

MOONIKA TEPPU

Predicting Lower Secondary School  
Students' Intrinsic Motivation  
in Science Learning:  
the Role of Context and  
Teaching-Learning Approaches





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## **LIST OF ABBREVIATIONS**

CBL	–	Context-based learning
CFA	–	Confirmatory factor analysis
CFI	–	Comparative fit index
EFA	–	Exploratory factor analysis
ESEM	–	Exploratory structural equation modelling
OECD	–	Organization for Economic Cooperation and Development
PISA	–	Programme for International Student Assessment
RMSEA	–	Root mean square error of approximation
SDT	–	Self-determination theory
SEM	–	Structural equation modelling
TALIS	–	Teaching and Learning International Survey
TLI	–	Tucker-Lewis index

## LIST OF ORIGINAL PUBLICATIONS

The dissertation is based on the following original publications, which are referred to in the text using Roman numerals.

- I 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*, 5(1), 130–170. <https://doi.org/10.12697/eha.2017.5.1.05>
- II Teppo, M.,** Soobard, R., Rannikmäe, M. (2021). A Study Comparing Intrinsic Motivation and Opinions on Learning Science (Grades 6) and Taking the International PISA Test (Grade 9). *Education Sciences*, 11(1), 14. <https://doi.org/10.3390/educsci11010014>
- III 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. <https://doi.org/10.33225/jbse/21.20.119>
- IV Teppo, M.,** Soobard, R., Rannikmäe, M. (2023). Grade 6 and 9 Students' Perceived Competence and Choice as Predictors of their Intrinsic Motivation towards Science Learning. [Manuscript submitted for publication].

### Author's contribution:

- Article I** participating in the following stages: composing the theoretical framework, formulating the research questions, developing and adapting the instruments, conducting the data analysis and writing the article as the main author in cooperation with co-authors.
- Article II** participating in the following stages: composing the theoretical framework, formulating the research questions, developing and adapting the instruments, conducting the data analysis and writing the article as the main author in cooperation with co-authors.
- Article III** participating in the following stages: composing the theoretical framework, formulating the research questions, developing and adapting the instruments, conducting the data analysis and writing the article as the main author in cooperation with co-authors.
- Article IV** participating in the following stages: composing the theoretical framework, formulating the research questions, developing and adapting the instruments, conducting the data analysis and writing the article as the main author in cooperation with co-authors.

# 1. INTRODUCTION

## 1.1. Research problem

Educators and teachers recognise that motivation is a crucial prerequisite for successful learning, performance and well-being (Pintrich & Zusho, 2002; Schunk et al., 2014). When studying student motivation, it is important to distinguish between intrinsic and extrinsic motivation, as they affect the learning process differently based on the reasons or goals that give rise to action (Ryan & Deci, 2000b). In the current research the focus is on intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, compared to extrinsic motivation, where an external incentive provides the reason for taking action (Deci & Ryan, 1985). Consequently, the central question in education concerns how to intrinsically motivate students to act and behave with little or no external pressure (Ryan & Deci, 2000a).

According to research in recent decades, declining student motivation in science learning, especially during adolescence – from elementary to secondary school – is an ongoing concern (Hazelkorn et al., 2015; Liou et al., 2020; Potvin & Hasni, 2014; Vedder-Weiss & Fortus, 2011; Vedder-Weiss & Fortus, 2012). Furthermore, studies do not typically distinguish between different science subjects, although the decline in student motivation has shown to be domain-specific (Gottfried et al., 2001; Salta & Koulougliotis, 2020). Previous research has shown that in countries where science subjects are taught separately in lower secondary school (grades 8 and 9), students are much less positive about learning chemistry and physics than biology and geography (Lamanauskas et al., 2004; Mullis et al., 2020). In addition, there is relatively little research reporting on the implementation of a longitudinal research to determining student motivation in science subjects learning at the lower secondary level (e.g. Liou et al., 2020); however, some longitudinal studies of intrinsic motivation have been conducted in maths from elementary through upper secondary school (Gottfried et al., 2001) or during elementary school (ages 7–10) (Garon-Carrier et al., 2016; Spinath & Steinmayr, 2008). Therefore, it is necessary to investigate the factors influencing declining student motivation under different circumstances – across science subjects as well as cross-sectionally and using a repeated cross-sectional approach over time.

In recent years, considerable attention has been paid to investigating factors that influence student intrinsic motivation in science learning. It can be hypothesised, based on self-determination theory (SDT) (Deci & Ryan, 1985; Ryan & Deci, 2017) that the decline in student intrinsic motivation occurs at least partly due to the decreasing satisfaction of basic psychological needs (need for autonomy, competence and relatedness) (Gnambs & Hanfstingl, 2016) – each being seen as crucial for fostering the development and maintenance of intrinsic motivation (Ryan & Deci, 2000a, 2020). The relationships between these basic needs and the classroom learning environment have been extensively researched in

education (Conesa et al., 2022; Niemiec & Ryan, 2009; Wang et al., 2019), although only a few studies have focused on science education, specifically motivation in biology (Kaiser et al., 2020). Furthermore, most of the studies have addressed only one basic need – autonomy support (Chang et al., 2017; Núñez & León, 2015; Patall et al., 2017; Thomas & Müller, 2014), competence (Patall et al., 2014; Spinath & Spinath, 2005; Spinath & Steinmayr, 2008) or relatedness (Furrer & Skinner, 2003; Trenshaw et al., 2016). Therefore, there is a need for an overall investigation of all three basic needs and their impact on learning motivation in different science subjects (biology, geography, chemistry, physics).

The role and influence of the teacher on student outcomes in the classroom environment has been an important research issue in education over the past 40 years (Fraser, 1998; Fraser & Walberg, 1981; Hattie, 2009), more specifically focusing on the motivation to learn and achievement in subject areas. It has also been found that cooperation between student and teacher as well as perceived support from teachers and classmates positively influence student motivation and achievement (Aldridge & Rowntree, 2021; Cirik, 2015; Wentzel, 1998). Research suggests that teacher-student and student-student interactions change in the transition from elementary to secondary school – the learning environment becomes less supportive, which relates to decreased student motivation, engagement and performance (Ryan & Patrick, 2001).

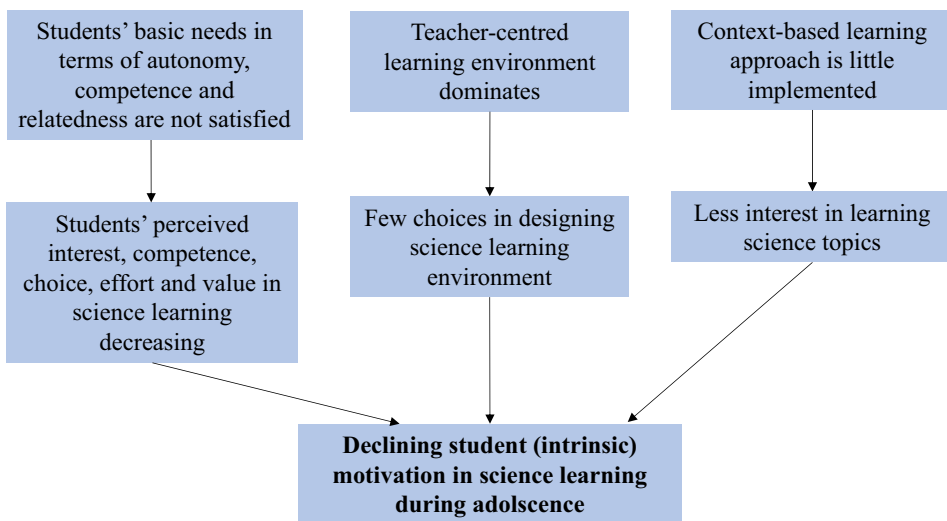
A number of recent studies have found positive relationships between student motivation to learn science and their perceptions of the science learning environment (e.g. Aldridge & Rowntree, 2021; Hafizoglu & Yerdelen, 2019). For example, a study by Hafizoglu and Yerdelen (2019) found that both science motivation and achievement are significantly predicted by the science learning environment. The Estonian Report for the Teaching and Learning International Survey (TALIS) (Taimalu et al., 2019) indicates that the proportion of Estonian teachers who often use learning activities aimed at the cognitive activation of students (e.g. working in groups, critical thinking, solving complex tasks) is below the average level compared with OECD countries and economic areas that participated in the TALIS survey. In addition, Estonian PISA 2015 results indicate that 15-year-old students rarely undertake practical activities or plan experiments in science lessons compared with the OECD average (OECD, 2016). These results illustrate the dominance of a teacher-centred learning environment in science classrooms; simultaneous comparative data from both students and teachers in regard to the frequency of using student-centred vs. teacher-centred approaches are missing.

A number of researchers have pointed out that context-based learning (CBL) has become an accepted and widespread approach in science education indicating the promotion of positive intrinsic motivational effects and thus facilitating the relevance of science for learning (de Putter-Smits et al., 2013; Podschuweit & Bernholt, 2018; Slovinsky et al., 2021). CBL approaches have influenced curriculum development and teaching in many countries and in different science subjects (Nentwig & Waddington, 2006; Pilot & Bulte, 2006; Sevian et al., 2018). For example, Eilks and Hofstein (2015) explore the relationship between

chemistry as a less popular school subject and its perception as irrelevant. Gilbert (2006) has paid attention to the formation of coherent mental schema and students failing to solve problems using the same concepts in other situations because they are unable to transfer the learning content as it has not become relevant for them.

The relevance of science content in the Estonian National Curriculum for Basic Schools (Estonian Government, 2011) up to grade 6, where the science content is highly related to nature and everyday life issues (i.e. biology and geography centred), is generally expressed at the macro level (i.e. can be seen, touched and smelt). Research has shown that science becomes increasingly more abstract and complex with age; this is manifested in the use of micro notations (atoms, molecules) and also representations (symbols, equations) (Johnstone, 1982, 2000). This change in science content and context (representation of meaning, application of science to real-world situations or problems) with age is seen as impacting student motivation and interest in science learning. Previous research highlights the need for the contexts to be perceived as interesting and relevant to the students (e.g. Habig et al., 2018; Osborne & Collins, 2001; Ramsden, 1997); however, less is known about the effects of context (science curriculum topics presented in different contexts) on student intrinsic motivation in science learning when comparing students at different grade levels.

With the above concerns in mind, less attention has been paid to investigating the effects of declining intrinsic motivation on lower secondary school students. Accordingly, this doctoral thesis combines different facets and focuses on the role of teaching-learning approaches and components of context-based learning in predicting intrinsic motivation in science learning for lower secondary school student (grade 6 and 9). The problems emphasised in the current thesis are shown in Figure 1.



**Figure 1.** Problems emphasised in the current thesis

## 1.2. Aim and research questions

The overall aim of the thesis is to investigate perceptions of science learning motivation in grade 6 and 9 students. More specifically, to develop a model predicting intrinsic student motivation in science learning in relation to teaching-learning approaches and the contextual presentation of topics in the science curriculum. The following four research questions are put forward:

1. What is the role of context for students learning topics in the science curriculum considering the different contexts perceived by grade 6 and 9 students? (Articles I, II)
2. How do students and science teachers perceive the frequency of the use of teaching-learning approaches in different science subjects? (Article III)
3. How intrinsically motivating do grade 6 and 9 students perceive science subjects at school (Article II) and what changes in student intrinsic motivation (in terms of interest, competence and choice) can be identified from the long-term perspective? (Article IV)
4. What are the effects of the contextual presentation of science education and the frequency of the use of teaching and learning approaches in predicting intrinsic motivation in science learning for grade 6 and 9 students? (further in the thesis)

Based on the aim and research questions, this doctoral thesis comprises four main studies presented in the following four original publications:

- Study I* contributes to answering research question 1 by identifying the role of the contextual presentation of topics in the science curriculum and comparing the perceptions of grade 6 and 9 students (Articles I and II) and
- Study II* investigates research question 2 by examining how grade 6 and 9 students and science teachers perceive the frequency of the use of different teaching-learning approaches in science classes (Article III).
- Study III* investigates intrinsic student motivation in science learning and determines changes in intrinsic student motivation in the long term by comparing student outcomes in grade 6 and grade 9 in order to answer research question 3 (Articles II, IV).
- Study IV* focuses on research question 4 by developing a model predicting intrinsic motivation in science learning through the contextual presentation of topics in the science curriculum and teaching-learning approaches perceived by grade 6 and 9 students. RQ4 is further addressed in the doctoral thesis (see chapters 4 and 5).

## 2. THEORETICAL BACKGROUND

This chapter provides a theoretical overview for the topic of this thesis. First, the role of intrinsic motivation and relevant theories indicated in the literature are discussed. This is followed by describing the factors that influence intrinsic student motivation in science learning. The third and fourth sub-sections respectively provide an overview of the role of context in science learning and teaching-learning approaches. In the last sub-section, the theoretical ideas underpinning the model of the motivational science learning environment are provided showing the relationships between teaching-learning approaches, the contextual presentation of topics in the science curriculum, as well as intrinsic motivation.

### 2.1. Motivation

#### 2.1.1. Definition and types of motivation

Motivation as a theoretical concept has different definitions – at the general level motivation is seen as a theoretical construct that initiates, directs and sustains goal-directed behaviour (Murphy & Alexander, 2000; Schunk et al., 2014). In other words, motivation *moves* students to act and learn and helps them complete the task (Schunk et al., 2014). Another view of motivation is conceptualised as an inner desire that drives students to engage in an activity because of the satisfaction derived from this activity (Theobald, 2006), which incorporates the self-determination theory (SDT) perspective, according to which students are intrinsically motivated when their three basic psychological needs (autonomy, competence, relatedness) are satisfied and supported (Deci & Ryan, 1985; Ryan & Deci, 2017, 2020). Therefore, motivation does not just refer to the factors that activate behaviour, but also involves the factors that direct and maintain these goal-directed actions (Schunk et al., 2014).

Motivation is differentiated between intrinsic and extrinsic, depending on the extent to which activities are driven by internal or external factors (Ryan & Deci, 2000b). Extrinsic motivation is taken from outside the individual and is often stimulated by rewards and reinforcements (awards, prizes) so as to establish and maintain patterns of behaviour (Wentzel & Brophy, 2014). On the other hand, an intrinsically motivated student undertakes activities and exhibits behaviours for their *own sake*, or for the inherent interest and enjoyment (Ryan & Deci, 2000b). In other words, intrinsically motivated students do what they do because of internal motives rather than because they need to or are told to (Wentzel & Brophy, 2014). Both intrinsic and extrinsic motivation are important for driving students to learn (Theobald, 2006), but the effects of intrinsic motivation last longer and have a deeper impact on student behaviour as they relate to the combination of the students' perception of the value of the task together with their expectation of succeeding (Wigfield & Eccles, 2000). In addition, intrinsically motivated students tend to perform better and wish to succeed (Theobald, 2006). In the school

context, intrinsic motivation becomes weaker with advancing grades (Ryan & Deci, 2000a); in other words, elementary school students tend to act from intrinsic motivation, whereas adolescents from extrinsic influences for doing activities that are not inherently interesting for them (Cook & Artino Jr, 2016).

### 2.1.2. Theories of motivation in education

Contemporary perspectives on motivation frequently studied in education are based on expectancy-value theory (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000), goal and goals orientation theory (Ames, 1992; Ames & Archer, 1988; Locke & Latham, 1984, 1990), social cognitive theory (Bandura, 1986; Schunk et al., 2014), self-determination theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2017), and interest theory (Harackiewicz et al., 2016; Harackiewicz & Knogler, 2017; Hidi & Renninger, 2006; Krapp, 1999) (see Table 1 for short overview).

**Table 1.** Overview of common motivational theories in education

Motivation Theory	Basic concepts	Main idea
Expectancy-Value Theory (EVT)	Expectancy, value	Describes the relationship between students' expectancy of success at a task and perceived value they place on that task.
Goal Orientation Theory (GOT)	Mastery goal, performance goal	Suggests that student motivation and achievement-related behaviours can be influenced by their goal orientation (mastery- or performance-oriented reasons).
Social Cognitive Theory (SCT)	Self-efficacy, outcome expectations, self-regulation	Emphasises the role of social learning and cognitive processes in shaping human behaviour and motivation. Explains that motivational processes are goals and self-evaluations of progress, self-efficacy, social comparisons, and outcome expectations.
Self-Determination Theory (SDT)	Amotivation, extrinsic motivation, intrinsic motivation	Posits that motivation varies in terms of type (intrinsic, extrinsic, amotivation (lack of motivation)) and form (autonomous, controlled). Suggests that people become self-determined (intrinsically motivated) when their basic psychological needs for competence, relatedness, and autonomy are fulfilled.
Interest Theory (IT)	Personal and situational interest	Emphasises the importance of interest as a motivational variable influencing student achievement and learning. Interest can develop over time, from a triggered situational interest to a maintained individual interest.

