. M., Gegenfurtner, A., & Lewalter, D. (2015). How situational is situational interest? Investigating the longitudinal structure of situational interest. *Contemporary Educational Psychology*, 43, 39–50. <https://doi.org/10.1016/j.cedpsych.2015.08.004>
- Kotkas, T., Holbrook, J., & Rannikmäe, M. (2016). Identifying characteristics of science teaching/learning materials promoting students' intrinsic relevance. *Science Education International*, 27(2), 194–216. <https://eric.ed.gov/?id=EJ1104649>
- Krajcik, J. S., & Blumenfeld, P. C. (2005). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 317–334). Cambridge University Press. <https://doi.org/10.1017/CBO9780511816833.020>
- Krajcik, J. S., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards. *Journal of Science Teacher Education*, 25(2), 157–175. <https://doi.org/10.1007/s10972-014-9383-2>

- Krapp, A. (1993). The construct of interest: Characteristics of individual interests and interest-related actions from the perspective of a person-object-theory. *Studies in Educational Psychology*, 4.
- Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European Journal of Psychology of Education*, 14(1), 23–40. <https://doi.org/10.1007/BF03173109>
- Krapp, A. (2002). Structural and dynamic aspects of interest development: Theoretical considerations from an ontogenetic perspective. *Learning and Instruction*, 12(4), 383–409. [https://doi.org/10.1016/S0959-4752\(01\)00011-1](https://doi.org/10.1016/S0959-4752(01)00011-1)
- Krapp, A., Hidi, S. E., & Renninger, K. A. (1992). Interest, learning, and development. In K. A. Renninger, S. E. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 3–27). Psychology Press. <https://doi.org/10.4324/9781315807430>
- Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, 33(1), 27–50. <https://doi.org/10.1080/09500693.2010.518645>
- Lavonen, J., Ávalos, B., Upadyaya, K., Araneda, S., & Salmela-Aro, K. (2021). Upper secondary students situational interest in physics learning in Finland and Chile. *International Journal of Science Education*, 43(16), 2577–2596. <https://doi.org/10.1080/09500693.2021.1978011>
- Lee, Y., Cho, Y. H., Park, T., & Choi, J. (2023). Situational interest during individual reading and peer reading activities using PALS: Its relationship to students reading skills and reading motivations. *Educational Studies*, 49(5), 842–860. <https://doi.org/10.1080/03055698.2021.1898341>
- Lehrer, R., & Schauble, L. (2004). Modeling natural variation through distribution. *American Educational Research Journal*, 41(3), 635–679. <https://doi.org/10.3102/00028312041003635>
- Linnenbrink-Garcia, L., Patall, E. A., & Messersmith, E. E. (2013). Antecedents and consequences of situational interest. *British Journal of Educational Psychology*, 83(4), 591–614. <https://doi.org/10.1111/j.2044-8279.2012.02080.x>
- Logan, M., & Skamp, K. (2008). Engaging students in science across the primary secondary interface: Listening to the students voice. *Research in Science Education*, 38(4), 501–527. <https://doi.org/10.1007/s11165-007-9063-8>
- Logan, M., & Skamp, K. R. (2013). The impact of teachers and their science teaching on student science interest: A four-year study. *International Journal of Science Education*, 35(17), 2879–2904. <https://doi.org/10.1080/09500693.2012.667167>
- Lyons, T. (2006). Different countries, same science classes: Students experiences of school science in their own words. *International Journal of Science Education*, 28(6), 591–613. <https://doi.org/10.1080/09500690500339621>
- Massolt, J., & Borowski, A. (2020). Perceived relevance of university physics problems by pre-service physics teachers: Personal constructs. *International Journal of Science Education*, 42(2), 167–189. <https://doi.org/10.1080/09500693.2019.1705424>
- Means, T. B., Jonassen, D. H., & Dwyer, F. M. (1997). Enhancing relevance: Embedded ARCS strategies vs. purpose. *Educational Technology Research and Development*, 45(1), 5–17. <https://doi.org/10.1007/BF02299610>
- Millar, R. (2004). *The role of practical work in the teaching and learning of science* (Paper prepared for the committee). National Academy of Sciences. https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_073330.pdf

- Mirlohi, M., & Herman, D. (2024). The role of challenge-skills balance in task engagement. In *Task engagement across disciplines*. Routledge.
- Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology*, 85(3), 424–436. <https://doi.org/10.1037/0022-0663.85.3.424>
- Mosely, G., Wright, N., & Wrigley, C. (2018). Facilitating design thinking: A comparison of design expertise. *Thinking Skills and Creativity*, 27, 177–189. <https://doi.org/10.1016/j.tsc.2018.02.004>
- Muenks, K., Miele, D. B., & Wigfield, A. (2016). How students perceptions of the source of effort influence their ability evaluations of other students. *Journal of Educational Psychology*, 108(3), 438–454. <https://doi.org/10.1037/edu0000068>
- Muthén, L. K., & Muthén, B. O. (2020). Mplus. <https://www.statmodel.com/>
- National Research Council. (2012). *A framework for K12 science education: Practices, crosscutting concepts, and core ideas* (Curriculum document). National Academies Press. <https://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states>
- Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2023). Predicting situational interest by individual interest and instructional activities in physics lessons: An experience sampling approach. *Journal of Baltic Science Education*, 22(6), 1063–1073. <https://doi.org/10.33225/jbse/23.22.1063>
- Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2025). Students' situational interest and perceived relevance during designed coherent physics learning modules. *International Journal of Science Education*, Advance online publication. <https://doi.org/10.1080/09500693.2025.2488400>
- Neito, R., Vilhunen, E., Lavonen, J., & Vesterinen, V.-M. (2025). The effect of instructional activities and collaborative tasks on interest and effort in a climate change education module. *Research in Science & Technological Education*, Advance online publication. <https://doi.org/10.1080/02635143.2025.2603291>
- Newton, D. P. (1988). *Making science education relevant*. Kogan Page.
- Nezlek, J. B. (2017). A practical guide to understanding reliability in studies of within-person variability. *Journal of Research in Personality*, 69, 149–155. <https://doi.org/10.1016/j.jrp.2016.06.020>
- Nordine, J., Sorge, S., Delen, I., Evans, R., Juuti, K., Lavonen, J., Nilsson, P., Ropohl, M., & Stadler, M. (2021). Promoting coherent science instruction through coherent science teacher education: A model framework for program design. *Journal of Science Teacher Education*, 32(8), 911–933. <https://doi.org/10.1080/1046560x.2021.1902631>
- Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education: Theory and Practice*, 15(5), 625–632. <https://doi.org/10.1007/s10459-010-9222-y>
- Nuutila, K., Tapola, A., Tuominen, H., Molnár, G., & Niemivirta, M. (2021). Mutual relationships between the levels of and changes in interest, self-efficacy, and perceived difficulty during task engagement. *Learning and Individual Differences*, 92, 102090. <https://doi.org/10.1016/j.lindif.2021.102090>
- OECD. (2016). PISA results (Volume I): Excellence and equity in education. <https://doi.org/10.1787/9789264266490-en>
- OECD. (2017). *PISA 2015 assessment and analytical framework*. <https://doi.org/10.1787/9789264281820-en>

