

# Predictors of Change in Intrinsic Motivation Factors on Adolescent Science Learning

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## ABSTRACT

Non-cognitive factors, such as motivation, have shown to play a significant role in adolescents science learning. However, there is little longitudinal research investigating students' intrinsic motivation in science learning over school years. Based on self-determination theory, this study examines the change in, and associations between, students' intrinsic motivation factors, such as interest/enjoyment, perceived competence, and perceived choice toward science learning over a 3-year period. Utilizing data from 171 lower secondary school students who have twice completed a self-reported questionnaire - first in grade 6 and 3 years later in grade 9, the predictive associations of perceived competence and perceived choice on interest/enjoyment are examined across time using structural equation modeling. The results indicate that students' interest/enjoyment and perceived competence toward science learning significantly decrease over time, whereas the perceived level of choice remains the same. The results show that perceived choice significantly positively predicted the variance of interest/enjoyment and perceived competence, both in grades 6 and 9. However, perceived competence not directly predicted adolescents' interest/enjoyment in science learning. Based on the results, it is argued that there is a need to enhance students' perceptions of choice and competence for promoting interest and motivation in science learning at school.

**KEY WORDS:** Adolescence, intrinsic motivation, longitudinal study, science learning

## INTRODUCTION

Over the last decades, the emphasis on students declining interest and motivation in science learning is ongoing (Liou et al., 2020; Osborne et al., 2003; Potvin and Hasni, 2014a). Findings from the Trends in International Mathematics and Science Study 2019, among fourth and eighth-grade students, tested in 64 participating countries, indicate that eighth-grade students are less positive (in terms of likeness) about learning science than fourth-grade students, especially in countries where science subjects are taught separately in the eighth grade (Mullis et al., 2020). These trends, supported by a growing body of research, indicate the decline in progressing from elementary to secondary school, i.e., during the onset of adolescence (Gottfried et al., 2001; Liou et al., 2020; Logan and Skamp, 2008; Potvin and Hasni, 2014b; Vedder-Weiss and Fortus, 2011; Vedder-Weiss and Fortus, 2012). Furthermore, there is a lack of research on the implementation of a longitudinal, or repeated-measure approach, to determining a change in intrinsic motivation factors on adolescent science learning (e.g. Liou et al., 2020; Logan and Skamp, 2008).

Based on self-determination theory (SDT) (Deci and Ryan, 1985; Ryan and Deci, 2017), the decline in students' motivation from elementary to secondary school may occur, at least partly, due to changes in the level of satisfaction of three basic psychological needs - autonomy, competence and relatedness

(Gnams and Hanfstingl, 2016), each being seen as crucial for the development and maintenance of intrinsic motivation (Ryan and Deci, 2020). In other words, a higher degree of autonomy and engagement in an activity leads to higher interest and competence and, therefore, greater intrinsic motivation (Deci et al., 1991; Ryan and Deci, 2020). However, research studies that investigate the associations between students' motivation and satisfaction of their perceived basic psychological needs in a science learning context are rare (Kaiser et al., 2020).

To gain a more comprehensive vision of student intrinsic motivation, addressing research gaps, the current study, grounded on SDT, explores students' perceptions of interest/enjoyment, perceived choice, and perceived competence in science learning from grades 6–9. The following research questions are put forward:

1. What changes occur in students' intrinsic motivation factors, such as interest/enjoyment, perceived competence, and perceived choice, toward science learning over a 3-year period?
2. What is the effect of perceived choice and perceived competence on predicting grades 6 and 9 students' interest/enjoyment in science learning?
3. What is the effect of perceived choice on predicting grades 6 and 9 students' perceived competence in science learning?

## LITERATURE REVIEW

### Motivation

Motivation is a key factor playing an important role in students' academic performance and successful learning (Pintrich and Zusho, 2002; 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 and Deci, 2000a). Intrinsic motivation, the focus of the current research, 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 and Ryan, 1985).