These theories are applied to understand how socio-environmental and psychological factors influence student motivation, engagement and learning (Schunk et al., 2014), indicating a conceptual overlap and disagreement in the terminology (Murphy & Alexander, 2000). For example, most theories include concepts related to beliefs about competence, such as expectancy of success (EVT), self-efficacy (SCT), competence (SDT); the concept of value beliefs includes terms such as task value (EVT), outcome expectations (CST), intrinsic motivation (enjoyment, value) (SDT), individual interest (IT), and social-cognitive interactions expressed as social support (SCT) or relatedness (SDT) (Cook & Artino Jr, 2016; Dostert & Müller, 2020). The conceptual differences among these theories go much deeper than definitions can resolve; therefore, caution must be used when drawing theoretical and empirical conclusions (Cook & Artino Jr, 2016).

### 2.1.3. Self-determination theory

The current thesis is guided by self-determination theory (Deci & Ryan, 1985). SDT is a theory of human motivation that proposes a distinction between two forms of motivation – autonomous and controlled motivation – and hypothesises three main types of motivation – amotivation (lack of motivation), extrinsic motivation, and intrinsic motivation (Deci & Ryan, 1985; Ryan & Deci, 2000b). Putting these types and forms of motivation together, Deci and Ryan (2000b) think of motivation as a continuum ranging from “non-self-determined” to “self-determined.” On the left side of the continuum there is amotivation, which refers to the lack of motivation (an absence of self-determination and autonomy), where individuals feel a lack of competence and value or non-relevance. In the middle, there are several levels of extrinsic motivation (referred to as controlled motivation) ranging from external to internal regulation styles, where individuals may feel pressure to behave in a certain way, and therefore experience little or no autonomy. At the right end of the continuum, there is intrinsic motivation, which is also referred to as autonomous motivation, where individuals are engaged in (self-determined) behaviours, where they feel a sense of choice, personal endorsement, interest, enjoyment, and inherent satisfaction (Ryan & Deci, 2000a, 2020). Both, intrinsic and extrinsic motivation influence individual behaviour and drive individuals to meet the three basic psychological needs identified by SDT.

SDT focuses on the social and environmental factors that facilitate vs. undermine intrinsic motivation introduced by two sub-theories (out of five) – cognitive evaluation theory (CET) and organismic integration theory (OIT) (Deci & Ryan, 1985). CET incorporates the presence and satisfaction of three basic psychological needs – relatedness, competence and autonomy – that foster greater intrinsic motivation (Ryan & Deci, 2000a). Competence concerns the feeling of mastery and is best satisfied within environments that offer optimal challenges, positive feedback, and opportunities for growth; relatedness concerns a sense of belonging and connectedness with others and is facilitated by genuine respect and caring; and autonomy refers to the concerns of the opportunity to control one’s actions and is supported by experiences of interest and value (Ryan & Deci, 2020).

Consequently, to achieve a high level of intrinsic motivation (i.e. values and goals are internalised and fully integrated), the three psychological needs need to be fulfilled (Ryan & Deci, 2000a). In the field of science learning, little research has been conducted to investigate the role of one or a combination of psychological needs on student intrinsic motivation. For example, a study by Meyer et al. (2013) found that the fifth grade students who could choose the biology topics in their next biology lesson indicated higher intrinsic motivation than students who had no such choice. Kaiser et al. (2020) found that both autonomy and competence were predictors of intrinsic motivation and identified regulation during biology classes, whereas relatedness had no predictive power.

Within SDT, a second sub-theory, organismic integration theory, differentiates between extrinsic motivation regulation styles and the contextual factors that either promote or hinder internalisation and integration along a motivation continuum (amotivation, extrinsic motivation, intrinsic motivation) (Deci & Ryan, 1985). This starts with amotivation (lack of determination), followed by four kinds of extrinsic motivation (external, introjected, identified and integrated regulation) and ends up with intrinsic motivation (most autonomously regulated kind of motivation) (Ryan & Deci, 2000a, 2020). Integrated regulation, as the final stage of extrinsic motivation, occurs when the value of the task is deeply integrated into one's values, but in contrast to intrinsic motivation the behaviour is still externally regulated (activities are worthwhile, even if not enjoyable) (Ryan & Deci, 2020).

#### **2.1.4. Components of intrinsic motivation**

In the current thesis, intrinsic motivation is viewed based on SDT as incorporating the students' perception of interest, competence, choice, effort and value in science learning, which are considered important preconditions for inherent satisfaction and promoting intrinsic motivation.

In SDT, interest is defined as a natural inclination or attraction towards an activity or topic that an individual finds enjoyable, satisfying, or personally significant (personally relevant) (Deci, 1992). Interest is closely linked to intrinsic motivation and is seen as a key component in the development of self-determined behaviour (Ryan & Deci, 2000a). According to SDT, interest is believed to be a powerful motivator for individuals to engage in activities and pursue their goals, as it can lead to sustained engagement, enjoyment, and personal fulfilment (Ryan & Deci, 2020). In other words, when individuals engage in activities that align with their interests, they are more likely to experience intrinsic motivation, which is the motivation that comes from within, rather than extrinsic motivation from external rewards or pressures.

According to SDT, perceived competence refers to the need in individuals to experience opportunities and support for their activity and their ability to express their knowledge, skills, abilities, or talents (Ryan & Deci, 2017). Perceived competence involves the need to feel capable of achieving desired outcomes, and in that way satisfying the need for competence through positive feedback enhances intrinsic motivation, whereas negative feedback tends to thwart the satisfaction

of the need for competence and thus undermines intrinsic motivation (Deci & Ryan, 2000). In other words, when students feel competent in a particular domain, they are more likely to engage in activities related to that domain, leading to increased intrinsic motivation. Following the motivation continuum, students with amotivation have a lack of perceived competence or do not believe they will yield the desired outcome compared to intrinsically motivated students, who believe in their abilities and have a high level of competence to succeed (Ryan & Deci, 2000a). Therefore, perceived competence is considered a very strong predictor of intrinsic motivation.

SDT suggests that individuals have a fundamental need for autonomy, which involves the experience of perceived choice and volition in one's actions (Deci & Ryan, 2000). When individuals feel that they have a choice in their actions, they are more likely to experience a sense of ownership and engagement, leading to increased intrinsic motivation and internalisation, as they achieve greater autonomy (Ryan & Deci, 2000a). However, the role of choice in motivation is complex, and not all choices are equally motivating (Deci & Ryan, 2000). For example, Patall et al. (2014) investigated the role of competence in the effect of choice on motivation and found that the provision of choice generally enhanced motivation when initial perceptions of task competence were high, but diminished motivation when perceived competence was low. Furthermore, research has shown that the more the teacher encourages and allows autonomous decisions by students and provides students with opportunities to make co-decisions, the more the students perceived the learned topics as useful, which in turn leads to increased intrinsic motivation (Daniels, 2010; Radovan & Makovec, 2015).

Effort is seen as a key factor in the development of competence, as it is through effort that individuals develop the skills and knowledge necessary to achieve their goals (Ryan & Deci, 2000a). Perceived effort refers to the person's investment of his/her abilities in what he/she is doing and reflects the level of involvement and effort put into a given activity (McAuley et al., 1989). Effort through the development of competence supports the process of internalisation and the development of intrinsic motivation. However, the more students are externally regulated the less effort they invest and they indicate the tendency not to take responsibility for their outcomes (Ryan & Deci, 2000a).

Value based on SDT is related to the idea that people internalise and become self-regulating with respect to activities that they experience as useful or valuable for themselves (Ryan & Deci, 2000b). Following the motivation continuum, the role of value increases from amotivation to intrinsic motivation in that value becomes both internalised (personally important) as well as integrated (fully assimilated with other aspects of self) (Ryan & Deci, 2000a, 2020).

In conclusion, the facilitation of more self-determined learning requires teachers to provide students with the different opportunities afforded by a classroom that supports autonomy; that is, creates the conditions that support the satisfaction of basic psychological needs (Ryan & Deci, 2000a). However, teaching that supports autonomy is not easy to implement, as it involves constraints in time, resources and curricula (Ryan & Deci, 2020).

## 2.2. The role of contexts in science learning

The current trend in science education is to adopt a context-based learning (CBL) approach to teaching, as this is seen as having positive effects on student motivation (de Putter-Smits et al., 2013; Slovinsky et al., 2021) and hence interest (Habig et al., 2018; Swirski et al., 2018) in science learning. Generally CBL refers to the use of real-life contexts or applications of science as the starting point in order to learn through actual practical experience to improve learning with the aim of making science content more relevant to students (Bennett & Holman, 2003; King, 2012; Overman et al., 2014). Researchers have argued that CBL is consistent with the social constructivist view on learning supporting a student-centred approach in a way that students should be given opportunities to engage meaningfully and actively through inquiry, problem solving, group work, and discussions, in contrast with more traditional approaches that cover scientific ideas first, before looking at applications (Bennett et al., 2005; Bennett & Holman, 2003; Overman et al., 2014). The CBL approach has been implemented widely in science education at the secondary school level, especially in the teaching and learning of chemistry (Bennett & Holman, 2003; Gilbert, 2006; Habig et al., 2018; Parchmann et al., 2006; Pilot & Bulte, 2006).

### *The characteristics and effects of context on student interest and motivation*

The word *context* has different meanings, but in science education it is generally meant as the application of science to real-world situations or problems (King, 2012). Different context domains have been put forward (e.g. personal, social, professional, scientific and technological) in science learning with the aim of helping students to better understand the abstract and theoretical concepts through personalisation and meaningful learning (de Jong, 2008; Gilbert, 2006). Walkington and Bernacki (2014) suggest personalising learning so that instructions are presented in a context related to the students' individual interest areas (e.g. sport, music, nature) which in turn promote intrinsic motivation.

When teaching science in the classroom, teachers should have an understanding of which contextual topics are appropriate to enhance learning. However, there is less research on the criteria of contextual situations and the effects of different contextual topics on student learning. For example, Habig et al. (2018) provide an overview of the most common context characteristics based on the literature – a) authenticity (degree of reality), b) type of presentation (presentation format), c) degree of complexity (number of elements and interrelations), and d) familiarity (addresses everyday life). Taking this into account, research has suggested that teachers should apply some of the contextual elements in science learning making it more familiar and authentic for the everyday life of the students, which in turn increases student engagement, motivation, and achievement in science learning (Walkington & Bernacki, 2014).

The international research project ROSE (Relevance of Science Education) distinguishes between science content (e.g., electricity, heat, mechanics, botany,

chemistry) placed in different contexts (e.g., social, technical, ethical, practical, theoretical) and has indicated that 15-year-old students in more developed countries show less interest in practical, relevant and every-day related science and technology topics compared to those in developing countries (Sjøberg & Schreiner, 2010). This contrasts with the relationship between the characteristics of contexts and everyday life and is seen as an opposing trend; however, ROSE does not distinguish between students of different ages nor does it report on long-term effects.

Although the current thesis is not built directly on implementing the context-based learning approach, it is possible to justify certain characteristics of CBL based on its role in the presentation of topics in the science curriculum in different contexts.

### 2.3. Teaching-learning approaches

In the literature different researchers distinguish between approach, method and technique (Richards & Rodgers, 2001) or approaches, strategies and methods (Gill & Kusum, 2017). Based on Anthony's hierarchical model, three levels of conceptualisation and organisation, referred to as approach, method, and technique are identified (Richards & Rodgers, 2001). Approach is seen as a broader term, referring to the philosophy (theory) related to how teaching and learning occurs, while method of teaching is taken to be procedural, indicating a systematic way of teaching (i.e. putting theory into practice) that forms an implementable technique that helps students to learn and achieve their goals (Richards & Rodgers, 2001). In other words, approach is a more general way of teaching (e.g. teacher-centred, student-centred approach), while method is a narrow term describing the practical realisation of an approach (e.g. lecture, discussion, role-play) (Gill & Kusum, 2017). For example, different researchers in science learning have undertaken investigations of approaches using a variety of terminology; for example, teaching methods (Hasni & Potvin, 2015; Juuti et al., 2010), teaching and learning activities (Hampden-Thompson & Bennett, 2013), and teaching and learning practices (Ebenezer & Zoller, 1993). In the current thesis the general term *approaches* is used, which can be characterised through different activities conducted in science classrooms and measured through a self-reported questionnaire.

Teaching and learning happens in an environment where two types of instructional approaches can generally be distinguished: the teacher-centred approach and student-centred approach, also synonymous with traditional vs. constructivist forms of teaching and learning (Arends, 2012; Good & Lavigne, 2018; Smit et al., 2014; Tularam & Machisella, 2018). Traditional approaches are generally teacher-directed and dominated, where students are taught in a manner where they have less activity and initiative (Arends, 2012; Smit et al., 2014; Tularam & Machisella, 2018), whereas a student-centred approach is much more diverse, expecting the student to take an active role and aiming at developing learning autonomy and independence while the teacher acts as a facilitator rather than instructor (Jones,

2007). The teacher-centred approach comprises methods like lecturing, direct instructions, asking questions, doing demonstrations, and so on, focused on content learning using mainly textbooks and workbooks as the main sources of information (Smit et al., 2014). By contrast, the student-centred approach is much more diverse covering broad methods, such as problem solving, decision-making, role-plays, group work, and so on, where students are engaged actively and responsibly, and they can cooperate with and learn from their peers (Arends, 2012; Jones, 2007; Smit et al., 2014). Student-centred learning is based on those learning theories that consider learning as constructivist; that is, students actively construct or make their own knowledge and build this on previous learning experiences (Applefield et al., 2000; Bada & Olusegun, 2015; Elliott, 2000; Taber, 2011). More specifically, social constructivist theory emphasises that learning is socially and culturally constructed in an active way, focusing on the learner as part of a social group (Palincsar, 1998; Taber, 2011). In light of above, there is no right way or approach to use to achieve the learning goals, so teachers usually test and adopt different methods they consider appropriate considering the different subjects and grade levels.

### ***Research on teaching-learning approaches in science teaching***

A large number of empirical studies have researched teaching-learning approaches in science contexts examining the frequencies of the usage of different methods (Hasni & Potvin, 2015; Juuti et al., 2010), preferences for teaching methods (Ebenezer & Zoller, 1993; Hasni & Potvin, 2015) or the impact of approaches or methods on student motivation (Hampden-Thompson & Bennett, 2013; Smit et al., 2014; Sturm & Bogner, 2008). For example, Smit et al. (2014) show that students in the student-centred learning environment reported higher levels of perceived autonomy, competence, relatedness, and hence motivation, measured in terms of pleasure and effort compared to teacher-centred environments. Several researchers have also found a positive effect from inquiry-based instructions enhancing student motivation and interest in science learning (Potvin et al., 2017; Wang et al., 2015). Findings by Juuti et al. (2010) and Hasni and Potvin (2015) show that teacher-centred methods are most often perceived in science classes, even though students desire to participate more in student-centred classrooms. Ebenezer and Zoller (1993) argue that more emphasis must be placed on the role of science teachers and their teaching style in achieving educational change towards more constructivist and student-centred approaches.

Considering the results of previous research, the current doctoral thesis examines the perceptions of science teachers and students on the frequency that different teaching-learning approaches are applied in science lessons, as well as identifying the effects of teaching-learning approaches on student intrinsic motivation.

## 2.4. Theoretical model predicting student intrinsic motivation in science learning

The theoretical model put forward in the thesis (see Figure 2) focuses on three interrelated components of the learning environment referred to as (learning) topics in the science curriculum, teaching-learning approaches and intrinsic motivation. The model is limited to learning in science as a school subject and empirically tested based on the perceptions of Estonian lower secondary school students. The development of the model is based on the following theoretical standpoints.