- OECD. (2023). *PISA 2025 Science Framework* (Draft). OECD Publishing. https://pisa-framework.oecd.org/science-2025/assets/docs//PISA_2025_Science_Framework.pdf
- Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, 25(2), 177–196. <https://doi.org/10.1007/s10972-014-9384-1>
- Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (A report to the Nuffield Foundation). Kings College London. https://efepereth.wdfiles.com/local--files/science-education/Sci_Ed_in_Europe_Report_Final.pdf
- Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology*, 84(4), 429–434. <https://doi.org/10.1037/0022-0663.84.4.429>
- Paas, F., Tuovinen, J. E., van Merriënboer, J. J. G., & Aubteen Darabi, A. (2005). A motivational perspective on the relation between mental effort and performance: Optimizing learner involvement in instruction. *Educational Technology Research and Development*, 53(3), 25–34. <https://doi.org/10.1007/BF02504795>
- Palmer, D. (2007). What is the best way to motivate students in science? *Teaching Science: The Journal of the Australian Science Teachers Association*, 53(1), 38–42. <https://research.ebsco.com/linkprocessor/plink?id=6bb4f4f3-ff9b-34d6-ad80-8b59f8b27193>
- Palmer, D. (2009). Student interest generated during an inquiry skills lesson. *Journal of Research in Science Teaching*, 46(2), 147–165. <https://doi.org/10.1002/tea.20263>
- Palmer, D., Dixon, J., & Archer, J. (2016). Identifying underlying causes of situational interest in a science course for preservice elementary teachers. *Science Education*, 100(6), 1039–1061. <https://doi.org/10.1002/sce.21244>
- Palmer, D., Dixon, J., & Archer, J. (2017). Using situational interest to enhance individual interest and science-related behaviours. *Research in Science Education*, 47(4), 731–753. <https://doi.org/10.1007/s11165-016-9526-x>
- Palmer, T.-A., Burke, P. F., & Aubusson, P. (2017). Why school students choose and reject science: A study of the factors that students consider when selecting subjects. *International Journal of Science Education*, 39(6), 645–662. <https://doi.org/10.1080/09500693.2017.1299949>
- Potvin, P., Ayotte-Beaudet, J.-P., Hasni, A., Smith, J., Giamellaro, M., Lin, T.-J., & Tsai, C.-C. (2022). Development and validation of a questionnaire to assess situational interest in a science period: A study in three cultural/linguistic contexts. *Research in Science Education*, 53(1), 99–120. <https://doi.org/10.1007/s11165-022-10050-0>
- Potvin, P., & Hasni, A. (2014a). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education*, 50(1), 85–129. <https://doi.org/10.1080/03057267.2014.881626>
- Potvin, P., & Hasni, A. (2014b). Analysis of the decline in interest towards school science and technology from grades 5 through 11. *Journal of Science Education and Technology*, 23(6), 784–802. <https://doi.org/10.1007/s10956-014-9512-x>
- Priniski, S. J., Hecht, C. A., & Harackiewicz, J. M. (2018). Making learning personally meaningful: A new framework for relevance research. *Journal of Experimental Education*, 86(1), 11–29. <https://doi.org/10.1080/00220973.2017.1380589>
- R Core Team. (2022). R: A language and environment for statistical computing. <https://www.R-project.org/>

- Renninger, K. A., Bachrach, J. E., & Hidi, S. E. (2019). Triggering and maintaining interest in early phases of interest development. *Learning, Culture and Social Interaction*, 23(100260), 100260. <https://doi.org/10.1016/j.lcsi.2018.11.007>
- Renninger, K. A., & Hidi, H., Suzanne E. (2002). Student interest and achievement: Developmental issues raised by a case study. In A. Wigfield & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 173–195). Academic Press. <https://doi.org/10.1016/B978-012750053-9/50009-7>
- Renninger, K. A., & Hidi, S. E. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist*, 46(3), 168–184. <https://doi.org/10.1080/00461520.2011.587723>
- Renninger, K. A., & Hidi, S. E. (2015a). Defining interest: What is interest and how has it been conceptualized and studied? In *The power of interest for motivation and engagement*. Routledge.
- Renninger, K. A., & Hidi, S. E. (2015b). *The power of interest for motivation and engagement*. Routledge. <https://doi.org/10.4324/9781315771045>
- Renninger, K. A., & Hidi, S. E. (2020). To level the playing field, develop interest. *Policy Insights from the Behavioral and Brain Sciences*, 7(1), 10–18. <https://doi.org/10.1177/2372732219864705>
- Rintala, A., Wampers, M., Myin-Germeys, I., & Viechtbauer, W. (2019). Response compliance and predictors thereof in studies using the experience sampling method. *Psychological Assessment*, 31(2), 226–235. <https://doi.org/10.1037/pas0000662>
- Romine, W., Tsai, C.-L., Miller, M., Tang, N.-E., & Folk, W. (2020). Evaluation of a process by which individual interest supports learning within a formal middle school classroom context. *International Journal of Science and Mathematics Education*, 18(7), 1419–1439. <https://doi.org/10.1007/s10763-019-10032-1>
- Rotgans, J. I., & Schmidt, H. G. (2011a). The role of teachers in facilitating situational interest in an active-learning classroom. *Teaching and Teacher Education*, 27(1), 37–42. <https://doi.org/10.1016/j.tate.2010.06.025>
- Rotgans, J. I., & Schmidt, H. G. (2011b). Situational interest and academic achievement in the active-learning classroom. *Learning and Instruction*, 21(1), 58–67. <https://doi.org/10.1016/j.learninstruc.2009.11.001>
- Rotgans, J. I., & Schmidt, H. G. (2014). Situational interest and learning: Thirst for knowledge. *Learning and Instruction*, 32, 37–50. <https://doi.org/10.1016/j.learninstruc.2014.01.002>
- Rotgans, J. I., & Schmidt, H. G. (2017a). The relation between individual interest and knowledge acquisition. *British Educational Research Journal*, 43(2), 350–371. <https://doi.org/10.1002/berj.3268>
- Rotgans, J. I., & Schmidt, H. G. (2017b). Interest development: Arousing situational interest affects the growth trajectory of individual interest. *Contemporary Educational Psychology*, 49, 175–184. <https://doi.org/10.1016/j.cedpsych.2017.02.003>
- Rotgans, J. I., & Schmidt, H. G. (2018). How individual interest influences situational interest and how both are related to knowledge acquisition: A microanalytical investigation. *The Journal of Educational Research*, 111(5), 530–540. <https://doi.org/10.1080/00220671.2017.1310710>
- Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology*, 61, 101860. <https://doi.org/10.1016/j.cedpsych.2020.101860>