SDT was chosen as the theoretical framework due to its ability to explain the dynamics of intrinsic motivation in educational contexts, particularly in relation to students' perceived competence and choice in science learning, elaborating on the factors that facilitate or undermine intrinsic motivation (Ryan and Deci, 2020). Accordingly, research based on SDT in educational settings focuses on the extent to which the learning environment supports students' basic needs for competence, autonomy, and relatedness (Ryan and Deci, 2000a; 2020). Thus, classroom practices which support students' satisfaction for these three psychological needs, as well as interest in learning, are associated with greater intrinsic motivation for undertaking the activity (Niemi and Ryan, 2009).

Furthermore, SDT provides a valuable lens for understanding the challenges that arise as students' progress through school. For example, research shows that as students age, they often report feeling less competent (Gnambs and Hanfstingl, 2016; Spinath and Steinmayr, 2008), less autonomous (Niemi and Ryan, 2009; Patall et al., 2010a; 2017), and less connected to their peers and teachers (Niemi and Ryan, 2009; Ryan and Deci, 2000b), which negatively impacts their motivation and interest in learning. By applying SDT, this study aims to explore how students of different ages perceive learning science subjects over their school years (from grades 6–9). Therefore, SDT is well-suited to explore the motivational dynamics in this study, providing a strong theoretical framework for understanding the relationships between perceived competence, choice, and interest/enjoyment.

### Interest

Interest is considered a precondition for intrinsic motivation (Hidi and Renninger, 2006). Intrinsically motivated behaviors are driven by the inherent enjoyment of the activity itself, rather than by any external rewards or consequences (Ryan and Deci, 2002). In other words, if a student is interested in learning a topic, or completing an activity, then he or she displays motivational behavior, which can be influenced by either intrinsic or extrinsic reasons (Schunk et al., 2014). In the current study interest/enjoyment is considered as a students' self-reported measure of intrinsic motivation being consistent with SDT (Deci and Ryan, 2016).

In science learning, students can show their interest when learning about science topics, a science activity, or the science

subject generally. Related to science topics, research has shown that, if the content is presented in a personally relevant context, students are more likely to be interested and hence intrinsically motivated in the learning (Broman et al., 2020; Teppo, 2021; Walkington and Bernacki, 2014). Furthermore, previous research has shown that students are more positive about learning biology and geography when compared with the learning of chemistry and physics (e.g. (Lamanauskas et al., 2004; Mullis et al., 2020)), and also that younger (elementary school) students show more interest and motivation in learning science compared with older (secondary school) students (Liou et al., 2020; Logan and Skamp, 2008; Potvin and Hasni, 2014a). This tendency with advancing age can be related besides the decreased level of satisfaction of three basic psychological needs also to the content-specific aspect: Increased abstractness level and the difficulty in understanding of the science content (Johnstone, 1991; Millar, 1991).

### Perceived Choice

Based on SDT, Ryan and Deci (2000b; 2017) recognize the need for autonomy as referring to a learner's ability to make decisions and take actions based on his or her own judgment and free will, rather than being dictated by others, or by external pressures. Research has shown that students, who perceive they have autonomy in the classroom, report high levels of intrinsic motivation (Reeve et al., 2004). However, the role of perceived choice in motivation is complex, and not all choices are equally motivating (Ryan and Deci, 2000b). For example, Mayer et al. (1994) indicate that, if students perceive autonomy, in the sense that are given a choice of topics to study during biology lessons, they report higher levels of intrinsic motivation compared with students who are not given that option. Patall et al. (2014) in investigating the role of competence in the effect of choice on motivation, have found that the provision of choice generally enhanced motivation when initial perceptions of task competence are high, but diminish motivation when perceived competence is low. However, despite providing possibilities for student-autonomous supportive classrooms, students, unfortunately, can still lack control over the choices of activities implemented in lessons, i.e., the learning can still be externally driven and evaluated by the teacher (Daniels, 2010; Niemi and Ryan, 2009).