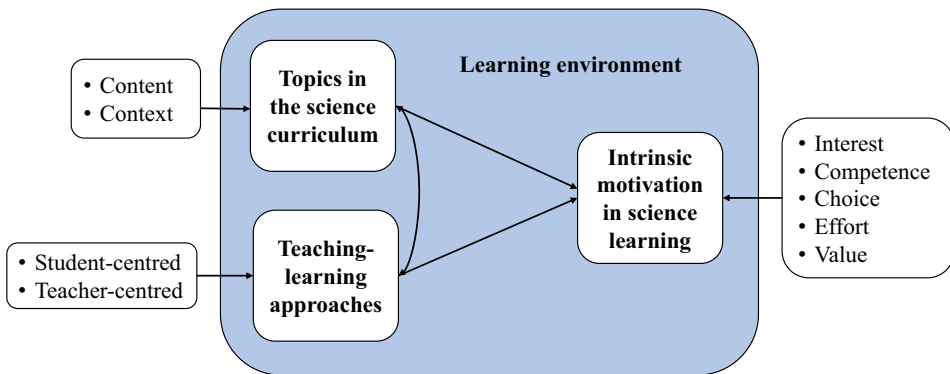
First, the model takes into consideration the social constructivist view of teaching and learning, according to which learning is constructed in an active way through social interactions (Palincsar, 1998). According to the theory of social constructivism developed by Vygotsky (1978), learning is a socially active rather than passive process, where students are engaged actively and responsibly and interact and cooperate with each other, through a process that is also known as the student-centred approach as opposed to the teacher-centred approach to learning (Jones, 2007; Smit et al., 2014). Based on the social constructivist view, the theoretical model includes teaching and learning approaches hypothesised as predictors of intrinsic motivation. This hypothesis is based on the results of previous studies that have shown significant positive relationships between components of the learning environment (e.g. cooperation, involvement, teacher support) and student motivation in science learning (Aldridge & Rowntree, 2021; Hafizoglu & Yerdelen, 2019).

The second component of the model relates to student perceptions of learning topics in the science curriculum (covering topics from biology, geography, chemistry and physics) presented in different contexts seen as another predictor of intrinsic motivation. Context-based learning (CBL), which is widely used as an approach in science education, has been shown to have positive effects on student intrinsic motivation when using interventions (Sevian et al., 2018; Vaino et al., 2012). For example, Vaino et al. (2012) found that student intrinsic motivation (measured in terms of interest, autonomy, competence, relatedness and value) was significantly more highly related to lessons based on context-based modules compared to their previous chemistry lessons, and was also increased whenever teachers used these context-based modules. On the other hand, how science content presented in different contexts influences student intrinsic motivation and interest has been studied little (Schreiner & Sjøberg, 2004; Sjøberg & Schreiner, 2010), and therefore the current thesis aims to fill this gap.

Intrinsic motivation as the third component of the model is seen an important factor in the learning process for activating and stimulating student behaviour so as to achieve the desired goal or learning outcome (Murphy & Alexander, 2000; Schunk et al., 2014). Intrinsic motivation is conceptualised based on SDT (Deci & Ryan, 1985; Ryan & Deci, 2000b, 2000a) taking into account five sub-components (interest, competence, choice, effort and value) included in the model. In the model, intrinsic motivation as an independent variable is predicted by two

dependent variables: topics in the science curriculum and teaching-learning approaches.

Different researchers have proposed hypothetical models investigating the relationships between components of the learning environment and student intrinsic motivation in science learning. The current model (see Figure 2) is further developed based on models proposed by Hafizoglu and Yerdelen (2019) and Aldridge and Rowntree (2021). Unlike the models indicated in the literature the current model includes science curriculum topics as a new component hypothesised to be significantly related to intrinsic motivation. The literature on science education suggests that grade level is an important variable when investigating student motivation (Fortus & Touitou, 2021), and therefore the perceptions of students of different ages (grade 6 and 9) are explored. This leads to the need to devise two separate models, one for grade 6 and another for grade 9, to be tested empirically.



**Figure 2.** Theoretical model of the relationships between topics in the science curriculum, teaching-learning approaches and student intrinsic motivation in science learning

## 3. METHODOLOGY

### 3.1. The Estonian science teaching-learning environment

The learning environment refers to the social, physical, psychological, and pedagogical context in which the learning occurs and which affects cognitive, affective, and behavioural outcomes for students (Fraser, 2012; Fraser & Fisher, 1982). Learning can take place in different settings, locations and contexts, which are generally divided into formal and informal learning environments (Hofstein & Rosenfeld, 1996). In the current thesis, the learning environment is limited to learning science in formal classroom settings in school, where different teaching-learning approaches take place to achieve the learning goals.

The Estonian education system is based on the Lifelong Learning Strategy 2020 (Ministry of Education and Research, 2014) and the follow-up document, the Education Strategy 2021–2035 (Ministry of Education and Research, 2021), which guide the most important developments in the area of education. Teaching and learning science in Estonian basic schools (grades 1 to 9) is based on the National Curriculum for Basic School (Estonian Government, 2011), which includes a general part with appendixes for different subjects. The appendix related to science subjects (see annex 4), presents guidelines for the planning and conducting of science teaching as well as the subject curriculum and a description of topics.

In Estonia, science subjects (general science, biology, geography, chemistry and physics) are taught separately depending on the school level starting with general science in grades 1–7, adding biology and geography in grades 7–9 and chemistry and physics in grades 8–9 (Estonian Government, 2011). Up to grade 6, science as a single subject is taught mostly by the class teacher, and starting from grade 7 usually by different science teachers for each science subject; however, in smaller schools one science teacher can teach several science subjects.

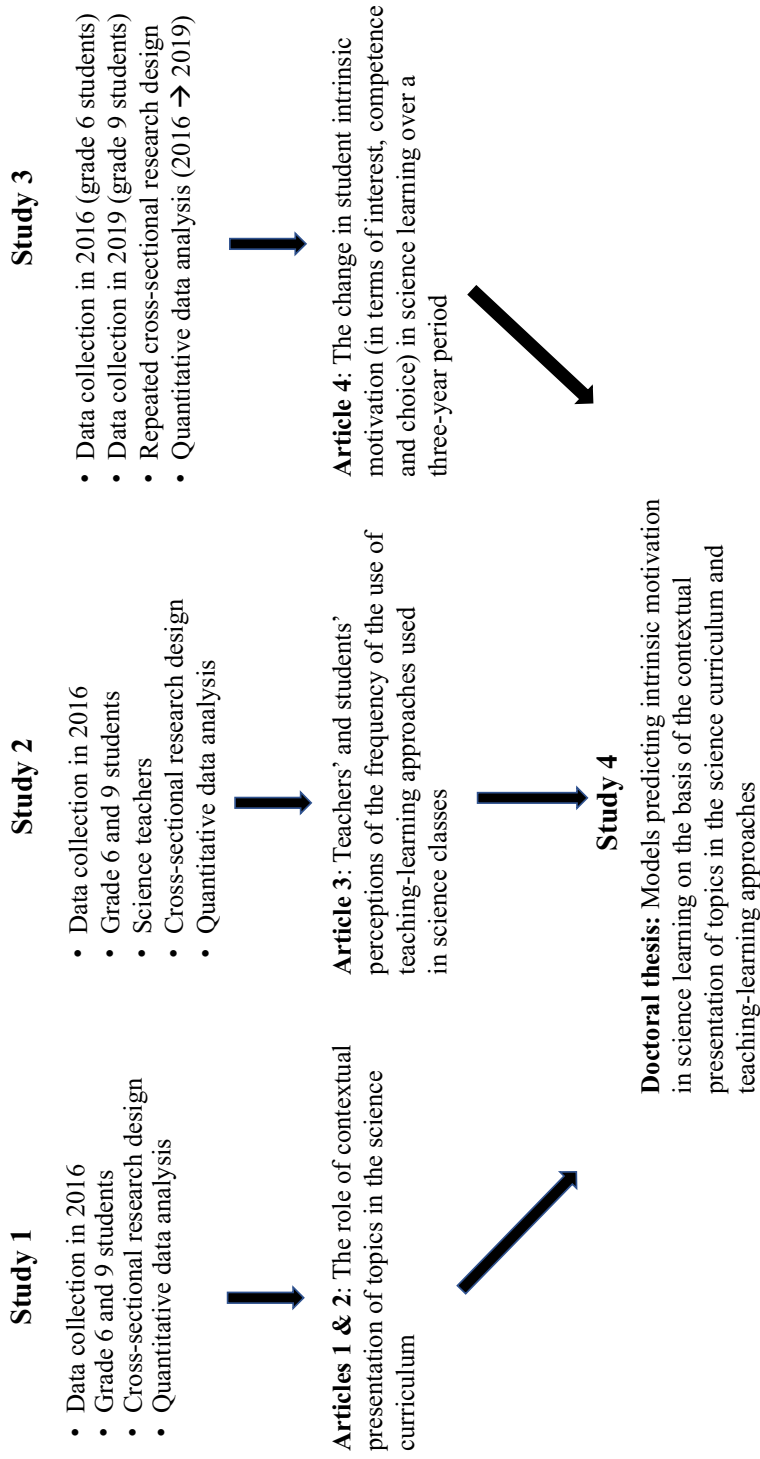
The current science curriculum in basic school is designed to enhance scientific and technological literacy, focusing on solving science-related problems via inquiry-based learning (Estonian Government, 2011). The curriculum further stipulates that learning is student-centred and based on the social constructivist approach. Over the ten years since 2011, different expert groups have engaged with the modernisation of the competencies and learning outcomes of all subject areas, and by 2023 curriculum updates have been made and approved by the Government with the aim of giving teachers more time and opportunities to apply a learner-centred approach in supporting the achievement of specific learning outcomes and focus on the development of general competences. However, the changes within science subjects have been minor – only the learning outcomes of the environment topic (green turn, climate neutrality, biodiversity) have been updated, and some learning outcomes regarding practical skills (since practical works are no longer part of the regulation) have been added (Estonian Government, 2023). The updated curriculum will take effect gradually from 2023/2024 during the next two academic years.

As one of the developments, from the 2017/2018 school year, national electronic proficiency tests (e-testing) in science have been conducted to evaluate different competencies, including science-related problem solving and decision-making based on the inquiry-based learning approach (Pedaste et al., 2015), in students in grade 4, 7, 10 and 12 (Pedaste, 2018; Rannikmäe et al., 2021). Based on the e-testing, the assessment of the knowledge and skills of students in grades 10 and 12 emphasises the role of task context; for example, in everyday life, the social environment, careers, or the nature of science (Rannikmäe et al., 2021).

The Estonian education system is well-known for its high degree of autonomy and very good level of student achievement in science, math and reading based on the international PISA test (OECD, 2016; Tire et al., 2016, 2019). Teachers have the freedom to design the learning environment and use different methodologies when conducting science lessons (Estonian Government, 2011). For example, in addition to textbooks and workbooks, Estonian science teachers can use a variety of digital resources (e-learning environments) and technological equipment (laboratory as well as smart devices) to teach science in the classroom (Kori, 2022). At the same time, Estonia is facing a lack of science teachers – on average, every fifth science teacher in Estonia is at least 60 years old (Mets & Viia, 2018) and the teacher shortage is ongoing. On the other hand, based on the 2019 TALIS report, more than 75% of science and foreign language teachers (teaching in grades 7 to 9) in Estonia have at least a master's degree or an equivalent educational level – being in the best position in terms of qualification requirements compared with other subject teachers (Taimalu et al., 2019).

### **3.2. Research design**

The dissertation focuses on the development of the model investigating the relationships between lower secondary school students' perceptions of the contextual presentation of topics in the science curriculum, teaching-learning approaches and intrinsic motivation in science learning. Figure 3 illustrates how the three studies contribute to the doctoral thesis through data collection and analysis and reporting through the articles. A cross-sectional research design is used in Studies 1 and 2 to collect and analyse the data from grade 6 and 9 students and science teachers at a particular point in time (2016). In Study 3, a repeated cross-sectional design is utilised to investigate change in student intrinsic motivation by comparing the same students' perceptions over a three-year period (2016 → 2019). Quantitative research methods are used throughout the studies. With regard to the quantitative methods, group-level comparisons (grade 6 and 9 students, students and science teachers, science subjects) are used to determine patterns between the groups. The doctoral thesis culminates in empirical models describing the motivational science learning environment for grade 6 and 9 students (Study 4).



**Figure 3.** Overview of the research design illustrating the interconnections between the studies

To answer to the first research question, the perceptions of grade 6 and 9 students about the contextual presentation of topics in the science curriculum are analysed comparatively within Study 1 (Articles I and II). Study 2 seeks to answer research question 2 through examining the perceptions of students and science teachers of the frequency of using different teaching and learning approaches in science classes. In Study 3, data is gathered in 2016 and three years later as a follow-up study in 2019 to provide data over a longer time frame. Through research question 3, the change in the intrinsic motivation of students over three years is explored (Article IV). The previous three studies all provide input to help answer research question 4, focusing on developing and testing a model for predicting intrinsic motivation in science learning via the contextual presentation of topics in the science curriculum and teaching-learning approaches as perceived by students in grade 6 and 9. A detailed overview of the research design and methodology with respect to the research questions is provided in Table 2.

### **3.3. Procedure**

For articles I, II and III empirical data is collected as part of the large-scale project “Smart technologies and digital literacy in promoting a change of learning” in spring (March to May) 2016, and for Article IV as a follow-up study in May 2019. The schools were chosen in 2016 to be representative of Estonian schools considering the following criteria: general education schools (except schools with special needs), schools with Estonian as the main language, more than five students in a class (from both grade 6 and 9), location of schools (rural and urban schools) and the type of schools (basic school and gymnasium) (for more information see Adov, 2022). After considering the criteria, 326 schools were identified. Finally, invitations to participate in the project were sent out to 202 school leaders by email. Those schools that did not respond within a certain period of time were contacted by phone and the invitation to participate remained. In total 147 schools took part in the study forming a representative sample of Estonian schools. Among them, grade 6 students responded from 123 schools and grade 9 students from 48 schools, while students from both grade 6 and 9 participated from 27 schools.

After three years, in May 2019, a follow-up study was carried out with the aim of collecting data from grade 9 students that could be compared with responses from grade 6 students three years earlier. The invitation was sent to all the schools who had participated in 2016. Many of the schools withdrew their participation and justified this on the basis of a lack of time because of other national surveys being implemented at the same time. Ultimately, 31 schools agreed to participate in the follow-up study.

**Table 2.** Overview of the research design and methodology

Study	Research questions	Articles	Design and data collection	Samples	Sections of the instrument	Data analyses
<b>Study 1</b>	<b>RQ1:</b> What is the role of context for students learning topics in the science curriculum considering the different contexts perceived by grade 6 and 9 students?	I, II	Cross-sectional design (2016)	Grade 9 (N=848) Grade 6 (N=2673)	I. Topics in the science curriculum	Exploratory factor analysis (EFA) Confirmatory factor analysis (CFA)
<b>Study 2</b>	<b>RQ 2:</b> How do students and science teachers perceive the frequency of the use of teaching-learning approaches in different science subjects?	III	Cross-sectional design (2016)	Grade 9 (N=848) Grade 6 (N=2673) Science teachers (N=205)	III. Teaching-learning approaches	Exploratory structural equation modelling (ESEM) Mann-Whitney U test Kruskal-Wallis H Test
<b>Study 3</b>	<b>RQ 3:</b> How intrinsically motivating do grade 6 and 9 students perceive science subjects at school (Article II) and what changes in student intrinsic motivation (in terms of interest, competence and choice) can be identified from the long-term perspective (Article IV)?	II, IV	Repeated cross-sectional design (2016 and 2019)	Grade 6 and 9 (N=171)	II. Intrinsic motivation	Confirmatory factor analysis (CFA) Mann-Whitney U test Kruskal-Wallis H Test Wilcoxon Signed Rank Test
<b>Study 4</b>	<b>RQ 4:</b> What are the effects of the contextual presentation of science education and the frequency of the use of teaching and learning approaches in predicting intrinsic motivation in science learning for grade 6 and 9 students?	analysis in the thesis	Cross-sectional design (2016)	Grade 9 (N=848) Grade 6 (N=2673)	I. Topics in the science curriculum II. Intrinsic motivation III. Teaching-learning approaches	Structural equation modelling (SEM) Spearman Rank Order correlation analysis

For both data collections (2016 and 2019), an electronic format was used. The instrument for the students was administered electronically either using the school computers, or tablet computers provided by a data collector responsible for implementing the survey at the school. Students were asked to answer a self-reported questionnaire during a regular science lesson in the presence of the science teacher and the members of the research team. It took approximately 20 minutes to respond to the science-related items. Similarly, science teachers answered an electronic questionnaire in 2016, which was sent by email to all science teachers (general science, biology, geography, physics and chemistry) who taught at the same schools where the student survey had been conducted.