- Sadler, T. D., Xu, Z., & Fortus, D. (2025). Restructuring the science curriculum around grand challenges. *International Journal of Science Education*, 47(15-16), 2093–2112. <https://doi.org/10.1080/09500693.2025.2490777>
- Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist*, 26(3-4), 299–323. <https://doi.org/10.1080/00461520.1991.9653136>
- Schneider, B., Krajcik, J. S., Lavonen, J., & Salmela-Aro, K. (2020). *Learning science - the value of crafting engagement in science environments*. Yale University Press.
- Schneider, B., Krajcik, J. S., Lavonen, J., Salmela-Aro, K., Broda, M., Spicer, J., Bruner, J., Moeller, J., Linnansaari, J., Juuti, K., & Viljaranta, J. (2016). Investigating optimal learning moments in U.S. and Finnish science classes. *Journal of Research in Science Teaching*, 53(3), 400–421. <https://doi.org/10.1002/tea.21306>
- Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia and Analgesia*, 126(5), 1763–1768. <https://doi.org/10.1213/ANE.0000000000002864>
- Shenhav, A., Musslick, S., Lieder, F., Kool, W., Griffiths, T. L., Cohen, J. D., & Botvinick, M. M. (2017). Toward a rational and mechanistic account of mental effort. *Annual Review of Neuroscience*, 40, 99–124. <https://doi.org/10.1146/annurev-neuro-072116-031526>
- Shrout, P. E., & Lane, S. P. (2012). Psychometrics. In *Handbook of research methods for studying daily life* (pp. 302–320). The Guilford Press.
- Shubina, T., Järvenoja, H., & Mänty, K. (2023). The relationship between secondary school students situational interest and their collaborative learning interactions. *SN Social Sciences*, 3(8), 1–22. <https://doi.org/10.1007/s43545-023-00738-z>
- Sikorski, T.-R., & Hammer, D. (2017). Looking for coherence in science curriculum. *Science Education*, 101(6), 929–943. <https://doi.org/10.1002/sce.21299>
- Slavin, R. E. (2014). Aprendizaje cooperativo y rendimiento académico: Por qué funciona el trabajo en grupo?[Cooperative learning and academic achievement: Why does groupwork work?] *Anales de Psicología*, 30(3), 785–791. <https://doi.org/10.6018/analesps.30.3.201201>
- Song, J., Howe, E., Oltmanns, J. R., & Fisher, A. J. (2023). Examining the concurrent and predictive validity of single items in ecological momentary assessments. *Assessment*, 30(5), 1662–1671. <https://doi.org/10.1177/10731911221113563>
- Song, J., Kim, S.-I., & Bong, M. (2019). The more interest, the less effort cost perception and effort avoidance. *Frontiers in Psychology*, 10, 2146. <https://doi.org/10.3389/fpsyg.2019.02146>
- Song, S. H., & Keller, J. M. (2001). Effectiveness of motivationally adaptive computer-assisted instruction on the dynamic aspects of motivation. *Educational Technology Research and Development*, 49(2), 5–22. <https://doi.org/10.1007/BF02504925>
- Sothayapetch, P., Lavonen, J., & Juuti, K. (2013). An analysis of science textbooks for grade 6: The electric circuit lesson. *Eurasia Journal of Mathematics, Science and Technology Education*, 9(1), 59–72. <https://doi.org/10.12973/eurasia.2013.916a>
- Steidtmann, L., Kleickmann, T., & Steffensky, M. (2023). Declining interest in science in lower secondary school classes: Quasiexperimental and longitudinal evidence on the role of teaching and teaching quality. *Journal of Research in Science Teaching*, 60(1), 164–195. <https://doi.org/10.1002/tea.21794>
- Stratton, S. K., Hagevik, R., Feldman, A., & Bloom, M. (2015). Toward a sustainable future: The practice of science teacher education for sustainability. In S. K. Stratton,

- R. Hagevik, A. Feldman, & M. Bloom (Eds.), *Educating science teachers for sustainability* (pp. 445–457). Springer International Publishing. https://doi.org/10.1007/978-3-319-16411-3_23
- Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of relevance in science education and its implications for the science curriculum. *Studies in Science Education*, 49(1), 1–34. <https://doi.org/10.1080/03057267.2013.802463>
- Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching*, 49(4), 515–537. <https://doi.org/10.1002/tea.21010>
- Tan, A. L., Gillies, R., & Jamaludin, A. (2023). Psychophysiological methods to study the triggers of interest: A Singapore case study. *Current Psychology*, 42(32), 28298–28308. <https://doi.org/10.1007/s12144-022-03936-9>
- Tapola, A., Veermans, M., & Niemivirta, M. (2013). Predictors and outcomes of situational interest during a science learning task. *Instructional Science*, 41(6), 1047–1064. <https://doi.org/10.1007/s11251-013-9273-6>
- Teppo, M., Semilarski, H., Soobard, R., & Rannikmäe, M. (2017). 9. klassi õpilaste huvi eri kontekstis esitatud loodusteaduslike teemade õppimise vastu ja motivatsioon õppida loodusteadusi [Grade nine students learning interests towards science topics presented in different contexts and their motivation to learn science]. *Eesti Haridusteaduste Ajakiri. Estonian Journal of Education*, 5(1), 130–170. <https://doi.org/10.12697/eha.2017.5.1.05>
- Teppo, M., Soobard, R., & Rannikmäe, M. (2021). Grade 6 & 9 student and teacher perceptions of teaching and learning approaches in relation to student perceived interest/enjoyment towards science learning. *Journal of Baltic Science Education*, 20(1), 119–133. <http://files.eric.ed.gov/fulltext/EJ1298193.pdf>
- Trautwein, U., Lüdtke, O., Nagy, N., Lenski, A., Niggli, A., & Schnyder, I. (2015). Using individual interest and conscientiousness to predict academic effort: Additive, synergistic, or compensatory effects? *Journal of Personality and Social Psychology*, 109(1), 142–162. <https://doi.org/10.1037/pspp0000034>
- Tsai, Y.-M., Kunter, M., Lüdtke, O., Trautwein, U., & Ryan, R. M. (2008). What makes lessons interesting? The role of situational and individual factors in three school subjects. *Journal of Educational Psychology*, 100(2), 460–472. <https://doi.org/10.1037/0022-0663.100.2.460>
- Tytler, R. (2007). Re-imagining science education: Engaging students in science for Australia's future. *Teaching Science*, 53(4), 14–17. <https://doi.org/10.3316/informit.417229511040066>
- Urhahne, D., & Wijnia, L. (2023). Theories of motivation in education: An integrative framework. *Educational Psychology Review*, 35(2), 45. <https://doi.org/10.1007/s10648-023-09767-9>
- Vachon, H., Viechtbauer, W., Rintala, A., & Myin-Germeys, I. (2019). Compliance and retention with the experience sampling method over the continuum of severe mental disorders: Meta-analysis and recommendations. *Journal of Medical Internet Research*, 21(12), e14475. <https://doi.org/10.2196/14475>
- van Tilburg, W. A. P., & Igou, E. R. (2012). On boredom: Lack of challenge and meaning as distinct boredom experiences. *Motivation and Emotion*, 36(2), 181–194. <https://doi.org/10.1007/s11031-011-9234-9>
- Van Aalsvoort, J. (2004). Activity theory as a tool to address the problem of chemistry's lack of relevance in secondary school chemical education. *International*