### Perceived Competence

Based on SDT, the need for competence refers to a feeling of mastery, in a sense that when one can succeed, one achieves (Ryan and Deci, 2020). In other words, the need for competence is being satisfied if a student has optimal challenges so as to achieve, thus permitting the student to attain a feeling of self-efficacy when performing, or completing a task and hence can gain positive feedback from peers, or teachers (Ryan and Deci, 2017; 2020). To satisfy the need for competence, it is important that students perceive themselves as competent in learning.

The need for competence can be supported through the choice of learning activities and practices, which require an active role by students. More precisely, competence is enhanced by

offering optimally challenging activities, which are achievable with reasonable effort and assistance (Elliot et al., 2002). Wood (2019) reports that students feel their perceived competence is further enhanced by teachers who give feedback, promote further clarity of concepts, utilize a positive questioning style and are able to facilitate students' feelings of being competent during science lessons. Furthermore, studies emphasise that teachers significantly influence students' perceptions of their competence through the classroom environment, the feedback they provide, and their support of student autonomy, which in turn affects students motivation and engagement in learning (Niemic and Ryan, 2009; Patrick et al., 2007). Thus, a feeling of competence also fosters interest and intrinsic motivation, especially when students are given the opportunity to make choices about their learning activities (Patall et al., 2014). For example, an empirical study by Spinath and Steinmayr (2008) reports that the intrinsic motivation and competence beliefs of German elementary school students decrease (e.g. in maths, German and school in general) throughout an investigated 1 year period, which raises the issue of the need to investigate also secondary school students' perceived competence in science learning over time. As students get older, they are often taught different science subjects by different teachers, depending on the country's education system. This can lead to variations in students' perceptions of competence across different science subjects.

### Perceived Relatedness

While autonomy and competence have received significant attention in the context of intrinsic motivation, and relatedness, the need to feel connected to others, also plays a crucial role. Research suggests that when students experience positive social relationships with peers and teachers, their intrinsic motivation in learning increases (Kaefer and Chiviawosky, 2021; Niemic and Ryan, 2009; Ryan and Deci, 2000b; 2020). Thus, alongside autonomy and competence, fulfilling the need for relatedness is essential for promoting sustained intrinsic motivation and enhancing students' overall learning experience and achievement. However, in this study, relatedness was not explicitly investigated, as the primary focus was on autonomy and competence.

### Intrinsic Motivation, Perceived Competence, and Perceived Choice

The interplay between students' perceived competence, perceived choice, and intrinsic motivation is little researched in the context of science subjects learning. For example, previous studies have focused on relationships between competence beliefs and intrinsic motivation (Spinath and Steinmayr, 2008) or the effects of choices on intrinsic motivation (Patall et al., 2010b). Research has also investigated autonomy-supportive classroom on students' motivation from an SDT perspective (Chang et al., 2017; Núñez and León, 2015; Painter, 2011; Thomas and Müller, 2014). An empirical study by Kaiser et al. (2020) shows that perceptions of autonomy and competence are significant predictors of intrinsic motivation, whereas

relatedness has no predictive power in the context of a biology class. Similarly, Patall et al. (2014) report that the provision of choice generally enhances intrinsic motivation when students' initial perceived competence is high but decreases when competence is low. In addition, a study by Painter (2011) shows that 8<sup>th</sup> grade students' perceptions of autonomy support are positively related to students' perceived competence in science and intrinsic motivation. Overall, the literature suggests that students' perceptions of competence and choice play crucial roles in fostering intrinsic motivation in science learning. While the relationship between these factors has been studied separately, there is a gap in research exploring how they interact within the context of science education. These findings highlight the need for further research into the combined effects of perceived competence and choice on intrinsic motivation (in terms of interest/enjoyment) in science learning, particularly across different grade levels.