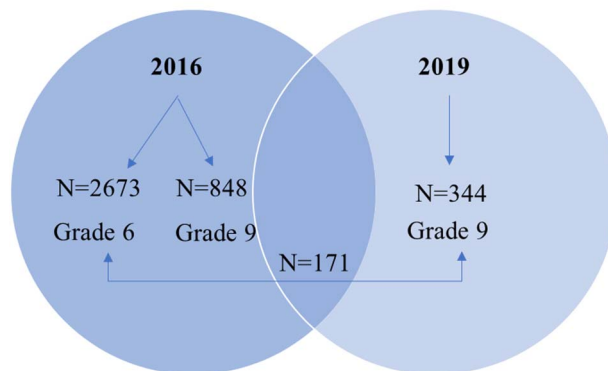
Prior to the data collection, informed consent from the parents, permission from the school heads and approval from the Research Ethics Committee of the University of Tartu were obtained. Only students who had received parental approval were included in the study.

### 3.4. Participants

#### 3.4.1. Students

Data from students from 2016 was used in articles I, II and III and from 2016 and 2019 in Article IV. The sample from 2016 consisted of 2,673 grade 6 students and 848 grade 9 students (Figure 4). The average age of the students in grade 6 was 12.6 years ( $SD = 0.63$ ) and in grade 9 was 15.6 years ( $SD = 0.54$ ).

In 2019, data was gathered altogether from 485 grade 9 students. However, as there was missing data, after cleaning, 344 students were taken into the further analysis. As the purpose of Study 3 was to investigate the same students answering in grade 6 and 9, after comparing the datasets from 2016 and 2019, a sample of 171 students who participated in both grades was taken for the repeated cross-sectional analysis (see Figure 4). The average age of the students was 12.6 years ( $SD = 0.53$ ) in grade 6 and 15.6 years ( $SD = 0.60$ ) in grade 9.



**Figure 4.** Overview of the student sample used in the doctoral thesis

### 3.4.2. Science teachers

For Article III, comparative data was collected in 2016 from 205 science teachers, 155 of whom reported teaching grade 6, and 92 grade 9, while 70 indicated they taught both grades in lower secondary school level. The sample of 205 teachers was used in Study 2 to investigate science teachers' perceptions of the frequency of the use of teaching and learning approaches in science classes.

## 3.5. Instruments

Two separate questionnaires (one for students and another for science teachers) were developed, piloted and validated for answering the research questions. A detailed overview of the research design and methodology (samples, instrument, data analysis methods) is provided in Table 2.

### 3.5.1. Students' questionnaire

A questionnaire for students was developed to collect data from grade 6 and 9 students about their perceptions of science learning covering three sections: topics in the science curriculum presented in different contexts, intrinsic motivation, and teaching-learning approaches.

#### *I. Topics in the science curriculum presented in different contexts*

The first section of the questionnaire covered the science learning content presented in the Estonian National Curriculum for Basic Schools (Estonian Government, 2011). It consisted of 36 science topics, presented as different content and using different contexts so that within every science subject (biology, geography, chemistry and physics) there were 9 content areas, presented in 3 contexts – personal, social and content related to the science curriculum (see Article I, Table 1). All topics were presented using a 4-point agreement scale (1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree).

#### *II. Intrinsic motivation*

The second section of the questionnaire was associated with measuring students' intrinsic motivation in science learning using an adapted and shortened Intrinsic Motivation Inventory Instrument (IMI) developed by Deci and Ryan (2016). In this questionnaire, 5 sub-scales were used as follows: interest (4 items), perceived competence (4 items), perceived choice (4 items), effort (3 items) and value (5 items). All responses were based on a 5-point agreement scale (1 – strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, 5 – strongly agree).

#### *III. Teaching-learning approaches*

The third section of the questionnaire was associated with measuring students' perceptions of the frequency of the use of teaching-learning approaches in science lessons. Eighteen different approaches were selected and modified based on earlier

research and instruments (Ebenezer & Zoller, 1993; Juuti et al., 2010) and on the theoretical cross-model of teaching and learning approaches grounded on social constructivist theory (see Article III) considering both students' and teachers' views and the Estonian science learning environment. Students were asked to evaluate the perceived frequency (number of times – never, sometimes or often) for 18 teaching-learning approaches undertaken in science lessons.

For sections two and three (intrinsic motivation and teaching-learning approaches) grade 6 students responded about science, while grade 9 students provided data for different science subjects (each science subject was evaluated by randomly selected students) based on the four different subjects studied (biology, geography, chemistry and physics).

### 3.5.2. Teachers' questionnaire

As a part of teachers' questionnaire, similar to students, science teachers were asked to indicate their opinions regarding the perceived frequency of the use of teaching-learning approaches in their science lessons. The same number of teaching-learning approaches (18) were originally included in the questionnaire with a 3-point scale (1 – never, 2 – sometimes or 3 – often).

An overview of the questionnaire sections used both among students and science teachers is presented in the table below (Table 3).

**Table 3.** Overview of the questionnaire' sections administered to students and science teachers

Sections of the instrument	Grade 6 students	Grade 9 students	Science teachers
I. Topics in the science curriculum	– school science subject topics (25) – science topics related to everyday life (10)	– school science subject topics (23) – science topics related to everyday life (13)	not measured
II. Intrinsic motivation	– interest (4) – competence (4) – choice (4/3) – effort (3) – value (5/4)	– interest (4) – competence (4) – choice (4/3) – effort (3) – value (5/4)	not measured
III. Teaching-learning approaches	– traditional (4) – cooperative (7) – experimental (3) – problem solving and decision-making (2)	– traditional (4) – cooperative (7) – experimental (3) – problem solving and decision-making (2)	– traditional (4/3) – cooperative (7) – experimental (3) – problem solving and decision-making (2)

*Note.* Numbers in the brackets indicate the number of the items used within the corresponding construct before/after data analysis. Factors identified under each section were found based on factor analysis.

### 3.5.3. Reliability and validity of the instruments

The developed students' questionnaire was piloted by asking a select group of students from both grade 6 and 9 from different schools to provide feedback on the clarity and appropriateness of the items. Based on the students' responses, minor changes were made regarding item wording.

To achieve content validity in the students' questionnaire, interviews with three experts (one science teacher, one science education professor and one researcher) were held to evaluate the questionnaire's accuracy (usability, relevance) in the Estonian science learning environment, especially its suitability for lower secondary school. Agreement between the experts was 85%. To ensure construct validity, confirmatory factor analysis (CFA) was used to assess how well the data fitted the constructs within each section of the questionnaire.

The teachers' questionnaire was piloted in a sample of science teachers to establish the comprehensibility and relevance of the items. CFA was also used to evaluate construct validity of the teachers' questionnaire.

Internal consistency (Cronbach's alpha) was calculated separately for grade 6 and 9 students and the science teachers. Cronbach's alpha ranged in all cases (within a single factor and the overall section) over all samples between .70 and .97 indicating acceptable values (Cortina, 1993) (see Table 4).

**Table 4.** Reliability values (Cronbach's  $\alpha$ ) by section of the questionnaire

Sections of the instrument (below factors within the section)	Grade 6 students	Grade 9 students	Science teachers
I. Topics in the science curriculum	.97	.97	n/a
– school science subject topics	.97	.96	n/a
– science topics related to everyday life	.92	.93	n/a
II. Intrinsic motivation	.85	.88	n/a
– interest	.93	.93	n/a
– competence	.92	.94	n/a
– choice	.71	.75	n/a
– effort	.70	.76	n/a
– value	.84	.87	n/a
III. Teaching-learning approaches	.82	.85	.80
– traditional approaches	.71	.71	.71
– cooperative approaches	.71	.75	.71
– experimental approaches	.70	.74	.70
– problem solving and decision-making	.85	.87	.85

*Note.* n/a– not available.

### 3.6. Data analysis

Quantitative analysis methods were used for all studies. Statistical analysis was carried out using the SPSS 27.0 and Mplus 8.4 software (Muthén & Muthén, 1998–2017). Depending on the purpose and research questions put forward in each study to answer the research questions in the thesis, different analysis methods were applied (see Table 2).

Descriptive statistics (means, standard deviations) were calculated for each item or group of items (e.g. latent variables, factors) through all studies. Since the data was non-normally distributed, the non-parametric tests (Mann-Whitney U Test, Kruskal-Wallis H Test and Wilcoxon Signed Rank Test) were used for group comparisons. To find out differences between science subjects, pairwise comparisons of the Dunn-Bonferroni tests were conducted.

The goodness of all models (CFA, ESEM and SEM) was assessed using a maximum likelihood (MLR) estimation with robust standard errors within each section separately for grade 6 and 9 students and teachers (Articles II, III, IV). Well-established indices and criteria to assess the goodness of fit of the measurement models –  $\chi^2$ ,  $\chi^2/df$ , CFI, TLI, RMSEA were assessed as follows:

- $\chi^2/df$  less than 2 gives an indicator that the model fits the data (Kline, 2011).
- A CFI and TLI range from 0 to 1, with higher values indicating a better fit:  $\geq 0.95$  good fit (Hu & Bentler, 1999),  $\geq 0.90$  acceptable fit (Kline, 2011).
- RMSEA, lower values indicating a better fit, between 0.03 and 0.08 acceptable fit depending on the sample size (Hair et al., 2013).

#### 3.6.1. Study 1

In this study, at first, EFA was used to determine the factor structure of the science topics presented in different contexts separately for the data from grade 6 and 9 students. Principal axis factoring (PAF) with a direct oblimin rotation was conducted, as well as the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett’s tests for sphericity in order to determine whether the principal axis factor analysis was appropriate for these datasets. The final EFA resulted in a two-factor solution for both grades and named the *school science subject factor* and *science topics related to everyday life factor* (see Article II, Table 3). Second, CFA was used to confirm the final two-factor solution, and third, descriptive statistics were used to determine the tendencies of grade 6 and 9 students’ perceptions on these factors.

#### 3.6.2. Study 2

In Study 2, exploratory structural equation modelling (ESEM) was first carried out separately on the data from grade 6 and 9 students and the data from the teachers to group the single items (approaches) into factors for further analysis. The ESEM integrated CFA and EFA was the preferred method for testing model fit, being robust for the non-normality of the data. Second, the Mann-Whitney U

Test was used to compare grade 6 and 9 students in order to determine whether there was statistical evidence of a difference between the grades and across the teaching-learning approach factors. Third, the Kruskal-Wallis H Test was conducted to identify differences between science subjects for grade 9 students across teaching-learning approaches.

### **3.6.3. Study 3**

Students' intrinsic motivation in science learning was assessed through a single cross-sectional (Article II) and a repeated cross-sectional study (Article IV). In both cases, CFA was initially used to test the theoretical factor structure of the intrinsic motivation section of the instrument. The Mann-Witney U test and Kruskal-Wallis H Tests were conducted to compare group differences as a part of the single cross-sectional research. The Wilcoxon Signed Rank test of the related samples was conducted to compare the changes in student interest, perceived competence and perceived choice in science learning in the repeated study.

### **3.6.4. Study 4**

Structural equation modelling (SEM) was carried out to analyse structural relationships; that is, the predictive direct effect of the contextual presentation of topics in the science curriculum and teaching-learning approaches on intrinsic motivation in science learning separately based on student perceptions in grade 6 and 9. The hypothetical model for testing the relationships is presented in Figure 1. Bivariate correlations between the latent variables were computed using Spearman Rank Order correlation analysis.

## **3.7. Ethical considerations**

Research conducted within the frames of the current thesis followed the guidelines, values and principles for action described in the Estonian Code of Conduct for Research Integrity (2017). Prior to data collection, the Research Ethics Committee of the University of Tartu was consulted, and the positive approval of the project was obtained. In addition, schools, parents, students and science teachers were informed about the research aims, how the anonymity of the students and teachers would be protected, how participation was voluntary for the students and teachers, how the data would be stored and who had the access to the collected data. Only students whose parents gave their agreement were included in the research. Student anonymity was protected by replacing their names with numeric codes, the key to which was kept separate from the data files. Data analysis was conducted using the coded dataset. All collected data were kept in one password protected computer and data files were accessible only to the author of this thesis and for other project team members. The project team shared the main results obtained from the current study with participating teachers and schools after the data analysis of the main study.

## 4. RESULTS

The results of the thesis are presented in four sub-sections in accordance with the four research questions. First, the thesis focuses on determining the role of the contextual presentation of topics in the science curriculum as perceived by grade 6 and 9 students. Second, it provides a comparison of how students and science teachers perceive the frequency of the use of teaching-learning approaches implemented in science classes. Third, student intrinsic motivation is studied through cross-sectional and repeated cross-sectional research. Fourth, the effects are tested of the contextual presentation of topics in the science curriculum and the perceived frequency of the use of teaching-learning approaches in predicting the intrinsic motivation of grade 6 and 9 students in science learning.

### 4.1. The contextual presentation of topics in the science curriculum

The focus of Study 1 was to find out what perceptions grade 6 and 9 students have towards learning topics in the science curriculum presented in different contexts and how these vary between grades.

At first, an EFA was carried out to reduce the single topics (36 items) to a smaller set of latent factors resulting in a two-factor solution for grade 6 and 9: topics in school science presented on the basis of content (e.g. chemical properties of detergents, formation of different landforms, atomic structure and chemical bonding, photosynthesis, electric circuits and their parts) and science topics related to everyday life presented in personal and social contexts (e.g. poisonous plants and their effects on the human body, natural hazards affecting tourism development, causes of road accidents and the damage to society). School science subject factors consisted of 25 topics for grade 6 and 23 topics for grade 9, and factors of science topics related to everyday life consisted of 10 topics and 13 topics, respectively. One item was excluded from the grade 6 EFA due to the low loading (below .40). The KMO measure of sampling adequacy was 0.98 and 0.97 for the two-factor solutions for grades 6 and 9, indicating adequate values (Field, 2013), and the Bartlett's test of sphericity was significant ( $p < .001$ ) for both grades.

Second, a CFA was conducted to test the two-factor solution. The initial results of the fit indices for the two-factor empirical models for both grades showed poor fits (CFI and TLI  $\leq .87$ , RMSEA  $\geq .08$ ) (see Article II, Table 4). Based on the suggestions of the modification indices, the error values of several topics permitted correlation to support the decision to find better fits of the models (Cortina, 2002; Hermida, 2015). These topics may seem similar in content for the students but were presented in different contexts. An overview of the error values of the topics that permitted correlation are presented in Appendix 1. After the modifications, both revised models fitted the data at an acceptable level (Table 5).

**Table 5.** Summary of fit indices for revised two-factor CFA models

Models	$\chi^2$	<i>df</i>	$\chi^2/df$	<i>p</i>	CFI	TLI	RMSEA
Grade 6	4522.77	542	8.34	<.001	.91	.90	.05
Grade 9	1987.55	566	3.51	<.001	.91	.90	.05

Third, the perceptions of grade 6 and 9 students were compared according to these factors. However, the content (topics) of two factors were not identically the same for grade 6 and 9 students, so it was not possible to conduct the statistical group comparison analysis. But the tendencies showed that grade 6 students indicated higher perceptions of learning the topics related to everyday life ( $M = 2.77$ ,  $SD = 0.75$ ) compared to school science topics ( $M = 2.37$ ,  $SD = 0.76$ ) (see Article II, Table 5). Similarly, grade 9 students showed more interest in learning topics related to everyday life ( $M = 2.61$ ,  $SD = 0.70$ ) compared to school science topics ( $M = 2.27$ ,  $SD = 0.71$ ).

## 4.2. Students' and science teachers' perceptions of teaching-learning approaches used in science lessons

To determine the teaching-learning approaches that students and teachers employ in science lessons, ESEM was conducted first to reduce single items into factors. Regarding the students, the analysis showed that teaching and learning approaches were divided into four factors: traditional (teacher-centred) (e.g. lecturing, asking questions), cooperative (e.g. role-play, group work, debate), experimental (formulation of hypotheses and research questions, carrying out experiments, making conclusions) and problem solving and decision-making. Since, two items – student individual work and teacher giving feedback to student work – had loadings < .30, these were excluded, and the factor analysis was carried out with the remaining 16 items leading to the following four factors: teacher-centred (4 items), cooperative approaches (7 items), experimental approaches (3 items), plus solving problems and decision-making (2 items). Within the analysis of the data from the teachers, one additional item was excluded (new content is presented by the teacher as a lecture) in addition to the two items from the students. The four-factor structure indicated acceptable fit indices for both the students' and teachers' models as follows:  $\chi^2(62) = 688.67$ , CFI = .96, TLI = .93, RMSEA = .05 and  $\chi^2(51) = 79.68$ , CFI = .96, TLI = .93, RMSEA = .05 (see Article III, Table 5).