- Journal of Science Education*, 26(13), 1635–1651. <https://doi.org/10.1080/0950069042000205378>
- Vilhunen, E., Tang, X., Juuti, K., Lavonen, J., & Salmela-Aro, K. (2021). Instructional activities predicting epistemic emotions in Finnish upper secondary school science lessons: Combining experience sampling and video observations. In O. Levrini, G. Tasquier, T. G. Amin, L. Branchetti, & M. Levin (Eds.), *Engaging with contemporary challenges through science education research. Contributions from science education research* (pp. 317–329, Vol. 9). Springer. https://doi.org/10.1007/978-3-030-74490-8_25
- Vilhunen, E., Vesterinen, V.-M., Äijälä, M., Salovaara, J., Siponen, J., Lavonen, J., Salmela-Aro, K., & Riittanen, L. (2025). Promoting university students' situational engagement in online learning for climate education. *The Internet and Higher Education*, 65(100987), 100987. <https://doi.org/10.1016/j.iheduc.2024.100987>
- Wallace, R. M., Kupperman, J., Krajcik, J., & Soloway, E. (2000). Science on the web: Students online in a sixth-grade classroom. *Journal of the Learning Sciences*, 9(1), 75–104. https://doi.org/10.1207/s15327809jls0901_5
- Webb, N., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 841–873). Macmillan.
- Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, 25(1), 68–81. <https://doi.org/10.1006/ceps.1999.1015>
- Zayac, R. M., Poole, B. D., Gray, C., Sargent, M., Paulk, A., & Haynes, E. (2021). No Disrespect: Student and Faculty Perceptions of the Qualities of Ineffective Teachers. *Teaching of Psychology*, 48(1), 55–62. <https://doi.org/10.1177/0098628320959978>
- Zirkel, S., Garcia, J. A., & Murphy, M. C. (2015). Experience-sampling research methods and their potential for education research. *Educational Researcher*, 44(1), 7–16. <https://doi.org/10.3102/0013189X14566879>

Appendix A. A DETAILED DESCRIPTION OF THE LEARNING MODULE DESIGNED FOR STUDY 1

Learning outcomes

- Describe and characterise oscillations.
- Explain the difference between the period and frequency of an oscillation.
- Identify which parameters affect the period and frequency of oscillations.
- Use sensors and digital tools to measure periods and frequencies.
- Describe the phenomenon of resonance, its causes, and how to dampen it.
- Apply the knowledge by constructing a model skyscraper with an earthquake-dampening system.

The description of the core ideas and science and the engineering practices of the oscillations module are formed according to the module's learning outcomes. The form of the core ideas and the practices are described in line with the US NGSS (National Research Council, 2012).

Core ideas

- Forces and motion: when the past motion of an object exhibits a regular pattern, future motion can be predicted from it.
- Types of interactions: objects in contact exert forces on each other.
- Relationship between energy and forces: when two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the objects.
- Wave properties: a simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

Science and engineering practices

- Developing and using models: building a model pendulum and a high-rise building that can be adjusted.
- Planning and carrying out investigations: experiments involving pendulums.
- Analysing and interpreting data: data gathered through manual and digital measurements.
- Using mathematics and computational thinking: calculating frequency and assessing how to measure accurately.

Description

The module enables students to learn about oscillations and their characteristics through various experiments, in which they can manipulate parameters such as the mass and the weight of a pendulum. It starts with the driving question and a teacher-led introduction defining the characteristics, including periodic movement, period, frequency, and amplitude. This knowledge is reinforced by two simple multiple-choice questions. Next, students are tasked with building a pendulum using the given materials and measuring its period. They are also guided to consider how best to do this: either by measuring a single oscillation or by measuring several and dividing by the number of oscillations.

The first ESM questionnaire appears approximately during this task.

After this, they modify the pendulum by adjusting the position of the weight or using a heavier weight, and compare two pendulums side by side. The idea is for students to identify which parameters affect the oscillatory period and which do not. While the previous tasks were done with a stopwatch, the next task involves using a sensor and a graph displayed on a tablet to measure either the period or frequency. The aim here is to teach students how to use modern equipment, which can also be applied in situations too fast for manual measurement.

The second ESM questionnaire appears approximately during this task.

Next, students learn about resonance when they are asked to shake the frames to which their pendulums are fixed. The goal is to make the pendulum complete a full circular trajectory and to find a strategy for achieving this. Students should see that moving the frame with the same frequency as the pendulum's swing causes it to resonate and increase in amplitude. The effect is explained by the teacher, who also shows a short video of a real-life scenario where a newly constructed bridge was destroyed by wind-induced resonance. The topic is then directed towards earthquakes, and students briefly consider the effects of earthquakes on tall buildings such as skyscrapers.

This is approximately the time when the third ESM questionnaire appears.

At the end of the module, students build a model high-rise building and test how its height affects its resonant frequency. Finally, returning to the driving question, students apply the knowledge they have acquired to attach a pendulum to their model building and adjust it so that when it is shaken by the frame (simulating an earthquake), the pendulum counteracts the shaking and stabilises the model. The module then concludes.

ACKNOWLEDGEMENTS

This journey has been eventful, and a number of people deserve credit for helping me reach its end. The first in line are my supervisors: Kaido, Jari, and Elisa. Kaido, thank you for creating the perfect conditions for me to work on my PhD and for asking questions that kept me grounded in the teaching world! You provided me with the freedom I needed to focus on writing and worked in the shadows to keep me from getting stuck in assignments that would have derailed my progress. Jari, thank you for giving so much valuable input and feedback on my work and for urging me to attend conferences I would not have attended myself! You were the theoretical lighthouse I could always count on when I needed to navigate the sea of previous studies. Elisa, thank you for motivating me at times when the situation seemed the bleakest! The SciCar Helsinki seminar was a jumpstart for my PhD, and at the end of all our discussions on the current paper or thesis progress, I felt that things were actually going pretty well, and that I could be proud of where I am. I believe the three of you made a great supervising team, with each member giving a valuable contribution that I could not have finished without. At the same time, you let me swim enough on my own that I had to adapt and learn to make it independently.

Besides my supervisors, there were many others who made meaningful contributions to my work. Thank you, Veli-Matti, for co-authoring my third paper, helping to make sense of its data, and being a good friend along the way (and whose presentations I always love to listen to)! Thank you, Miia, for pulling me into the SciCar project, providing me with the funding to attend various conferences, and generally rooting for my progress! I also want to thank my various attestation committees and the pre-defence council for providing me with valuable feedback, but most importantly, for assuring me that I was on the right track! The reviewers of my thesis, Anna-Liisa Jõgi and Karin Täht, also deserve my sincere gratitude. Although their comments were not easy to address, and the days I spent polishing my thesis will not be remembered fondly, their feedback was invaluable in transforming my thesis into something I can be proud of.

First through the SciCar project, and later through various other events, I had the opportunity to meet many wonderful PhD students who gave me a sense of belonging in a warm community. Of my Finnish friends, I would like to thank Miikka, Anna, Inka, Perttu, and Henri! Of my Estonian friends, I would like to thank Lauri, Janari, and Marie! Furthermore, I must thank Regina for introducing and urging us to attend the ESERA Summer School, which provided one of the most awesome opportunities to meet fellow early-career researchers and ensured that there would be at least some familiar faces at all future ESERA conferences!