### The Current Study

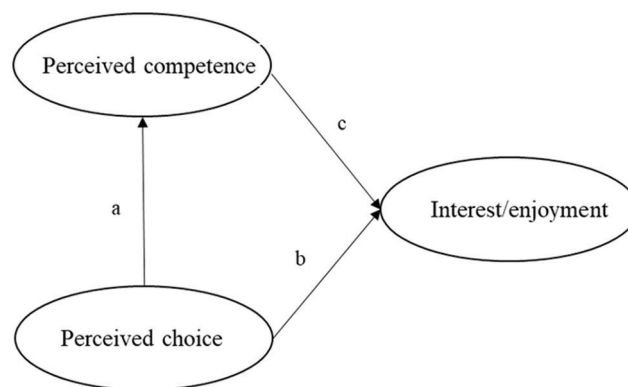
Noting the literature outcomes, the current study aims to explore:

1. The change in interest/enjoyment, perceived competence, and perceived choice within the Estonian science learning context, comparing students' perceptions in grades 6 and 9;
2. Based on a hypothesized model (Figure 1), to investigate the predictive effect of perceived choice on perceived competence (path a) as well as predictive effects of perceived choice and perceived competence on grade 6 and 9 students' (paths b and c).

## METHODOLOGY

### Sample

This research was based on data collected through a large-scale study with Estonian grade 6 and grade 9 students. The sample used for the study involved 171 lower secondary school students from 26 different schools who participated in both data collection times (in grades 6 and 9). The average age of students in the grade 6 sample was 12.6 years (SD = 0.53) and 15.6 years (SD = 0.60) for grade 9.



**Figure 1:** The hypothesised model for intrinsic motivation modified based on Patall et al. (2014)

## Instrument

An adapted version of the intrinsic motivation inventory (Deci and Ryan, 2016; McAuley et al., 1989) was used to assess students' interest/enjoyment, perceived competence, and perceived choice in science learning using a 5-point scale (1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4-agree, 5-strongly agree) as follows:

- Interest/enjoyment (4 items: "I enjoy doing science very much," "I think learning science is fun," "I think learning science is boring" (reversed item), "Learning science is very interesting"),
- Perceived competence (4 items: "I think I am pretty good at learning science," "After having learned science for a while, I feel pretty competent," "I am satisfied with my performance in science," "I know science very well"), and
- Perceived choice (4 items: "In science lessons, I have the opportunity to choose how I study," "I feel like I have to study science," "I study science because I have no other choice" (reversed), "I study science because I want to").

Students in grade 6 answered the items from the point of view of science, whereas students in grade 9 answered with respect to separate science subjects (biology, geography, physics, or chemistry), as in Estonia all four science subjects were taught separately from the 8<sup>th</sup> grade. In the further analysis related to grade 9, students' answers were examined as one sample, i.e., not differentiated between subjects' groups for comparative reasons and due to the modest sample size.

## Procedure

Data collection was conducted twice in the spring of 2016 and 2019. In 2016, the data collection was conducted through a cross-sectional study among Estonian grade 6 students, and after 3 years, in 2019, as a repeated cross-sectional study, with grade 9 students from the same schools.

Prior to data collection, informed consent from the parents, permission from the school's heads, and approval from the research ethics committee were obtained. The questionnaires, in electronic format, were completed by grade 6 and 9 students in a single 15–20 min session during classroom time carried out in the presence of the science teacher and members of the research team. Only students whose parents gave their agreement were included in the research.

## Data Analysis

Descriptive statistics, internal consistency, and bivariate correlations of the sub-scales were calculated using Statistical Package for Social Sciences (version 27), confirmatory factor analysis (CFA) and structural equation modeling (SEM) using Mplus software (version 8.4; Muthén and Muthén, 1998–2017).

At first, a comparison of descriptive statistics (mean, standard deviation) of the interest/enjoyment, perceived competence, and perceived choice as latent variables was undertaken using non-parametric analyses, because most of the single variables indicated a non-normal distribution according to the Shapiro–Wilk test (Shapiro and Wilk, 1965).