Second, group comparison analyses were conducted. The Mann-Whitney U analyses showed statistically significant grade differences across all four approach factors, so that traditional, cooperative and experimental approaches were perceived to be more frequently used by grade 6 students compared with grade 9 students (Table 6). In contrast, grade 9 students reported higher frequency for problem solving and decision-making approaches compared with grade 6 students.

**Table 6.** Grade differences in student perceptions of the frequency of the use of teaching-learning approaches

Teaching-learning approach factors	Grade 6	Grade 9	<i>U</i>	<i>p</i>
	( <i>N</i> =2673)	( <i>N</i> =848)		
	<i>Mean Rank</i>	<i>Mean Rank</i>		
Traditional approaches	1821.22	1571.48	973361.5	<.001
Cooperative approaches	1851.98	1474.65	891152.5	<.001
Experimental approaches	1806.12	1619.00	1013706.0	<.001
Problem solving and decision-making	1692.31	1977.19	950720.0	<.001

Note. Mann-Whitney U Test *U* statistic.

Third, the differences in the perceived use of teaching-learning approaches in separate science subjects (biology, geography, chemistry and physics) among grade 9 students were examined using the Kruskal-Wallis H Test. The results indicated that the differences appear between all factors except cooperative approaches (Table 7). The results also showed that grade 9 students perceive the use of traditional approaches most frequently in biology and geography, somewhat less frequently in physics and chemistry. In contrast, experimental approaches were used more frequently in chemistry and physics compared with biology and geography. Problem solving and decision-making approaches were most frequently used in physics lessons.

**Table 7.** Differences in how grade 9 students (*N* = 848) perceive the frequency of the use of teaching-learning approaches in separate science subjects

Teaching-learning approach factors	Biology	Geography	Chemistry	Physics	Kruskal-Wallis <i>H</i>
	( <i>N</i> =220)	( <i>N</i> =216)	( <i>N</i> =220)	( <i>N</i> =193)	
	<i>Mean Rank</i>	<i>Mean Rank</i>	<i>Mean Rank</i>	<i>Mean Rank</i>	
Traditional	452.20	445.53	391.37	409.35	9.60*
Cooperative	437.02	427.22	404.52	432.16	2.27
Experimental	420.16	319.59	469.92	497.29	66.66**
Problem solving and decision-making	408.28	430.43	401.74	464.50	9.33*

\**p* < .05; \*\**p* < .001.

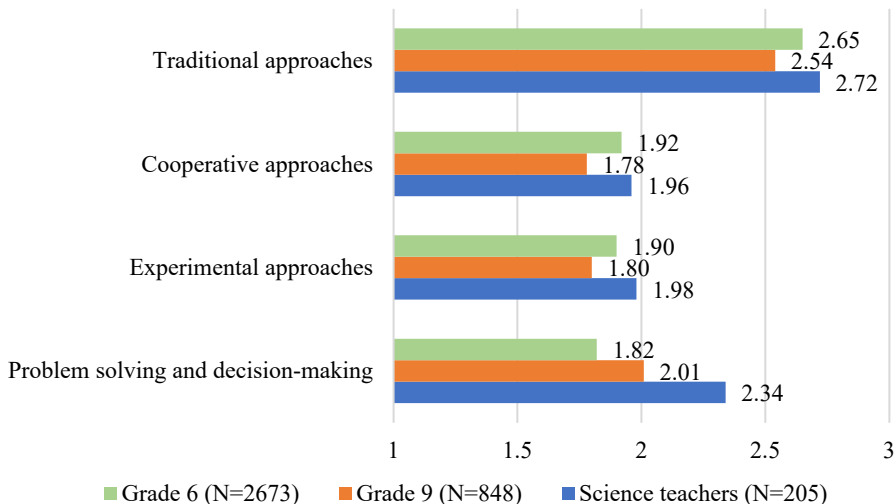
The post hoc Dunn-Bonferroni tests were conducted to test pairwise comparisons of different subjects. It was found that within experimental approaches geography was significantly different to chemistry (*p* < .001), physics (*p* < .001) and biology (*p* < .001), however there was no significant difference between chemistry with physics (*p* = .137), and biology (*p* = .004) (Table 8). In addition, significant differences were found between chemistry and geography and chemistry and physics both within traditional and cooperative approaches with higher perceived use of these approaches in biology and geography.

**Table 8.** Pairwise subjects' differences of the frequency of the use of teaching-learning approaches by grade 9 students (N = 848)

Pairwise comparisons	Traditional approaches	Cooperative approaches	Experimental approaches	Problem solving and decision-making approaches
	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
Chemistry-Physics	.446	.270	.137	.005
Chemistry-Geography	.018	.006	<.001	.190
Chemistry-Biology	.008	.009	.004	.764
Physics-Geography	.127	.125	<.001	.133
Physics-Biology	.069	.152	<.001	.013
Geography-Biology	.771	.909	<.001	.312

*Note.* Only *p*-values of pairwise comparisons are presented.

Finally, the comparative results from the perceptions of the students and science teachers (mean values) had quite the same pattern according to which traditional approaches were the most frequently used compared with the other approaches (Figure 5). The results demonstrated that science teachers had assessed all approaches as more frequently used in science lessons compared with the students. A significant difference between students and science teachers occurred in relation to problem solving and decision-making activities, according to which, science teachers perceived carrying out these approaches more frequently than students did.



**Figure 5.** A comparison the perceptions of students and science teachers of the frequency of the use of teaching-learning approaches in science lessons

### 4.3. Student intrinsic motivation in science learning

#### 4.3.1. Intrinsic motivation comparing grades and science subjects

Intrinsic motivation was measured through five components (sub-scales) – interest, perceived competence, perceived choice, effort and value in science learning. A CFA was conducted to test the fit of the theoretical construct to the data. As the two items (“I feel I must learn science” and “In science lessons I learn things, which are not needed in real life”) had low loadings (below .40) with the corresponding factors (perceived choice and value), then they were removed from the further analysis. After the changes, the final five-factor models with 18 items indicated good model fit indices for grade 6 ( $\chi^2(276) = 1127.00$ , CFI = .96, TLI = .95, RMSEA = .05) and for grade 9 ( $\chi^2(276) = 584.23$ , CFI = .96, TLI = .95, RMSEA = .05).

Second, student intrinsic motivation in science learning indicated significant grade differences according to all five sub-scales (Table 9). In other words, grade 6 students felt science learning more interesting and valuable, perceived more competence and choices and effort compared to grade 9 students.

**Table 9.** Comparison of intrinsic motivation in science learning for grade 6 and 9 students

Intrinsic motivation sub-scales	Grade 6 ( <i>N</i> = 2673)	Grade 9 ( <i>N</i> = 848)	<i>U</i>	<i>p</i>
	<i>Mean Rank</i>	<i>Mean Rank</i>		
Interest	1811.60	1601.75	999064.5	<.001
Perceived competence	1832.31	1536.59	943737.0	<.001
Perceived choice	1794.58	1655.33	1044547.5	<.001
Effort	1815.72	1588.77	988041.5	<.001
Value	1802.69	1629.80	1022875.0	<.001

*Note.* Mann-Whitney U Test *U* statistic.

The results of the analysis between science subjects revealed significant differences across all sub-scales of intrinsic motivation except effort (Table 10). Biology was seen as the most interesting science subject. Students perceived the highest competence and choices for biology as well as value in biology learning compared with other science subjects. In contrast, chemistry and physics were perceived as the less interesting subjects; in addition, students felt the least competence and less choices in chemistry and physics learning. According to the grade 9 students, physics is considered the science subject they perceived the most effort. Similar to biology, grade 9 students had high perceived competence and value in geography learning.

**Table 10.** Intrinsic motivation differences in learning science subjects among grade 9 students (N = 848)

Intrinsic motivation sub-scales	Biology (N=220)	Geography (N=216)	Chemistry (N=220)	Physics (N=193)	Kruskal-Wallis <i>H</i>
	<i>Mean Rank</i>	<i>Mean Rank</i>	<i>Mean Rank</i>	<i>Mean Rank</i>	
Interest	479.63	410.75	399.42	407.85	15.14*
Perceived competence	475.05	470.20	357.88	393.87	36.54**
Perceived choice	470.15	433.22	403.48	388.87	13.81*
Effort	413.30	398.60	432.10	459.78	7.19
Value	465.58	449.37	358.49	427.29	24.64**

\* $p < .05$ ; \*\* $p < .001$ .

The post hoc Dunn-Bonferroni tests indicated that within interest, biology was significantly different to chemistry ( $p < .001$ ), physics ( $p = .003$ ) and geography ( $p = .003$ ) (Table 11). Within perceived competence significant differences were found between chemistry and geography ( $p < .001$ ), chemistry and biology ( $p < .001$ ) as well as between physics and geography ( $p = .002$ ) and physics and biology ( $p < .001$ ). In terms of perceived choice, chemistry was significantly different to biology ( $p = .004$ ) and physics to biology ( $p < .001$ ). Within value significant differences were found between chemistry to physics ( $p = .004$ ), to geography ( $p < .001$ ) and to biology ( $p < .001$ ).

**Table 11.** Pairwise subjects' differences of intrinsic motivation by grade 9 students (N = 848)

Pairwise comparisons	Interest	Perceived competence	Perceived choice	Effort	Value
	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>	<i>p</i>
Chemistry-Physics	.726	.134	.543	.248	.004
Chemistry-Geography	.628	<.001	.202	.150	<.001
Chemistry-Biology	<.001	<.001	.004	.418	<.001
Physics-Geography	.905	.002	.066	.011	.360
Physics-Biology	.003	<.001	<.001	.053	.111
Geography-Biology	.003	.835	.113	.528	.488

*Note.* Only *p*-values of pairwise comparisons are presented.

### 4.3.2. The change in intrinsic motivation

Regarding Study 3, the repeated cross-sectional data analysis based on a sample of 171 students indicated that student interest and perceived competence towards science learning significantly decreased over time, while perceived choice level remained the same (Article IV). This outcome is partly consistent with the results

of cross-sectional research comparing grade 6 and 9 students as separate samples, indicating significant grade differences according to all five intrinsic motivation components.

#### **4.4. Predicting student intrinsic motivation in science learning**

Input from Studies 1 and 2 was then used in Study 4 (doctoral thesis) to investigate the direct effects of the contextual presentation of topics in the science curriculum and the perceived frequency of the use of teaching-learning approaches for predicting the intrinsic motivation of grade 6 and 9 students in science learning. First, a correlation analysis showed several moderate to high connections between the factors, mainly within the first and second sections (contextual presentation of topics in the science curriculum and intrinsic motivation) (Table 12). Second, SEM was used to test the theoretical model (see Figure 1) and the relationships between the factors separately using the data from grade 6 and 9 students.

##### **4.4.1. Model for grade 6 students**

The model indicated that the factor for science topics related to everyday life was seen as a positive significant predictor of interest ( $\beta = .401, p < .001$ ), perceived competence ( $\beta = .543, p < .001$ ), perceived choice ( $\beta = .297, p < .001$ ), effort ( $\beta = .453, p < .001$ ), and value ( $\beta = .687, p < .001$ ) in grade 6 science learning, being the highest predictor of value. In contrast, the factor for school science topics predicted significantly negatively perceived competence ( $\beta = -.182, p < .001$ ), and value ( $\beta = -.228, p < .001$ ), and positively perceived choice ( $\beta = .228, p < .001$ ) (see Figure 6). In other words, having a higher preference for learning school science topics raises the chances that grade 6 students perceive more choices but less value and perceived competence for learning science at school.

Considering teaching-learning approaches, the factor for traditional approaches was seen as the most powerful factor positively predicting grade 6 students' interest ( $\beta = .222, p < .001$ ), competence ( $\beta = .241, p < .001$ ), choice ( $\beta = .209, p < .001$ ), effort ( $\beta = .194, p < .001$ ), and value ( $\beta = .260, p < .001$ ) in science learning. This means that the more frequently traditional approaches were used in science classes the chances of higher intrinsic motivation in terms of interest, perceived competence, perceived choice, effort and value increased.

**Table 12.** Bivariate correlations between the factors for grade 6 (above) and 9 (below)

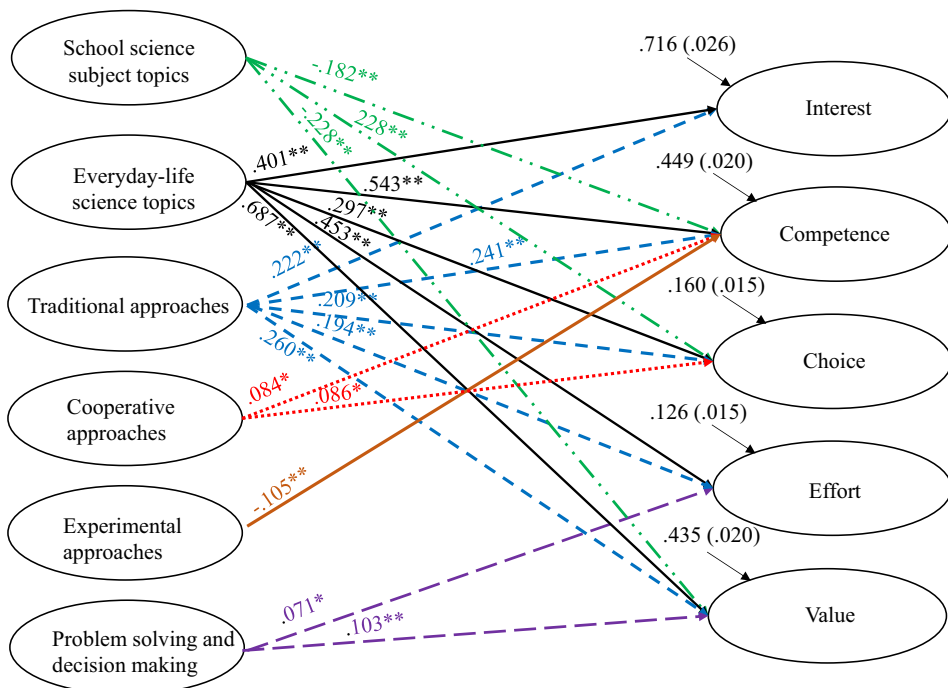
Grade 6	1	2	3	4	5	6	7	8	9	10	11
1. School science subject topics	1.000										
2. Science topics related to everyday life	.801**	1.000									
3. Interest	.414**	.458**	1.000								
4. Perceived competence	.283**	.383**	.644**	1.000							
5. Perceived choice	.375**	.382**	.650**	.513**	1.000						
6. Effort	.327**	.360**	.423**	.327**	.372**	1.000					
7. Value	.398**	.494**	.636**	.561**	.532**	.534**	1.000				
8. Traditional approaches	.104**	.170**	.260**	.265**	.224**	.186**	.312**	1.000			
9. Cooperative approaches	.199**	.154**	.170**	.123**	.189**	.145**	.202**	.297**	1.000		
10. Experimental approaches	.268**	.202**	.182**	.103**	.189**	.180**	.225**	.251**	.601**	1.000	
11. Problem solving and decision-making	.228**	.188**	.130**	.101**	.138**	.157**	.230**	.145**	.327**	.338**	1.000

Grade 9	1	2	3	4	5	6	7	8	9	10	11
1. School science subject topics	1.000										
2. Science topics related to everyday life	.808**	1.000									
3. Interest	.350**	.344**	1.000								
4. Perceived competence	.250**	.261**	.672**	1.000							
5. Perceived choice	.331**	.299**	.717**	.596**	1.000						
6. Effort	.339**	.361**	.443**	.301**	.369**	1.000					
7. Value	.275**	.334**	.646**	.588**	.556**	.510**	1.000				
8. Traditional approaches	.056	.103**	.336**	.308**	.255**	.180**	.343**	1.000			
9. Cooperative approaches	.199**	.132**	.265**	.124**	.229**	.103**	.188**	.338**	1.000		
10. Experimental approaches	.228**	.175**	.225**	.056	.168**	.168**	.149**	.218**	.627**	1.000	
11. Problem solving and decision-making	.221**	.192**	.328**	.254**	.310**	.230**	.391**	.343**	.409**	.374**	1.000

\*\* $p < .001$ .