I would like to thank my family and closest friends for being there with me through the difficult times (of which there were quite a few). Dad will have to translate for Mom, but I do want to say that I am very grateful for the support you have provided me, not just during my PhD studies, but for the whole way!

I would like to say that this is now the end of my studies, but I cannot promise that in later years I will not decide to learn something new – perhaps how to play a musical instrument. I doubt even Mom thought her prediction about my future career choice would go that far: not just a teacher, but a PhD degree in Education. My friends deserve my thanks for listening to my rants every time I got pissed off writing articles! I think they will be quite happy that it is finally over.

Last, but surely not least, my thanks go to my wife Merli, who certainly had to endure my complaining and moments of insanity the most, but who was always there to calm me down again and who also generously offered to read through some of my work to improve it. I am very thankful for all of that, but I reckon, seeing what the process did to me, you will think at least ten times before you ever get the idea to chase a PhD yourself!

SISUKOKKUVÕTE

Õpilaste situatsioonihuvi seos õppijate omaduste ja õppetegevustega sidusas füüsikahariduses

Sissejuhatus

Õpilaste huvi loodusteaduste vastu on viimastel aastakümnetel kogu maailmas järjepidevalt vähenenud (Potvin & Hasni, 2014a). Uuringud on näidanud, et huvi kahanemine algab põhikooli teises õppeastmes ehk just siis, kui omandatakse teadmisi loodusteaduste alustalade kohta (Hidi *et al.*, 2004; Potvin & Hasni, 2014b). Niisugust suundumust on täheldatud nii loodusteadusi õppivate kui ka teiste õpilaste puhul (Steidtmann *et al.*, 2023). Huvi on õppimise seisukohalt oluline, kuna see on seotud teadmiste omandamise, pingutuse ja õpitulemuste kujunemisega (Dunlosky *et al.*, 2020; H. Kang *et al.*, 2010; Rotgans & Schmidt, 2011b). Huvi mõjutab ka edasisi haridus- ja karjäärivalikuid (Blotnicky *et al.*, 2018), mis on olulised selliste üleilmsete probleemide seisukohalt, nagu kliima soojenemine või viirusepuhangute haldamine. Nimetatud probleemide lahendamine eeldab loodusteaduste põhjalikku tundmist, mistõttu on oluline, et vähemalt osa inimestest oleks loodusteadustest piisavalt huvitatud, valimaks teadlasekarjäär (Kearney, 2016). Samuti on vajalik, et avalikkusel oleks piisav huvi ja motivatsioon loodusteaduse teemadega kursis olla, tegemaks nendes valdkondades kaalutletud otsuseid (Cologna *et al.*, 2025).

Huvi vähenemist on seostatud mitme teguriga. Loodusteadusi peetakse sageli keerulisemaks ja abstraktsemaks kui teisi õppeaineid ning õpilased ei pruugi näha seoseid koolis õpitava ja tegeliku elu vahel (Christidou, 2011; Logan & Skamp, 2008; Potvin & Hasni, 2014b). Keskne roll huvi toetamisel on õpetajal, kelle pädevus, õpetamise kvaliteet ja suhtumine oma ainesse mõjutavad oluliselt õpilaste huvi kujunemist (M. Keller *et al.*, 2017; Steidtmann *et al.*, 2023). Kui eeldada, et õpetaja on motiveeritud ja pädev, tekib küsimus, kuidas kavandada õppetööd nii, et see toetaks õpilaste huvi. Millised tegevused on õpilastele paraja raskusega ja kuidas seostada õpitut igapäevaeluga? Nendele ja teistele küsimustele vastamiseks on vaja paremini mõista seda, kuidas huvi tundides kujuneb ja muutub ning kuidas mõjutavad seda õppijate omadused ja ka õpetamispraktikad. Selline teadmine võimaldab õpetajatel kasutada oma aega teadlikumalt, et luua põnev ja toetav õpikeskkond.

Minu doktoritöö eesmärk oli selgitada välja, millised õppijatega seotud omadused ja õpetamispraktikad on seotud õpilaste situatsioonihuviga füüsikatundides. Jagasin õppijatega seotud omadused taust- ja olukorraomadusteks. Taustomadused olid õpilaste sugu, klass, isiklik huvi ja füüsika kui teaduse tajutud relevantsus. Olukorraomadused olid käesoleva tegevuse tajutud relevantsus, sellega seotud väljakutse ja oskused ning see, kui palju oldi valmis konkreetse tegevuse käigus pingutama. Õpetamispraktikatena uurisin tundides kasutatud õppetegevusi.

Minu doktoritöö uurimisküsimused olid:

1. Kuidas on sugu, klass, isiklik huvi ja füüsika kui teaduse tajutud relevantsus seotud õpilaste situatsioonihuviga?
2. Kuidas on õppetegevused, nende tajutud relevantsus ning nendega seotud pingutus, väljakutse ja oskused seotud õpilaste situatsioonihuviga?
3. Mil määral ennustab eelnev situatsioonihuvi järgnevat situatsioonihuvi?
4. Kuidas situatsioonihuvi füüsika õpetamismoodulite jooksul muutub?

Kirjanduse ülevaade

Huvi on motivatsiooniga tihedalt seotud nähtus, mida on määratletud kui seost inimese ja objekti vahel (Krapp, 1993) ning millel on teadmiste, väärtuste ja emotsioonidega seotud komponendid. Objektideks võivad olla tekst, midagi kuuluvat või nähtavat, inimesed või loomad, keskkond, tegevused või ka ideed (Renninger & Hidi, 2015b). Huvi jaguneb situatsioonihuviks, mida mõjutavad välistegurid, ja isiklikuks huviks, mis tuleneb inimese sisemistest omadustest. Situatsioonihuvi võib väljenduda huvis sisu, konteksti või tegevuste vastu (Häussler, 1987). Mõni tegevus, näiteks katsete tegemine (D. Palmer *et al.*, 2017), soodustab huvi. Teiste puhul, nagu rühmatöö, ei ole seos huviga alati ühesugune (Shubina *et al.*, 2023) ning mõni, näiteks märkmete tegemine, võib huvi hoopis vähendada (Logan & Skamp, 2013). Oma doktoritöös keskendusin situatsioonihuvile, kuna õpetajad saavad seda välisteguritest sõltuvuse tõttu hõlpsamini mõjutada.

Relevantsus on huviga sarnane ja sellega osaliselt kattuv omadus, millel puudub üheselt mõistetav määratlus (Priniski *et al.*, 2018). Ühe uuringu kohaselt – millele toetun ka oma doktoritöös – koosneb relevantsus isiklikust, ühiskondlikust ja karjääriga seotud mõttest (Stuckey *et al.*, 2013). Väljakutse on määratluse järgi ülesande keerukus, mis vastab õpilase oskustele või veidi ületab neid (Fulmer & Tulis, 2013), ning selle mõju huvile sõltub ootustest ja ülesande omadustest (Nuutila *et al.*, 2021). Oskusi on kirjeldatud kui kindlate ülesannete lahendamise meisterlikkust (Schneider *et al.*, 2016), mis on seotud huvi ja väljakutsega vooseisundi kaudu (ingl *flow*, Csikszentmihalyi, 1990). Huvi ja õppimise seost vahendab pingutus (H. Kang *et al.*, 2010), mida saab mõista kolmel viisil: keerukusest tuleneva vajadusena, lahendamisest tekkiva väsimusena või teadliku panusena ülesande lahendamiseks (Grund *et al.*, 2024). Oma doktoritöös lähtusin viimastest. Õppetegevused (ingl *instructional activities*) on õpilaste tegevused (näiteks katsete tegemine või arvutusülesannete lahendamine), mida õpetajad kavandavad ja juhivad (Vilhunen *et al.*, 2021).