Second, The Wilcoxon Signed Rank test of the related samples was conducted to compare students' interest/enjoyment, perceived competence, and perceived choice in science learning among grade 6 and 9. Bivariate correlations between the latent variables were computed using Spearman rank order correlation analysis. In addition, Cronbach's alpha as a measure of internal consistency was calculated for each latent variable.

Third, SEM was carried out to analyze structural relationships, i.e. predictive effects of students' perceptions of competence and choice on interest/enjoyment (intrinsic motivation) toward science learning separately by students answers in grades 6 and 9. Well-established indices and criteria were used to assess the goodness of fit of the models - Chi-square test, comparative fit index (CFI  $\geq 0.90$ ), Tucker-Lewis index (TLI  $\geq 0.90$ ), root mean square error of approximation ( $0.03 < RMSEA < 0.08$ ) and standardized root mean squared residual ( $\leq 0.08$ ) (Hair et al., 2013; Hu and Bentler, 1999). An  $\chi^2$  statistic divided by its degrees of freedom ( $\chi^2/df$ ),  $< 2$ , was taken as an indicator that the model gave a meaningful fit with the data (Kline, 2011).

## Validity and Reliability

CFA was conducted to determine if the three-factor structure showed a meaningful fit with the data, separately, in grades 6 and 9. The self-reported questionnaire initially consisted of 12 items, divided equally into three subscales: Interest/enjoyment, perceived competence, and perceived choice. Preliminary analysis showed that the item "I feel like I have to study science" did not fit well, having low factor loadings ( $< 0.30$ ) with the perceived choice factor and was therefore omitted from both (grades 6 and 9) models. Thus, the perceived choice sub-scale included three items in the final models.

Within the other subscales, no changes were made. Both final models had adequate fit indices:  $\chi^2(41) = 62.33$ ,  $p = 0.017$ ,  $RMSEA = 0.06$ ,  $CFI = 0.98$ ,  $TLI = 0.97$  for grade 6 and  $\chi^2(41) = 97.61$ ,  $p < 0.001$ ,  $RMSEA = 0.08$ ,  $CFI = 0.95$ ,  $TLI = 0.94$  for grade 9.

Cronbach's alpha value, as a reliability estimate of the sub-scales, was calculated and in ranging between 0.60 and 0.94 (Table 1), having acceptable values (Taber, 2018).

## RESULTS

### Descriptive Results and Correlation Matrix

Table 1 gives the descriptive statistics and bivariate correlates between the latent variables, as well as Cronbach alpha values for each latent variable. Mean values show that students in grade 6 have higher interest/enjoyment and perceive competence in science learning comparing with grade 9. Students' perceived choice has almost the same mean values in both grades.

Bivariate correlations between the scales show positive significant associations among students' answers, either within grade 6 or 9, but not across grades. A strong significant correlation occurs between perceived competence and interest/enjoyment within grade 9 ( $r_s = 0.70$ ,  $p < 0.001$ ) and within grade 6 ( $r_s = 0.58$ ,  $p < 0.001$ ). In addition, between perceived choice and interest/enjoyment among grade 9

**Table 1: Means, standard deviations, reliabilities (Cronbach's  $\alpha$ ) for interest/enjoyment, perceived competence and perceived choice scales and bivariate correlations for grades 6 and 9**

Intrinsic Motivation Factors	M	SD	1	2	3	4	5	6
1. Interest/enjoyment g6	3.33	1.08	–					
2. Interest/enjoyment g9	3.06	1.04	0.20*	–				
3. Perceived competence g6	3.96	0.90	0.58**	0.14	–			
4. Perceived competence g9	3.41	1.03	0.17*	0.70**	0.15	–		
5. Perceived choice g6	3.11	0.89	0.63*	0.23	0.44**	0.17*	–	
6. Perceived choice g9	3.08	0.89	0.19*	0.76**	0.09	0.58**	0.29**	–
Cronbach's alpha			0.94	0.91	0.93	0.94	0.60	0.67