A significant negative relationship appeared between experimental approaches on perceived competence ( $\beta = -.105, p < .001$ ) so that the more experimental approaches were used in science lessons, the higher the chances that grade 6 students perceive less perceived competence in science learning. More frequent use of cooperative approaches positively predicted students' perceived competence ( $\beta = .084, p < .001$ ) and choice ( $\beta = .086, p < .001$ ) in science learning. Similarly, greater use of problem solving and decision-making approaches led to higher feeling of effort ( $\beta = .071, p < .001$ ) and value ( $\beta = .103, p < .001$ ) in science learning. However, the effects of cooperative, experimental and problem solving and decision-making approaches on intrinsic motivation components were small. The model had acceptable fit indices:  $\chi^2(2205) = 10184.96, p < .001, CFI = .92, TLI = .91, RMSEA = .04$ .



**Figure 6.** Model predicting grade 6 student intrinsic motivation

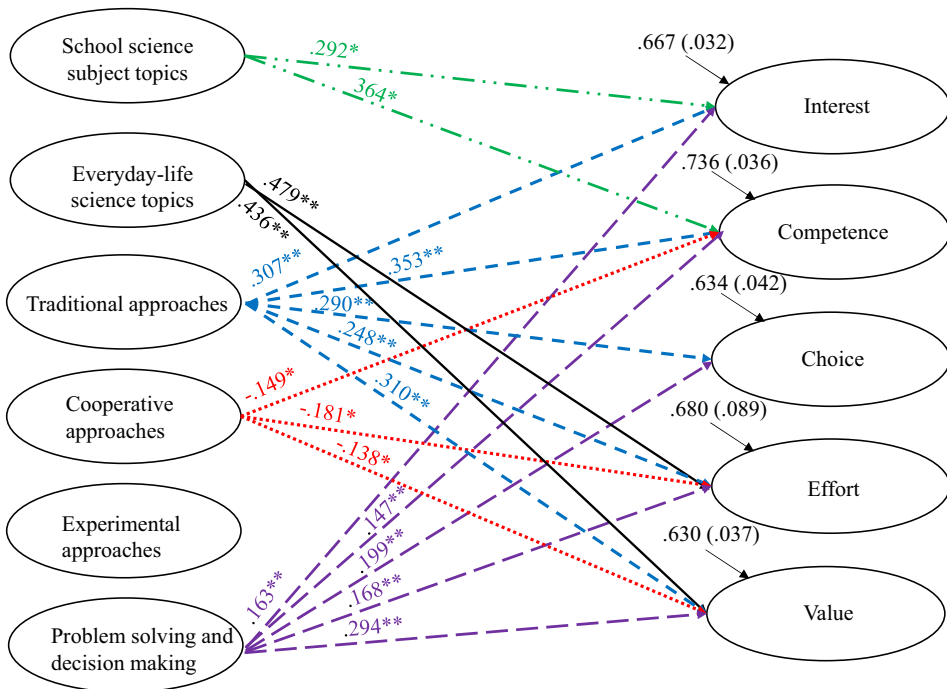
Note. Only significant standardised regression coefficients are presented at the level \* $p < .05$ , \*\* $p < .001$ .

#### 4.4.2. Model for grade 9 students

The model for grade 9 (see Figure 7) had some differences in its predictive effects on the components of intrinsic motivation compared to the grade 6 model. First, experimental approaches had no significant predictive effect on grade 9 student intrinsic motivation. Second, problem solving and decision-making approaches

had a significant positive effect on all components of intrinsic motivation (in grade 6, the effect was only on effort and value).

Regarding science curriculum topics, the factor for school science topics had a significant positive effect on interest ( $\beta = .292, p < .001$ ) and perceived competence ( $\beta = .364, p < .001$ ), while the factor for science topics related to everyday life is seen as a positive predictor for effort ( $\beta = .479, p < .001$ ) and value ( $\beta = .436, p < .001$ ) having the highest standardised regression coefficients compared with the other predictors. Similar to grade 6, the factor for traditional approaches, in addition to problem solving and decision-making, were seen as the most powerful factors positively predicting grade 9 student intrinsic motivation in terms of interest, perceived competence, perceived choice, effort and value in science learning. Contrary to the results of the grade 6 model, cooperative approaches had a negative significant effect on grade 9 students' perceived competence ( $\beta = -.149, p < .001$ ), effort ( $\beta = -.181, p < .001$ ) and value ( $\beta = -.138, p < .001$ ) in science learning. In other words, the more frequent use of cooperative approaches in science lessons led to lower levels of perceived interest, effort and value in science learning. The grade 9 model had an acceptable fit:  $\chi^2(2328) = 5523.68, p < .001, CFI = .91, TLI = .90, RMSEA = .04$ .



**Figure 7.** Model predicting grade 9 student intrinsic motivation

Note. Only significant standardised regression coefficients are presented at the level \* $p < .05$ , \*\* $p < .001$ .

## 5. DISCUSSION

The current doctoral thesis investigates factors of the classroom learning environment and their effects on the intrinsic motivation of lower secondary school students in science learning, considering the differences in science subjects at different grade levels. By understanding how students' perceptions of the frequency of the use of teaching-learning approaches in science lessons and the learning of science topics presented in different contexts can influence intrinsic motivation in science learning, teachers can design a supportive learning environment, which satisfies the basic psychological needs of their students and enhances science learning. The thesis presents the results from a self-reported questionnaire given to grade 6 and 9 students conducted cross-sectionally and as a follow-up cross-sectional study after a three-year gap. The discussion of the main outcomes will now be presented according to each of the research questions.

### 5.1. The role of the contextual presentation of topics in the science curriculum

This section of the doctoral thesis focuses on discussing the results with respect to the first research question about student perceptions of learning topics in the science curriculum presented in different contexts (Articles I and II). First, an EFA was used to group the single topics into factors, and second, the perceptions of grade 6 and 9 students according to these factors were investigated.

The EFA resulted in a two-factor solution for both grades as follows: the school science subject factor and the science topics related to everyday life factor. As a result of group comparison, both grade 6 and 9 students held higher perceptions of learning science topics related to everyday life (personal and social) compared with science subject topics (Article II). The results are generally in line with the CBL approach, according to which researchers have previously shown a positive influence of using context-based learning modules or materials on promoting student motivation and interest in science learning (de Putter-Smits et al., 2013; Habig et al., 2018; Slovinsky et al., 2021; Swirski et al., 2018; Vaino et al., 2012). Although the current research is not directly focused on implementing context-based learning materials, it still demonstrates a higher preference among students for learning science topics in relation to personal and social contexts, which in turn positively affects student intrinsic motivation towards science learning.

On the other hand, researchers have found that in traditional chemistry classrooms secondary school students perceived their teachers to be emphasising fundamental chemistry significantly more, as well as perceiving the significantly greater use of a teacher-centred approach than did students in context-based classrooms (Overman et al., 2014). This indicates that if we want learning to be more learner-centred and not just focused on memorising the content of the subject, a CBL approach is necessary. In addition, Habig et al. (2018) found that for

students with high initial interest, there is no need to express how the science content relates to their everyday life, as they are probably already intrinsically motivated or attracted by unfamiliar topics. We should also not assume that an apparently popular topic or context (e.g. everyday life or a social issue) will be automatically interesting or motivating for every student (Jones, 2007).

It seems that the use of different contexts (e.g. personal, social) becomes more important with advancing grades, starting from grades 7 and 8 in the Estonian school system, where science subjects are studied separately under different teachers and the learning content is perceived as more difficult to conceptualise and understand. In other words, elementary school science learning generally aims at understanding science at the macro level (simplified and related to everyday life); however, in lower secondary school, the focus is on understanding the content and processes at micro and presentation levels (Johnstone, 1982, 2000). The acquisition of more abstract science knowledge leads students to put more effort into understanding science, which in turn may move students away from learning science because of the difficulty and irrelevance of the content. The way forward should be directed towards more personalised learning – customising learning for each student’s strengths, needs, skills, and interests (Walkington & Bernacki, 2014). Unfortunately, this seems to be one of the biggest challenges for teachers due to the lack of different resources, and legislation that does not fully support the implementation of personalised learning.

## **5.2. Comparison of the perceptions of students and science teachers about teaching-learning approaches**

Study 2 investigated how students and science teachers perceived the frequency of the use of teaching-learning approaches in science lessons. Based on the four teaching and learning approach factors obtained via the ESEM (traditional, cooperative, experimental and problem solving and decision-making) the findings showed some similarities but greater differences in the frequency of the use of these approaches comparatively between grade 6 and 9 students, students and science teachers, and between the four science subjects in grade 9.

Traditional approaches (lecturing, asking questions and class discussions) were perceived to be the main teaching and learning methods commonly used in science lessons by both students and science teachers. Despite using different terminology in the literature (e.g. methods, activities, strategies), the current research findings are in accordance with other studies indicating that the traditional or teacher-centred approach is perceived to be the most often used in science lessons (Hasni & Potvin, 2015; Juuti et al., 2010). When comparing student results with science teachers’ perceptions, the tendency is the same for more traditional approaches. This is in line with the findings indicated by the TALIS report according to which Estonian teachers using cognitive activation (e.g., groupwork, undertaking critical thinking, or solving problems) to a relatively low extent especially among science and mathematics teachers when comparing OECD countries and the

countries that participated in the TALIS survey (Taimalu et al., 2019). Although the empirical evidence in the science education literature indicates a more teacher-centred approach, the trend in education should be towards a more student-centred and social constructivist approach (Palincsar, 1998; Taber, 2011). One of the most common forms to quickly transmit new knowledge is to use lecturing; however, researchers and educators argue that this is insufficient for education, as there is little interaction and cooperation by students and the students' needs and interests are not sufficiently addressed (Smit et al., 2014; Tularam & Machisella, 2018). One of the main reasons for the frequent use of traditional teaching approaches as perceived by Estonian lower secondary school students and teachers might be explained by the external pressure to achieve the learning outcomes and pass the final exams built into the curriculum.

Regarding student-centred approaches, the results showed that both students and science teachers perceived cooperative, experimental, and problem solving and decision-making approaches as being less frequently used in science lessons compared with traditional approaches. More precisely, the outcomes indicated significant differences between grades, and between students and teachers, in the way the use of these approaches is perceived, so that grade 6 students and science teachers perceived these approaches as being used more frequently compared with grade 9 students. Regarding experimental approaches, the results are consistent with the Estonian results from PISA 2015 (OECD, 2016) according to which 15-year-old students expressed that they rarely undertook practical activities in science lessons and had few opportunities to plan experiments compared with the OECD average. Regarding problem solving and decision-making approaches, the findings showed the greatest differences between the perceptions of students and science teachers in that these approaches were seen to be more frequently used by science teachers compared with students, especially grade 6 students. These findings might be explained in several ways. First, the outcomes can be influenced by the perceptions of how both students and teachers understand by one or another approach or method; that is, there could be different understandings for different ages of student versus teachers. Second, it was probably difficult for the students and teachers to identify how often or seldom these approaches were actually conducted in science lessons, as the results reflect only self-reported answers not the real situation in classrooms.

When analysing the perceptions of grade 9 students on the basis of the different science subjects (biology, geography, chemistry and physics), the results showed significant differences in regard to traditional, experimental and problem solving and decision-making approaches, in that they perceived the more frequent use of traditional approaches in biology and geography, experimental approaches in chemistry and physics, and problem solving and decision-making most frequently in physics lessons. This result was expected, as in physics and chemistry the emphasis should be on developing experimental skills; however, in biology and geography, the development of experimental and problem solving and decision-making skills should also be more enhanced.

### 5.3. Intrinsic motivation in science learning

In response to research question 3, the research moved a step further to investigate student intrinsic motivation in two ways – via a cross-sectional and a repeated cross-sectional study. The findings from the cross-sectional study indicated significant grade differences according to all five components of intrinsic motivation (interest, competence, choice, effort and value) in that grade 6 students felt science learning more interesting and valuable, perceived more competence, choices and effort compared to grade 9 students. The results from the repeated cross-sectional study indicated a similar declining trend in how the students perceived interest, competence and choice in science learning with a significant decrease in interest and perceived competence. The results from both analyses are in line with other international studies showing a similar decrease in motivation with age (Liou et al., 2020; Potvin & Hasni, 2014; Spinath & Steinmayr, 2008; Vedder-Weiss & Fortus, 2011; Vedder-Weiss & Fortus, 2012).

The cross-sectional comparison regarding separate science subjects indicated significant differences for interest, competence, choice and value (but not effort) perceived by grade 9 students. Biology was seen as the most interesting science subject, chemistry and physics were perceived as the less interesting subjects. Students perceived competence and value as higher for biology and geography learning, and competence and choices as lower in chemistry and physics learning. Therefore, the results confirm that students have subject-specific intrinsic motivation, which is in accordance with previous studies indicating the domain-specificity of student motivation (Gottfried et al., 2001; Salta & Koulougliotis, 2020). These results partly explain why students perceive chemistry but also physics as a difficult and effort demanding subject.

The decline in intrinsic motivation could be explained based on SDT with the insufficient satisfaction of psychological needs (autonomy, competence and relatedness), which are crucial for the development and maintenance of intrinsic motivation (Gnambs & Hanfstingl, 2016; Ryan & Deci, 2000b). In addition, compared with elementary school, the learning environment in lower secondary school can be characterised by rules, less student-teacher relationships and fewer opportunities for students to make decisions, while the need that adolescents have for autonomy, independence, and social interaction becomes more and more important (Wigfield et al., 1991).

This is expressed through student behaviour, where elementary school students tend to act and learn due to intrinsic motivation, while from the teenage years into adulthood students are motivated more by external (extrinsic) factors (Cook & Artino Jr, 2016; Diaconu-Gherasim et al., 2011). The transition from extrinsic back to intrinsic motivation requires that student values and goals become internalised and integrated, which in turn are promoted (or inhibited) by the satisfaction of three basic needs (Ryan & Deci, 2000a, 2020). Based on the results of the current thesis, and to facilitate this internalisation, it can be proposed that the students' need for autonomy can be supported by allowing students to make choices when design their own learning; competence can be supported by

positive feedback and teacher support to overcome difficulties, and relatedness by cooperation and by feeling respected and cared for by the teachers.

In the longer term, low motivation and dissatisfaction with science learning at school may lead students away from choosing science and technology related careers in the future, and this could further exacerbate labour shortages in this area (Hazelkorn et al., 2015).

#### **5.4. Predicting student intrinsic motivation in science learning**

This section of the thesis focuses on discussing the results with the respect to the fourth research question, investigating the effects of the contextual presentation of topics in the science curriculum and the perceived frequency of the use of teaching-learning approaches on intrinsic motivation in science learning separately for grade 6 and 9 students.

The results of the SEM indicated both similarities and differences in predicting intrinsic motivation in science learning when comparing the two models. It became evident that not all predictors influenced the components of intrinsic motivation to the same extent. For example, the perceived frequency of the use of traditional approaches positively predicted all five components of intrinsic motivation (interest, competence, choice, effort and value) using both models. In addition, science topics related to everyday life in grade 6 and problem solving and decision-making approaches in grade 9 were also the factors that positively predicted all five components of intrinsic motivation. The rest of the predictors influenced either single components or none of them (e.g. experimental approaches in the grade 9 model). In addition, the outcomes also showed negative relationships; for example, perceived competence, choice and effort were negatively predicted by cooperative approaches in grade 9, and perceived competence by experimental approaches in grade 6, although these effects were very small (i.e. explained less than 15% of the variance).

As indicated before, the use of traditional approaches influenced student intrinsic motivation to a significant extent predicting all five components. In other words, the more frequently grade 6 and 9 students perceived the use of teacher-centred approaches in science lessons, the more they felt interest, competence, autonomy, effort and value in science learning. This finding is somewhat unexpected and contradicts the educational-theoretical viewpoint on learning. Based on the social constructivist theory of learning, student-centred approaches are seen to promote student interest and motivation in learning (Palincsar, 1998; Vygotsky, 1978); however, the current findings indicated very little support for this (e.g. problem solving and decision-making approaches had only a minor predictive effect in regard to intrinsic motivation in grade 9 students). Similarly, the current results contradict Smit et al. (2014), who showed that students in a student-centred learning environment reported higher levels of perceived autonomy, competence, relatedness and motivation, measured in terms of pleasure and effort compared with teacher-centred environments. In addition, Hafizoglu and Yerdelen

(2019) and Aldridge and Rowntree (2021) reported positive direct effects of learning environment constructs (e.g. cooperation, involvement) on student motivation in science learning in terms of task value and self-efficacy, and are therefore also not in line with the results of this study.