Metoodika

Uuringute õppemoodulite teemad olid võnkumised, soojushulk temperatuuri muutumisel, soojushulk aine oleku muutumisel ning kliimamuutused ja energia kasutamine. Igas uuringus osales umbes 180 vabatahtlikku õpilast, kelle hulgas oli võrdselt poisse ja tüdrukuid ning kelle huvi füüsika vastu oli väga erinev.

Esimeses kahes uuringus osales kummaski seitse kooli ning mina õpetasin kõiki osalejaid. Kolmandas uuringus osales ühe kooli üheksa klassi, keda juhendasid neli soome õpetajat. Õppemoodulid kavandati koherentse loodusteadusliku hariduse (ingl *coherent science instruction*) põhimõtete alusel (Nordine *et al.*, 2021). Raamistik rõhutab, et sisu kontekst peab olema õppijale tähenduslik; õppijatele tehakse selgeks, milleks õpitavat vaja on; õppetöös keskendutakse vähestele tuumideele ja teaduslikele praktikatele ning neid rakendatakse probleemide lahendamisel. Tuumideed (ingl *core ideas*) kirjeldavad lühidalt loodusteaduste keskeid põhimõtteid (nt energia ja selle levimine) ning teaduslikud ja inseneriapraktikad (ingl *science and engineering practices*) on tegevused, mida teadlased ja insenerid igapäevatöös teevad (nt andmete analüüsimine ja tõlgendamine).

Andmete kogumiseks kasutasime taustküsimustikke ja kogemuse noppemeetodit (ingl *experience sampling method*). Taustküsimustikes uurisime õpilaste sugu, klassi, isiklikku huvi füüsika vastu ning füüsika kui aine tajutud relevant-sust. Noppemeetodi puhul kasutasime lühiküsimustikke, kus iga küsimus vastas ühele mõõdetavale suurusele. Meetodi nõrkused on piiratud usaldusväärsus ja kehtivus (Eisele *et al.*, 2021), sest ühe küsimusega ei saa rakendada tavapäraseid usaldusväärse hindamise viise ning sobivaid meetodeid alles katsetatakse (Dejonckheere *et al.*, 2022). Kehtivust saab siiski hinnata, mõõtes korrelatsioone teiste teoreetilistelt seotud suurustega (Shrout & Lane, 2012). Noppemeetodi eelis on seevastu see, et tundeid mõõdetakse vahetult kogemuse ajal, vältides meenutamist tulenevaid moonutusi (Hektner *et al.*, 2007). Minu uuringutes vastasid õpilased tunni jooksul kolm kuni neli korda küsimustikule, mis sisaldas küsimusi ja väiteid nagu „Mis tegevust sa parasjagu tegid?“, „See tegevus oli minu jaoks huvitav“ ning „Kui palju sa pingutasid seda tegevust tehes?“. Kõigis uuringutes toimus vastamine umbes iga 20–30 minuti järel. Esimeses uuringus oli ühes õppemoodulis kolm mõõtmishetke, teise uuringu kahes moodulis kokku kaheksa (igäühes neli) ja kolmandas uuringus ühes moodulis kokku 15 (iga tunni jooksul kolm) mõõtmishetke.

Andmete analüüsimisel kasutasin peamiselt keskkonna R eri versioone (R Core Team, 2022) Peale kirjeldava statistika rakendasin ANOVA meetodit, et võrrelda õppetegevusi vastavalt õpilaste situatsioonihuvile. ANOVA tulemuste kontrollimiseks kasutasin *post-hoc* Tukey testi. Põhianalüüsiks olid kahte tüüpi lineaarregressioonimudelid. Esimesed olid mitmetasandilised mudelid, millega uurisin taust- ja situatsioonimuutujate seost situatsioonihuviga. Teist tüüpi mudelid olid lihtsad regressioonimudelid, millega sain uurida varasema situatsioonihuvi mõju tulevasele situatsioonihuvile ja täpsemalt seda, kuidas olid õppijatega seotud omadused igas olukorras situatsioonihuviga seotud.

Tulemused

Esimesed kaks uuringut näitasid, et õpilaste sugu, klass ja füüsika kui teaduse tajutud relevantsus ei olnud olulisel määral situatsioonihuviga seotud. Siiski leidsid erandlikke juhtumeid, kus need tegurid olid olulised. Näiteks teise uuringu ühes olukorras oli poiste ja tüdrukute õppetegevuse tajutud relevantssuses märkimisväärne vahe ning sama uuringu teises olukorras oli üheksanda klassi õpilaste situatsioonihuvi suurem kui kaheksanda klassi õpilastel. Füüsika kui õppeaine tajutud relevantsus oli keskmises korrelatsioonis õpilaste isikliku huviga, kuid situatsioonihuviga ilmnis nõrk korrelatsioon vaid ühes olukorras. Isiklik huvi oli situatsioonihuviga tihedalt seotud, kuid tulemused olid vastuolulised. Esimeses uuringus kinnitasid seda mõlemad mudelid, kuid teises oli isiklik huvi oluline ainult teise õppemooduli mitmetasandilises mudelis. Sama mooduli lihtsates mudelites oli isiklik huvi oluline vaid kahes olukorras neljast. Korrelatsioonid kajastasid mudelite tulemusi ja olid esimeses uuringus mõõdukad. Teises uuringus olid korrelatsioonid kas nõrgad või mõõdukad kolmes olukorras kaheksast.

Õppetegevuste seos situatsioonihuviga oli kõikuv. Kõige selgemalt ilmnis see teises uuringus, kus esinesid olulised erinevused selliste tegevuste vahel nagu katsete tegemine, arvutusülesannete lahendamine ja töölehtede täitmine. Esimeses uuringus oli oluline erinevus vaid õppe- ja kõrvaliste tegevuste vahel ning kolmandas uuringus ei näidanud ANOVA analüüs olulisi erinevusi. Mitmetasandilised mudelid kinnitasid õppetegevuste olulisust esimeses kahes uuringus.

Teises uuringus oli õppetegevuse tajutud relevantsus situatsioonihuviga seotud peaaegu kõigis olukordades ning korrelatsioonid olid nõrgad või mõõdukad. Kolmandas uuringus mõõdetud pingutus, väljakutse ja oskused olid situatsioonihuviga seotud erinevalt. Seos väljakutsega oli kõige nõrgem, see ilmnis vaid vähestes olukordades ning väljakutse korreleerus huviga nõrgalt. Pingutus oli situatsioonihuviga seotud üheksas olukorras 15st ja korrelatsioonid varieerusid nõrkadest kuni mõõdukateni. Oskused olid situatsioonihuviga seotud kõigis olukordades ning korrelatsioonid olid enamasti tugevad.

Varasem situatsioonihuvi oli järgneva seotud peaaegu kõigis olukordades, eranditeks olid vaid mõned juhtumid teises ja kolmandas uuringus. Situatsioonihuvi keskmine tase muutus uuringuti erinevalt: esimeses uuringus kasvas, teises kahanes ja kolmandas vaheldus ilma selge suunata. Suurem situatsioonihuvi ilmnis katsete tegemise hetkedel ja teiste tegevuste ajal paistis huvi vähenevat.

Järeldused ja kokkuvõte

Soo ja situatsioonihuvi vahelise seose puudumine on kooskõlas PISA uuringute tulemustega (OECD, 2016). Klassi ja situatsioonihuvi seose puudumist võib selgitada õppemoodulite uudsus kõigi klasside jaoks ning asjaolu, et tegemist oli järjestikuste klassidega, mitte näiteks kuuenda ja üheksanda klassi võrdlusega (Steidtmann *et al.*, 2023). Füüsika kui teaduse tajutud relevantssuse seos situatsioonihuviga oli tõenäoliselt liiga kaudne, aga sellise relevantssuse tajumine võib

toetada õpilaste isikliku huvi kujunemist. Isiklik huvi oli situatsioonihuviga seotud, mida toetab ka teooria (Hidi, 2006), kuid varasemate uuringutega võrreldes oli oluline erinevus see, et isikliku ja situatsioonihuvi vaheline seos jäi püsima ka mõne õppemooduli lõpus. Sellist tulemust võiks samuti selgitada olukorra uuendusega (teine õpetaja, tahvelarvutite kasutamine, uued katsevahendid) ning katsetega seotud õppetegevuste mõjuga (D. Cheung, 2018).

Õppetegevuste mõju õpilaste situatsioonihuvile ei olnud selge. Võimalikud põhjused on õppemoodulite konteksti vähenenud muutlikkus ja tegevuste põimitus. Tõenäoliselt on õppetegevused eelkõige keskkond, mille kaudu teised tegurid on situatsioonihuviga seotud, kuid samas on tegevuste tunnis varieerimine jätkuvalt oluline (Mirlohi & Herman, 2024; D. Palmer, 2009). Õppetegevuste tajutud relevantsus paistis olevat vähem oluline tundide alguses, kuid see hüpotees vajab tulevastes uuringutes kinnitamist. Väljakutse ja situatsioonihuvi nõrka seost võib selgitada asjaolu, et õppemoodulis puudusid mõju tuvastamiseks sobivad tingimused, mille tähtsust varasemad uuringud on rõhutanud (Abuhamedh & Csikszentmihalyi, 2011). Pingutuse seos situatsioonihuviga võib olla mittelineaarne, kuid see on vaid hüpotees. Oskuste tähtsus ennustajana oli kooskõlas varasemate uuringutega, kuid nende mõju võib väheneda vooseisundi korral (Bricteux *et al.*, 2017; Schneider *et al.*, 2016).

Varasem situatsioonihuvi käitus olulise ennustajana sarnaselt eelnevatele uuringutele (Rotgans & Schmidt, 2011b). Erandjuhtudel võis tegemist olla eriti tugeva ühetaolise huviga, kus tasakaal kaldus tugevalt kas emotsionaalse või väärtustega seotud komponendi poole. Huvi muutumine õppemoodulite jooksul ei olnud varasemate uuringutega täielikus kooskõlas. Võimalik, et mõni õppemoodul suutis õpilaste huvi paremini toetada, mistõttu huvi ei vähenenud nii, nagu varasemad uuringud on ennustanud (Rotgans & Schmidt, 2017a).

Minu töö teoreetiline panus on seotud huviteooria täiendamise, mis puudutab õppetegevusi, situatsioonihuvi sõltuvust isiklikust huvist, väljakutset, oskusi ja pingutust. Praktiline panus tuleneb kavandatud õppemoodulitest, milles rakendatud põhimõtteid (näiteks töölehtede lõpus olevad sektsioonid „Kuidas need teadmised meile kasulikud on?“) saavad õpetajad kasutada oma igapäevatoos. Samuti näitasin, et mõne õppetegevuse puhul tasub rõhutada selle olulisust enam kui teiste puhul, sest see aitab õpetajatel oma piiratud aega paremini kasutada. Oluliseks piiranguks olid ebavõrdsed valimid, mille õpilased olid tõenäoliselt keskmisest enam huvitatud füüsilisest. Teiseks piiranguks olid andmete kogumiseks kasutatud küsimustikud. Kuna iga tegurit mõõdeti ühe küsimusega, ei olnud võimalik eristada mõõtmeid (näiteks huvi puhul emotsionaalne ja kognitiivne mõõde) ega hinnata küsimustike usaldusväärsust. Tulevastes uuringutes võiks uurida minu töös esile tõusnud tegureid koos ja kasutada usaldusväärsuse hindamiseks hiljuti välja töötatud tööriistu.

PUBLICATIONS

CURRICULUM VITAE

Personal data

Name: Rauno Neito
Date of birth: 01.10.1996
Citizenship: Estonian
E-mail: rauno.neito@gmail.com

Education

2021–... University of Tartu, doctoral studies in educational science
2019–2021 University of Tartu, masters studies in astrophysics
2016–2019 University of Tartu, bachelor studies in physics, chemistry and materials science

Employment

2021–... University of Tartu, junior research fellow
2020–... Kõrveküla Primary School, physics teacher
2019–2021 Kõrveküla Primary School, extracurricular activity instructor

Field of interest

Physics education and variables affecting students' interest.

Publications

- Ghoreyshi, M. R.; Jones, C. E.; Carciofi, A. C.; Kolka, I.; Aret, A.; Eenmäe, T.; Neito, R. (2024). Modeling the disc around the primary star of the X-ray binary system: MT91-213. *Monthly Notices of the Royal Astronomical Society*, 533 (3), 28672875. <https://doi.org/10.1093/mnras/stae1950>
- Kokori, A.; Tsiaras, A.; Edwards, B.; Rocchetto, M.; Tinetti, G.; Bewersdorff, L.; Jongen, Y.; Lekkas, G.; Pantelidou, G.; Poulourtzidis, E.; Wünsche, A.; Aggelis, C.; Agnihotri, V. K.; Arena, C.; Bachschmidt, M.; Bennett, D.; Benni, P.; Bernacki, K.; Besson, E.; Betti, L. Biagini, A. ... Zíbar, M. (2022). ExoClock project II: A large-scale integrated study with 180 updated exoplanet ephemerides. *The Astrophysical Journal Supplement Series*, 258 (2), 40. <https://doi.org/10.3847/1538-4365/ac3a10>
- Kokori, A.; Tsiaras, A.; Edwards, B.; Jones, A.; Pantelidou, G.; Tinetti, G.; Bewersdorff, L.; Iliadou, A.; Jongen, Y.; Lekkas, G.; Nastasi, A.; Poulourtzidis, E.; Sidiropoulos, C.; Walter, F.; Wünsche, A.; Abraham, R.; Agnihotri, V. K.; Albanesi, R.; Arce-Mansego, E.; Arnot, D. ... Zíbar, M.