The current research outcomes could be explained in many ways. First, the science learning environment at Estonian schools is perceived to be teacher-directed and there are less opportunities for students to investigate, collaborate and be more actively involved due to external pressures to meet the objectives of the curriculum or pass the final examinations or assessments. Second, the significant positive relationship between the frequent use of traditional approaches and students' perceived competence could be explained by the students' previous learning experiences and their beliefs about being competent. In other words, students felt themselves to be more competent when they could experience more traditional learning activities (lecturing, asking questions) instead of doing experiments or collaborating. Students in a traditional, teacher-centred environment probably take science learning more seriously in order to achieve the learning goals compared with the student-centred environment, which can be seen as more *playful*.

The findings also indicated that with age the role of science content and context became less decisive in predicting intrinsic motivation. For example, within grade 6 the science topics related to everyday life factor predicted all five components of intrinsic motivation, and the school science topics factor only three components (perceived competence, choice and value). At the same time, the school science topics factor was shown to positively predict perceived interest and competence in grade 9 students, while the science topics in everyday life factor predicted 48% of the variance for effort and 44% of the variance for value in science learning. The predictive effect of the science topics in everyday life factor was the highest in both grades (ranged between 30 and 69% depending on the variance of the component, see Figures 6 and 7) indicating the strongest influence on student intrinsic motivation and its components. These outcomes suggest support for the CBL approach and the considerable role of the contextual presentation of topics in the science curriculum for increasing student intrinsic motivation in science learning. In addition to teaching and learning, context-based tasks have also been introduced in Estonian e-testing instruments in recent years (Rannikmäe et al., 2021), indicating that over half of the grade 10 students perceived taking an e-test interesting but rather difficult (Rannikmäe et al., 2022). Taken this into account, more attention should be paid to the importance of using different contexts in both learning and assessment.

The results of the current thesis provide input for creating a more complex (multilevel) model for science teaching and learning, considering the different educational levels (e.g. grades 4–6, 7–9, 10–12). The developed model should be hierarchical (i.e. the previous level of education provides input for the next level of education) and needs to include more factors (e.g. teacher's perceptions) in addition to the components of the learning environment presented in this thesis (contexts, teaching approaches, motivation). The model could also be applied in teacher training to provide learning material for future science teachers.

## 6. CONCLUSIONS

*RQ1: What is the role of context for students learning topics in the science curriculum considering the different contexts perceived by grade 6 and 9 students?*

Based on the outcomes of Study 1, the findings showed that the context in which science topics were presented to students had an important role in grade comparison. The results indicated that students in both grades 6 and 9 held higher perceptions of learning science topics related to everyday life (personal and social) compared with science subject topics. This result is expected as topics related to everyday life presented in a personal and social context were seen to improve student interest and motivation in science learning compared with abstract and science content related topics, which in turn were associated with irrelevance and the difficulty in understanding these topics.

*RQ2: How do students and science teachers perceive the frequency of the use of teaching-learning approaches in different science subjects?*

Regarding Study 2, the findings showed significant differences in the perceptions of the frequency of the use of the four teaching-learning approaches (traditional, cooperative, experimental and problem solving and decision-making) comparatively between grade 6 and 9 students, the students and science teachers, and between the four separate science subjects in grade 9. In line with previous research findings in the literature, traditional approaches (e.g. lecturing, asking questions and class discussions) were perceived to be the main teaching-learning methods commonly used in science lessons by Estonian students (especially by grade 6 students) and science teachers. However, student-centred approaches (in terms of cooperative and experimental approaches) were perceived to occur less frequently compared with traditional approaches, especially by grade 9 students. Problem solving and decision-making approaches indicated the largest differences between the perceptions of students and science teachers in that these approaches were seen to be more frequently used by science teachers compared with students (especially grade 6 students).

*RQ3: How intrinsically motivating do grade 6 and 9 students perceive science subjects learning at school and what changes in student intrinsic motivation (in terms of interest, competence and choice) can be identified from the long-term perspective?*

The results from the Study 3 showed differences between grade levels and science subjects towards intrinsic motivation (in terms of interest, competence, choice, effort and value) in science learning. It became evident that student intrinsic motivation declines with age in that grade 6 students perceived science learning more intrinsically motivating compared with grade 9 students. Regarding the four

science subjects in grade 9, the results indicated a polarisation of subjects in that students perceived biology and geography as more interesting, valuable and had greater feelings of competence compared with chemistry and physics. By contrast, students felt the least competence and choices in chemistry and physics learning, and also perceived having to invest the most effort in physics. The results from the comparison of same students' perceptions over three years indicated that students' interest and perceived competence towards science learning significantly decrease over time, while perceived level of choice remained the same.

*RQ4: What are the effects of the contextual presentation of science education and the frequency of the use of teaching and learning approaches in predicting intrinsic motivation in science learning for grade 6 and 9 students?*

Fourth, the SEM showed acceptable fit indices for both models indicating that the theoretical model fits with the data well. The findings of the empirical models presented in Figures 6 and 7 showed both similarities and differences between the effects of factors predicting student intrinsic motivation in science learning. The results showed that five components of intrinsic motivation – interest, perceived competence, perceived choice, effort and value – in science learning were predicted by two to five different factors. The frequency of the use of traditional approaches in both grades, problem solving and decision-making approaches in grade 9 and perceptions of learning science topics related to everyday life in grade 6 were the factors that positively predicted student intrinsic motivation in terms of all five components (interest, perceived competence, perceived choice, effort and value in science learning). Unexpectedly, the use of student-centred approaches, such as cooperative and experimental approaches, had no effect, minor effects, or even negative direct effects on the components of intrinsic motivation. Compared to the other predictors, perceptions of learning science topics related to everyday life predicted student intrinsic motivation in science learning the most strongly but had significantly less predictive effect with age.

## 7. IMPLICATIONS

The results of the doctoral thesis have several theoretical and methodological implications for research and educational policy, as well as practical implications for science teaching and learning at different educational levels.

The results have the following implications **for academic research**:

- The factors included for predicting student intrinsic motivation need to be further developed not only in terms of the timelines, developments from lower to upper grades and teaching-learning approaches, but also factors associated with the teachers (e.g., awareness of student needs at different age levels).
- The results of the current research show that the involvement of grade 6 and 9 students in student-centred approaches, such as being cooperative and undertaking experimentation, have a minor direct, or even negative effects on intrinsic motivation, which raises the hypothesis that these effects may be indirect and need to be further explored based on SDT.

The results have the following implications for **educational policy**:

- There is a need to enhance science teaching based on the active engagement of students to create, express, collaborate and discover in order to foster student motivation and performance in science learning taking into account the updated Estonian curriculum. For this, teachers need to be continuously creative and develop both their content knowledge and pedagogical skills.
- The conception of the current e-tests supports an innovative approach to assessing student competences in science learning; this is consistent with the outcomes of the current thesis, emphasising the importance of a context-based learning approach.

With respect to the **practical level**, the results of the current thesis shed light on several implications and recommendations for science teaching and learning at school and for teacher training:

- The decline in intrinsic motivation through adolescence is not an inevitable developmental trend, but quite strongly influenced by the degree to which the school science learning environment can meet the basic psychological needs of students as indicated in SDT. The current results reinforce the importance of teacher behaviour in creating the learning environment in such a way that students' basic needs are supported, and their intrinsic motivation is promoted meaningfully and through the personalisation of science content.
- The contemporary approach to teaching and learning assumes the greater implementation of student-centred learning. Science learning needs to be

based on student autonomy and social relatedness, which can be supported by including sufficient choices and enabling a feeling of a sense of belonging among peers and teachers.

- Based on the results, interest and value in learning can be aroused and enhanced by offering situations focused on the usefulness and meaningfulness of science content, such as that related with everyday life or social contexts. The proposed way forward is to practice context-based learning approaches that foster student intrinsic motivation in science learning.
- Student perceived competence can be supported by teachers offering a variety of teaching and learning approaches that are optimally challenging, thereby allowing students to experience, collaborate and expand their academic capabilities. Furthermore, it is important that teachers provide students with relevant feedback to promote success and feelings of competence.
- The effectiveness of any teaching approach depends on how it is implemented in the classroom. Current research results suggest input for teacher training and professional development, indicating how to become aware of approaches which are effective for class and subject teachers teaching at different school levels aiming to foster student motivation and enhance learning.

## 8. LIMITATIONS AND FUTURE RESEARCH

Several limitations have been identified in relation to the research design and methodology that limit the wider generalisation of the results of this thesis.

The first limitation concerns the research instruments – questionnaires for students and teachers designed to measure self-reported constructs. When interpreting the results, it is important to consider the nature of self-reported questionnaires, as they can often reflect respondents' perceptions rather than the actual situation in the classroom. Nevertheless, self-reported questionnaires are widely implemented instruments for measuring student motivation (Fulmer & Frijters, 2009) and the frequency of activities or methods in use (Akinçi & Saunders, 2015). To validate the results and achieve a more detailed insight into lower secondary school students and science teachers, future studies should also contain direct observations and interviews that reflect an actual overview of science teaching and the learning environment.

Second, the thesis includes a repeated cross-sectional research design. Some students were involved in the study twice – in grade 6 (2016) and after three years in grade 9 (2019). The sample decreased significantly over the three years for several reasons: many schools refused to participate in the study again due to a lack of time and other national surveys that were being implemented at the same time. Some students moved away or were absent when the second measurement was taken, and several students did not complete the questionnaire fully, and so because of missing results these students had to be removed from the further analysis. In future studies, students who will knowingly be absent should be tested at another time or using other technical options. In addition, future studies might need to take into account more measurement points (e.g. once every year) when examining changes in student intrinsic motivation over several school years. Future longitudinal research is also needed to observe the move from lower secondary to upper secondary school, and to test whether intrinsic motivation can be fostered with age.

Third, the issue of technical procedures was also a problem area in the repeated cross-sectional study in 2019 (Article IV). Students conducted the questionnaire electronically, but during the answering process for some technical reasons, students were able to leave the questions unanswered and move on to the next question. However, this was not possible in the main study. Therefore, in future studies, the researchers and surveyors should pay attention to the quality of the testing conditions. For example, there could have been a pilot test before the follow-up study to ensure that there would be no technical issues.

The fourth limitation relates to the findings. Some bivariate correlations within the section on intrinsic motivation indicated strong relationships (e.g. between interest and choice), which means that distinguishing these constructs has to be treated with caution. However, the models themselves demonstrated acceptable fit indices in their description of the data. Regarding the structural models, future

studies could also look into the indirect effects that may occur when predicting intrinsic motivation.

The fifth limitation refers to interpreting the results. As different terminology has been used in the literature – context-based approaches (Pilot & Bulte, 2006), context characteristics (i.e. degree of reality and complexity, presentation form, familiarity) (Habig et al., 2018) or context domains (i.e. personal, social, professional, scientific and technological) (Gilbert, 2006) – caution should be taken when interpreting different research results, as the effect of the components of contexts (narrower term) or the contextual approach (more general term) have been measured using different methodologies and for different purposes.

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## APPENDICES

**Appendix 1.** Overview of the topics and error values permitted for correlation in the revised models for grade 6 and 9

Grade 6		Grade 9	
Content	Everyday	Content	Everyday
<i>Chemistry topics:</i>		<i>Chemistry topics:</i>	
t12 with t6		t12 with t6	
t2 with t6		t2 with t6	
t2 with t12		t2 with t12	
t17 with t16		t17 with t16	
t25 with t17		t25 with t17	
t34 with t25		t25 with t16	
t34 with t17		t8 with t17	
t33 with t6		t34 with t25	
t25 with t16			
<i>Biology topics:</i>	<i>Biology topics:</i>	<i>Biology topics:</i>	<i>Biology topics:</i>
t1 with t18	t13 with t29	t1 with t18	t13 with t29
	t13 with t4	t18 with t28	t13 with t4
	t4 with t29	t1 with t28	t4 with t29
		t1 with t11	t4 with t3
		t1 with t3	
	<i>Geography topics:</i>	<i>Geography topics:</i>	<i>Geography topics:</i>
	t15 with t15	t22 with t14	t23 with t15
	t15 with t23		t23 with t5
	t23 with t5		t5 with t15
		t7 with t22	
		t14 with t7	
<i>Physics topics:</i>		<i>Physics topics:</i>	
t30 with t36		t30 with t36	
		t26 with t20	
		<i>Interdisciplinary topics (content):</i>	
		t36 (physics) with t34 (chemistry)	
		t30 (physics) with t25 (chemistry)	

## SUMMARY IN ESTONIAN

### Õpi- ja õppetegevuste ning kontekstide roll põhikooliõpilaste sisemise motivatsiooni ennustamisel loodusainete õppimisel

Motivatsiooni roll õppimisel ja edu saavutamisel on väga suur. Motivatsioon soodustab õppimist, et saavutada soovitud eesmärged (Schunk et al., 2014). Enesemääratlusteooria (ingl *self-determination theory*) alusel eristatakse sisemist, välimist ja amotivatsiooni (motivatsiooni puudus), mis kõik mõjutavad õppimist erineval moel (Ryan & Deci, 2000a, 2020).

Selles doktoritöös on tähelepanu keskmes sisemise motivatsiooni ja seda mõjutavate tegurite uurimine põhikooliõpilaste hinnangul loodusainete õppimisel. Antud töös on õpilaste sisemist motivatsiooni mõjutavad õpikeskkonna tegurid piiritletud õpetaja- ja õpilaskesksete lähenemisviiside (edaspidi õppetegevuste) tajutud kasutamissagedusega loodusainetundides ning õpilaste hinnangutega erinevas kontekstis esitatud loodusteaduslike teemade (edaspidi kontekstide) õppimise vastu.

Ehkki õppijakeskne lähenemine (ingl *student-centred learning approach*) ja kontekstipõhine õppimisviis (ingl *context-based learning*) aitavad kaasa sisemise motivatsiooni alalhoidmisele ning suurendamisele loodusainete õppimisel, on aastakümnete jooksul tehtud uuringutest selgunud, et õpilaste motivatsioon loodusainete õppimisel hakkab vähenema puberteedia alguses ning see tendents jätkub põhikooli lõpuni (Hazelkorn et al., 2015; Liou et al., 2020; Potvin & Hasni, 2014; Vedder-Weiss & Fortus, 2011; Vedder-Weiss & Fortus, 2012). Selle üheks põhjuseks peetakse õpilaste psühholoogiliste põhivajaduste (autonoomia, kompetentsus ja seotus) vähest toetamist või mitterahuldamist õppimisel (Gnambs & Hanfstingl, 2016).

Paljudes riikides tavaliselt ei eristata motivatsiooni uurimisel õpilaste hinnangutes nelja erinevat loodusainet (bioloogia, geograafia, keemia ja füüsika), kuna põhikooli tasemel õpetatakse loodusteadusi ühe õppeainena (ingl *science*), kuigi uuringutest on ilmnenu, et õpilaste motivatsiooni kahanemine on just valdkonnaspetsiifiline (Gottfried et al., 2001; Salta & Koulougliotis, 2020). Ka varasemad uuringud riikide kohta, kus loodusaineid õpetatakse põhikoolis (nt 8. ja 9. klassis) eraldi, kinnitavad, et õpilased näitavad keemia ja füüsika õppimise vastu üles vähem huvi ning need meeldivad neile vähem kui bioloogia ja geograafia (Lamauskas et al., 2004; Mullis et al., 2020). Lisaks leidub suhteliselt vähe uuringuid, milles vaadeldakse õpilaste motivatsiooni loodusainete õppimisel pikaajaliselt (nt Liou et al., 2020).

Õpilaste sisemist motivatsiooni uurida on keeruline, kuna see sõltub nii õpikeskkonna kui ka õpilase ja õpetaja personaalsetest (nt uskumustest, hinnangutest) teguritest. Varasemad uuringud näitavad, et õpetaja roll õpikeskkonna kujundamisel ja õppimise tõhustamisel on määrava tähtsusega (Fraser, 1998; Fraser & Walberg, 1981; Hattie, 2009). Näiteks on leitud, et õpimotivatsiooni kahanemist mõjutavad õpetajakesksete õppetegevuste domineerimine (Hafizoglu & Yerdelen, 2019) ning loodusainete õppimise vähene seostatus igapäevaeluga

(nt Habig et al., 2018; Osborne & Collins, 2001; Ramsden, 1997). Veelgi enam, keemia kui kõige raskemaks peetava loodusaine õppimisel on ühe põhjusena esile toodud eelkõige selle sisu abstraktsus, mis väljendub mikro- või sümbolistlikul tasemel (Johnstone, 1982, 1991) ning ei võimalda õpilastel tekitada seoseid kas varem õpitu või igapäevaelulise kontekstiga. Paraku puuduvad sellised asjakohased uuringud, mis võtavad õpilaste sisemise motivatsiooni ennustamisel arvesse nii erinevaid loodusaineid, vanuseastet kui ka uuringu disaini (läbilõikeuuring (ingl *cross-sectional*) versus pikaajaline uuring (ingl *longitudinal*)).

Toetudes eespool mainitud uuringute tulemustele, vaadeldakse selles doktoritöös kolme õpikeskkonna teguri seoseid. Need tegurid on õpilaste tajutud sisemine motivatsioon, loodusainete tundide õppetegevused ja õpilaste hinnang loodusteadusliku sisuga kontekstidele. Väljatöötatud teoreetiline mudel põhineb sotsiaal-konstruktivistlikul lähenemisel (Palincsar, 1998) ja sellega seotud enesemääratlusteoorial (Ryan & Deci, 2000a, 2020) ning võtab arvesse nimetatud kolme õpikeskkonna tegurit, millevahelisi seoseid uuritakse empiirilisel eri vanuses põhikooliõpilaste seas.

Eelnevast lähtudes on doktoritöö põhieesmärk selgitada välja õpi- ja õppe-tegevuste ning kontekstide mõju 6. ja 9. klassi õpilaste sisemise motivatsiooni ennustamisele loodusainete õppimisel. Eesmärgi põhjal sõnastati doktoritöö jaoks järgmised uurimisküsimused.

1. Milline on konteksti roll erinevate loodusteaduslike teemade õppimisel 6. ja 9. klassi õpilaste hinnangul?
2. Kas ja mil määral erinevad 6. ja 9. klassi õpilaste ning loodusainete õpetajate hinnangud loodusainetundides kasutatavate õpi- ja õppetegevuste võrdluses?
3. Milline on 6. ja 9. klassi õpilaste tajutud sisemine motivatsioon õppida loodusaineid ning kuidas see muutub üleminekul 6. klassist 9. klassi?
4. Millised õpi- ja õppetegevused ning kontekstid ennustavad 6. ja 9. klassi õpilaste tajutud sisemist motivatsiooni loodusainete õppimisel?

Uurimisküsimustele vastuste saamiseks tehti neli alauuringut, mille tarvis koguti andmeid projekti „Nutikad tehnoloogiad ja digitaalne kirjaoskus õppimiskäsituse muutmisel“ raames 2016. aasta kevadel ning jätku-uuringu jaoks 2019. aasta kevadel. Nii 2016. kui ka 2019. aasta andmekogumisel kasutati elektroonilist küsimustikku, mille õpilased täitsid kas kooli arvutiklassi lauaarvutis või uuringu läbiviijate poolt kaasavõetud tahvelarvutis. Lisaks õpilaste kohta andmete kogumisele koguti neid samade koolide loodusainete õpetajatelt, kes täitsid küsimustiku samuti elektrooniliselt. Enne andmete kogumist küsiti lapsevanemate, koolijuhtide ja Tartu Ülikooli eetikakomitee nõusolekut. Uuringusse kaasati ainult lapsevanema nõusoleku saanud õpilased.

2016. aastal osales uuringus 3521 õpilast ja 205 loodusainete õpetajat. Osalenud õpilastest 2673 õppis 6. klassis (keskmine vanus 12,6 aastat) ja 848 õpilast 9. klassis (keskmine vanus 15,6 aastat). Jätku-uuring tehti samades koolides ja

selle raames koguti 2019. aastal andmeid 485-lt 9. klassi õpilaselt. Andmestiku puhastamise (puuduvate vastustega õpilaste andmed eemaldati) järel oli võimalik edasisse analüüsi kaasata 344 õpilast. Kuna pikaajalise uuringu eesmärk oli selgitada välja samade õpilaste hinnang 6. ja 9. klassis vastamisel, oli võimalik analüüsis kasutada ainult 171 õpilasest koosnevat valimit.

Uurimisküsimustele vastuste saamiseks töötati välja kaks küsimustikku: üks õpilastele ja teine loodusainete õpetajatele. Küsimustikke katsetati ja valideeriti.

Õpilaste küsimustik koosnes kolmest osast: kontekstide, sisemise motivatsiooni ja loodusainetundide õpi- ja õppetegevuste osast. Küsimustiku esimene osa sisaldas loodusteadusliku sisuga õppekaval põhinevat 36 teemat (iga loodusteadusliku õppeaine kohta 9 teemat), mis hõlmasid kolme konteksti: ainealast (ainekavast võetud sõnastus), teadusliku rakendamise konteksti ja sotsiaalteaduslikku probleemi kui konteksti. Teemasid hindasid õpilased neljapallisel Likerti tüüpi skaalal järgmiselt: 1 – ei ole nõus, 2 – pigem ei nõustu, 3 – pigem nõustun, 4 – nõustun. Küsimustiku teine osa põhines kohandatud sisemise motivatsiooni originaalinstrumentil (ingl *intrinsic motivaton inventory*) (Deci & Ryan, 2016) ning õpilastel paluti hinnata väiteid viiel alaskaalal: huvi (ingl *interest*), tajutud kompetentsus (ingl *percieved competence*), tajutud valik (ingl *perceived choice*), pingutus (ingl *effort*) ja väärtustamine (ingl *value*). Kokku hindasid õpilased 20 väidet viiepallisel Likerti skaalal järgmiselt: 1 – ei nõustu, 2 – pigem ei nõustu, 3 – nii ja naa, 4 – pigem nõustun, 5 – nõustun. Küsimustiku kolmandas osas paluti õpilastel hinnata 18 õpitegevust, lähtudes nende kasutamissagedusest („mitte üldse“, „mõnikord“, „sageli“) loodusainetundides. Õpi- ja õppetegevused valiti välja varasemate instrumentide põhjal (Ebenezer & Zoller, 1993; Juuti et al., 2010) ja neid kohandati Eesti loodusainetundides toimuvale. Kuna Eesti õppekavas on 9. klassis neli eraldi loodusainet, siis tuli õpilastel lähtuda küsimustiku teise ja kolmanda osa (sisemine motivatsioon ja õpi- ja õppetegevused) hindamisel ühest loodusainest (mitte hinnata neid kõigi nelja loodusaine puhul), mille olid nende koolis kohapeal uuringut teinud eksperdid eelseadistanud elektroonilisse küsimustikku.

Andmete statistiline analüüs tehti statistikaprogrammidega SPSS 27.0. ja Mplus 8.4. Andmeanalüüsis kasutati ainult kvantitatiivseid meetodeid. Kirjeldavad statistikud (keskmine, standardhälve) leiti nii üksikvaidete kui ka faktorite kohta. Gruppide (6. ja 9. klass, loodusained) võrdlemiseks kasutati mitteparameetrilisi Mann-Whitney U-testi, Kruskal-Wallace'i H-testi ja Wilcoxon Signed Rank Testi. Küsimustiku osade konstrukti valiiduse (ingl *construct validity*) hindamiseks kasutati nii kirjeldavat kui ka kinnitavat faktoranalüüsi ja sisemist motivatsiooni ennustava empiirilise mudeli jaoks struktuurilvõrrandite modelleerimist (ingl *structural equation modelling*). Küsimustiku usaldusväärsuse hindamiseks arvutati Cronbachi alfa väärtused kõikide küsimustiku osade lõikes ning eraldi 6. ja 9. klasside õpilaste ja loodusainete õpetajate jaoks.

Esimese uurimisküsimusega sooviti teada saada, milline on konteksti roll erinevate loodusteaduslike teemade õppimisel 6. ja 9. klassi õpilaste hinnangul. Grupivõrdluse tulemustest ilmsnes, et nii 6. kui ka 9. klassi õpilased hindavad kõrgemalt selliste loodusteaduslike teemade õppimist, mis on esitatud nende

igapäevaeluga seotud kontekstis (personaalses või sotsiaalses kontekstis), võrreldes ainealases võtmes esitatud teemadega. See on oodatav tulemus, kuna ka mitmed varasemad uuringud on kinnitanud konteksti olulisust õppimise tõhusamaks muutmisel ning motivatsiooni ja huvi äratamisel loodusteaduste õppimise vastu. Kontekstipõhist lähenemisviisi on soovitatud kasutada eelkõige keemia, aga ka teiste loodusainete õpetamisel eesmärgiga äratada õpilastes huvi teema edasiõppimise vastu, luues seoseid õpilaste igapäevaeluga ja muutes õppimist relevantsemaks. Õppimise personaliseerimine (õppija relevantsus) on aga väga keeruline õpetaja jaoks, kellel ühelt poolt tuleb anda edasi uusi teadmisi ja oskuseid ning hinnata saavutatud õpitulemusi, lähtudes õppekavast, ning samal ajal arvestada klassitäie õpilaste huve ning vajadusi tunde kavandades ja läbi viies.

Teise uurimisküsimuse kaudu sooviti teada saada, mil määral erinevad õpilaste ja õpetajate hinnangud loodusainetundides kasutatavate õpi- ja õppetegevuste võrdluses. Faktoranalüüsi tulemusel eristus neli õppetegevuste faktorit: 1) traditsiooniline, 2) koostöö, 3) eksperimentaalne ja 4) probleemide lahendamise ning otsuste tegemise faktor. Õppetegevuste kasutamise sageduse võrdluses ilmnemise hinnangutes erinevused nii 6. ja 9. klassi õpilaste, õpilaste ja loodusaineõpetajate kui ka nelja loodusaine puhul 9. klassis.

Grupivõrdluse tulemustest selgus, et nii 6. ja 9. klassi õpilased kui ka loodusainete õpetajad hindavad kõige sagedasemateks tegevusteks loodusainetundides traditsioonilisi õpi- ja õppetegevusi (loengu pidamine, küsimuste küsimine, klassiarutelu). Õpilaskeskseid tegevusi (koostöö ja eksperimentaalsed tegevused) tajuti võrreldes traditsiooniliste õpi- ja õppetegevustega harvemini esinevat, eriti just 9. klassi õpilaste hinnangul. Probleemide lahendamise ja otsuste tegemise puhul esinesid suurimad erinevused õpilaste ja loodusainete õpetajate vahel selliselt, et loodusainete õpetajad hindasid neid tegevusi sagedamini kasutatavatena kui õpilased (eriti 6. klassi õpilased).

Ka loodusainete (bioloogia, geograafia, keemia ja füüsika) võrdluses ilmnemise erinevused 9. klassi õpilaste hinnangutes. Tulemustest selgus, et bioloogia- ja geograafiatundides kasutatakse mõnevõrra sagedamini traditsioonilisi õpi- ja õppetegevusi, samal ajal kui keemia- ja füüsikatundides tajutakse läbi viidavat statistiliselt olulisel määral rohkem eksperimentaalseid tegevusi (hüpoteeside ja uurimisküsimuste püstitamine, katsete tegemine, järelduste tegemine). Koostöiste õppetegevuste (rühmatöö, rollimäng, väitlus, ajurünnak) puhul ei ilmnunud 9. klassi õpilaste hinnangutes loodusainete erinevusi. Siinse doktoritöö tulemused on kooskõlas varasemate uuringutega, mis näitavad traditsiooniliste (õpetajakesksete) õpi- ja õppetegevuste ülekaalu loodusainetundides ning vajadust senisest rohkemate eksperimentaalsete ja koostöiste tegevuste järele.

Vastusena kolmandale uurimisküsimusele ilmnes, et õpilaste sisemine motivatsioon (huvi, kompetentsuse, valiku, pingutuse ja väärtustamise seisukohalt) õppida loodusaineid on statistiliselt olulisel määral suurem 6. klassi õpilaste hinnangul võrreldes 9. klassi õpilastega. Sarnane langustendents ilmnes jätkuuringu tulemustest, mille järgi kahanes samade õpilaste hinnangul ( $N = 171$ ) nende huvi ja tajutud kompetentsus vanuse kasvades tunduvalt, kuid tajutud valik (ingl *perceived choice*) loodusainete õppimisel jäi samaks. Nelja loodusaine

puhul näitasid uuringutulemused õppeainete vahelisi erinevusi sisemise motivatsiooni komponentide võrdlemisel järgmiselt: 9. klassi õpilased tajusid bioloogia ja geograafia õppimist huvitavamana, väärtuslikuma ja kompetentsemana kui keemia ja füüsika õppimist, samas kui füüsika õppimist pidasid õpilased kõige suuremat pingutust nõudvaks. Selle uuringu tulemused on üldiselt kooskõlas varasemate rahvusvaheliste uuringute tulemustega, kinnitades loodusainete õppimise suhtes motivatsiooni ja huvi vähenemist koos õpilaste vanuse kasvamisega ning erinevate loodusainete spetsiifilisuse mõju motivatsioonile.

Neljanda uurimisküsimusega sooviti välja selgitada, millised tegurid ja mil määral mõjutavad 6. ja 9. klassi õpilaste sisemist motivatsiooni loodusainete õppimisel. Selleks kasutati regressioonanalüüsil põhinevat struktuuraalvõrrandite mudelit, et ennustada õpilaste sisemist motivatsiooni kontekstide ja õpi- ja õppe-tegevuste kaudu. Analüüsist ilmnas mitu olulist tulemust, mis näitavad klassidevahelisi sarnasusi ja erinevusi. Sarnasusena ilmnas, et traditsioonilised õpi- ja õppe-tegevused ennustavad positiivselt nii 6. kui ka 9. klassi õpilaste sisemist motivatsiooni: mida sagedamini neid tegevusi tehakse, seda suurem on õpilaste sisemine motivatsioon. Klassivaheliste erinevuste puhul ilmnas, et probleemide lahendamise ja otsuste tegemisega seotud õpitegevused ennustavad positiivselt 9. klassi õpilaste ning igapäeva elulised kontekstid 6. klassi õpilaste sisemist motivatsiooni. Õpilaskesksed õpitegevused (koostöö ja eksperimentaalne tegur) avaldasid kas väga väikest või isegi negatiivset mõju õpilaste sisemise motivatsioonile. Sellised tulemused on vastuolulised ja ootamatud, ent selgitavad Eesti loodusainete õppimise omapäraga: Eesti koolides on õpetamine suuresti õpetajakeskne ja suunatud õpitulemuste saavutamisele, mistõttu on õpilastel vähe võimalusi uurimiseks, koostööks ja katsetamiseks.

Doktoritöö tulemustele tuginedes saab anda soovitusi nii edasiseks uurimistööks sisemise motivatsiooni prognoosimisel loodusainete õppimisel kui ka praktika kohta teemal, kuidas toetada loodusainete õppimist senisest tõhusamalt. Sisemise motivatsiooni ennustamisel on tulevikus vaja arvestada rohkemate õpikeskkonda mõjutavate teguritega (nt õpetajategur), samuti hinnata erinevate tegurite võimalikke kaudseid mõjusid. Õpilaste sisemise motivatsiooni suurendamiseks ja hoidmiseks on tarvis pöörata senisest rohkem tähelepanu psühholoogiliste põhivajaduste rahuldamisele. Enesemääratlusteooria järgi peaks loodusainete õppimine õpimotivatsiooni suurendamise eesmärgil põhinema õpilaste autonoomial ja sotsiaalsel seotusel, mida omakorda soodustab õppijakeskne õpikeskkond ja kontekstipõhine lähenemine. Sellest lähtudes sõltub õppimise tõhusus ühtlasi sellest, kuidas rakendatakse loodusainetundides õppetegevusi, st doktoritöö tulemusi saab kasutada õpetajakoolituses ja õpetajate professionaalse arengu toetamisel. On tähtis, et õpetajad oleksid teadlikud sellest, millised õppetegevused ja kontekstid on loodusainete õpetamisel tõhusad erinevates vanuseastmetes, ning rakendaksid neid viisil, mis annab tõuke õpilaste sisemisele motivatsioonile või suurendab seda.

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## **PUBLICATIONS**

## CURRICULUM VITAE

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Lower secondary school students' motivation and interest in science learning.

### Publications:

Teppo, M., Saulep, M., Soobard, R., Rannikmäe, M. (2020). Factors influencing lower secondary school students' motivation to learn science and mathematics. *INTED2020 Proceedings* (pp. 6165–6173). <https://doi.org/10.21125/inted.2020.1673>

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Põhikooli õpilaste motivatsioon ja huvi loodusainete õppimisel.

### Publikatsioonid:

Teppo, M., Saulep, M., Soobard, R., Rannikmäe, M. (2020). Factors influencing lower secondary school students' motivation to learn science and mathematics. *INTED2020 Proceedings* (pp. 6165–6173). <https://doi.org/10.21125/inted.2020.1673>

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