- (2023). ExoClock project. III. 450 new exoplanet ephemerides from ground and space observations. *The Astrophysical Journal Supplement Series*, 265 (1), 4. <https://doi.org/10.3847/1538-4365/ac9da4>
- Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2023). Predicting situational interest by individual interest and instructional activities in physics lessons: An experience sampling approach. *Journal of Baltic Science Education*, 22(6), 10631073. <https://doi.org/https://doi.org/10.33225/jbse/23.22.1063>
- Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2025). Students situational interest and perceived relevance during designed coherent physics learning modules. *International Journal of Science Education*, Advance online publication. <https://doi.org/https://doi.org/10.1080/09500693.2025.2488400>
- Wiedemair, C.; Sterken, C.; Eenmae, T.; Neito, R.; Oberhauser, V.; Moser, D.; Mair, M.; Lercher, G. (2020). CCD photometry of CY Aquarii VI. The 2019-2020 seasons. *The Journal of Astronomical Data*, 26 (1), 18.

ELULOOKIRJELDUS

Isikuandmed

Nimi: Rauno Neito
Sünniaeg: 01.10.1996
Kodakondsus: Eesti
E-mail: rauno.neito@gmail.com

Haridus

2021–... Tartu Ülikool, doktoriõpe (haridusteadus)
2019–2021 Tartu Ülikool, magistriõpe (astrofüüsika)
2016–2019 Tartu Ülikool, bakalaureuseõpe (füüsika, keemia ja materjaliteadus)

Teenistuskäik

2021–... Tartu Ülikool, nooremteadur
2020–... Kõrveküla Põhikool, füüsika õpetaja
2019–2021 Kõrveküla Põhikool, huviringi juht

Uurimisvaldkond

Füüsikaharidus ja õpilaste huvi mõjutavad tegurid.

Publikatsioonid

- Ghoreyshi, M. R.; Jones, C. E.; Carciofi, A. C.; Kolka, I.; Aret, A.; Eenmäe, T.; Neito, R. (2024). Modeling the disc around the primary star of the X-ray binary system: MT91-213. *Monthly Notices of the Royal Astronomical Society*, 533 (3), 28672875. <https://doi.org/10.1093/mnras/stae1950>
- Kokori, A.; Tsiaras, A.; Edwards, B.; Rocchetto, M.; Tinetti, G.; Bewersdorff, L.; Jongen, Y.; Lekkas, G.; Pantelidou, G.; Poulourtzidis, E.; Wünsche, A.; Aggelis, C.; Agnihotri, V. K.; Arena, C.; Bachschmidt, M.; Bennett, D.; Benni, P.; Bernacki, K.; Besson, E.; Betti, L. Biagini, A. ... Zifar, M. (2022). ExoClock project II: A large-scale integrated study with 180 updated exoplanet ephemerides. *The Astrophysical Journal Supplement Series*, 258 (2), 40. <https://doi.org/10.3847/1538-4365/ac3a10>
- Kokori, A.; Tsiaras, A.; Edwards, B.; Jones, A.; Pantelidou, G.; Tinetti, G.; Bewersdorff, L.; Iliadou, A.; Jongen, Y.; Lekkas, G.; Nastasi, A.; Poulourtzidis, E.; Sidiropoulos, C.; Walter, F.; Wünsche, A.; Abraham, R.; Agnihotri, V. K.; Albanesi, R.; Arce-Mansego, E.; Arnot, D. ... Zifar, M. (2023). ExoClock project. III. 450 new exoplanet ephemerides from ground and

- space observations. *The Astrophysical Journal Supplement Series*, 265 (1), 4. <https://doi.org/10.3847/1538-4365/ac9da4>
- Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2023). Predicting situational interest by individual interest and instructional activities in physics lessons: An experience sampling approach. *Journal of Baltic Science Education*, 22(6), 10631073. <https://doi.org/https://doi.org/10.33225/jbse/23.22.1063>
- Neito, R., Vilhunen, E., Lavonen, J., & Reivelt, K. (2025). Students situational interest and perceived relevance during designed coherent physics learning modules. *International Journal of Science Education*, Advance online publication. <https://doi.org/https://doi.org/10.1080/09500693.2025.2488400>
- Wiedemair, C.; Sterken, C.; Eenmae, T.; Neito, R.; Oberhauser, V.; Moser, D.; Mair, M.; Lercher, G. (2020). CCD photometry of CY Aquarii VI. The 2019-2020 seasons. *The Journal of Astronomical Data*, 26 (1), 18.

DISSERTATIONES PEDAGOGICAE SCIENTIARUM UNIVERSITATIS TARTUENSIS

1. **Miia Rannikmäe.** Operationalisation of Scientific and Technological Literacy in the Teaching of Science. Tartu, 2001.
2. **Margus Pedaste.** Problem solving in web-based learning environment. Tartu, 2006.
3. **Klaara Kask.** A study of science teacher development towards open inquiry teaching through an intervention programme. Tartu, 2009.
4. **Anne Laius.** A longitudinal study of science teacher change and its impact on student change in scientific creativity and socio-scientific reasoning skills. Tartu, 2011.
5. **Katrin Vaino.** A case study approach to effect change of chemistry teacher beliefs for enhancing students' scientific literacy. Tartu, 2013, 176 p.
6. **Mario Mäeots.** Inquiry-based learning in a web-based learning environment: a theoretical framework of inquiry-based learning processes. Tartu, 2014, 126 p.
7. **Regina Soobard.** A study of gymnasium students' scientific literacy development based on determinants of cognitive learning outcomes and self-perception. Tartu, 2015, 142 p.
8. **Ana Valdmann.** Determining categories of self – efficacy and levels of teacher ownership following promotion of science teacher's operational needs. Tartu, 2018, 219 p.
9. **Tormi Kotkas.** Designing, Implementing and Evaluating Teaching and Learning Modules for Promoting Decision-making Towards STEM Careers. Tartu, 2021, 202 p.
10. **David Cerulli.** Investigating the Teaching and Learning of Natural Hazard Disaster Reduction. Tartu, 2022, 205 p.
11. **Helin Semilarski.** An Assessment of Biology Learning and an Evaluation of Biology Self-Perceptions by Upper Secondary School Students Related to Biological Literacy. Tartu, 2022, 152 p.
12. **Tapashi Binte Mahmud Chowdhury.** Establishing trans-contextual science education in promoting active informed citizenry for societal development. Tartu, 2022, 199 p.
13. **Helen Semilarski.** Improving Students' Self-Efficacy towards acquiring Disciplinary and Interdisciplinary Core Ideas and 21st Century Skills for Promoting Meaningful Science Learning. Tartu, 2022, 219 p.
14. **Moonika Teppo.** Predicting Lower Secondary School Students' Intrinsic Motivation in Science Learning: the Role of Context and Teaching-Learning Approaches. Tartu, 2023, 186 p.