M: Mean, SD: Standard deviation, g: Grade. \* $p < 0.05$ . \*\* $p < 0.001$

students' answers ( $r_s = 0.76$ ,  $p < 0.001$ ) and grade 6 students answers ( $r_s = 0.63$ ,  $p < 0.001$ ) and between perceived choice and perceived competence among grade 9 students' answers ( $r_s = 0.58$ ,  $p < 0.001$ ) and grade 6 students answers ( $r_s = 0.44$ ,  $p < 0.001$ ).

Standard deviation values indicate large dispersions (ranging from 0.89 to 1.08) across all subscales.

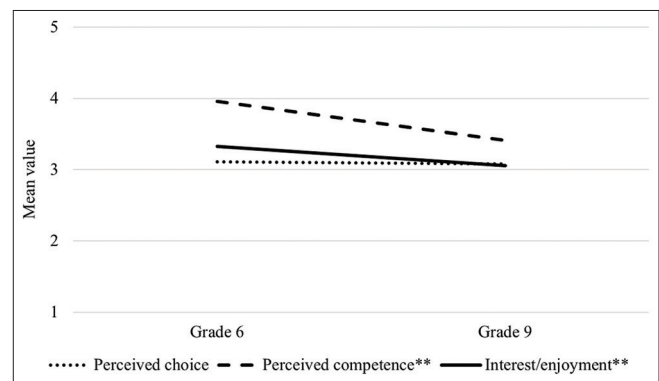
### Changes in Intrinsic Motivation Factors

To answer the first research question, the Wilcoxon signed rank test was used to determine whether there was a significant mean difference between grades 6 and 9 outcomes from interest/enjoyment, perceived competence, and perceived choice (Figure 2).

The results showed that there was a significant decrease regarding perceived competence comparing grades 6 and 9 ( $Z = -5.430$ ,  $df = 170$ ,  $p < 0.001$ , Cohen's  $d = 0.57$ ) and interest/enjoyment ( $Z = -2.681$ ,  $df = 170$ ,  $p < 0.001$ , Cohen's  $d = 0.25$ ), but not for perceived choice ( $Z = -0.472$ ,  $df = 170$ ,  $p = 0.637$ , Cohen's  $d = 0.03$ ). Perceived competence was the subscale in which students reported the highest mean scores in both grades, compared with interest/enjoyment and perceived choice.

### Relationships between Interest/Enjoyment, Perceived Competence and Perceived Choice in Science Learning

SEM analyses were performed to test the relationships between three intrinsic motivation factors, interest/enjoyment, perceived choice, and perceived competence, as indicated in Figure 3. Altogether, three direct effects within both datasets were tested (a, b, c, Figure 1). All paths were significant ( $p < 0.001$ ) except perceived competence on interest/enjoyment. The strongest significant direct effects were with regards to perceived choice on interest/enjoyment among both grades (accordingly  $\beta = 0.92$  and  $\beta = 0.78$  in grades 6 and 9). Similarly, perceived choice had a strong positive effect on perceived competence (accordingly  $\beta = 0.71$  and  $\beta = 0.76$  in grades 6 and 9). Surprisingly, perceived competence had no significant effect on interest/enjoyment in science learning in neither grade. Results showed that both grades 6 and 9 models demonstrated an adequate fit accordingly:  $\chi^2(41) = 62.33$ ,  $\chi^2/df = 1.52$ ,  $p < 0.05$ , CFI = 0.98, TLI = 0.97, RMSEA = 0.05 (for grade 6) and  $\chi^2(41) = 97.61$ ,  $\chi^2/df = 2.38$ ,  $p < 0.001$ , CFI = 0.95, TLI = 0.94, RMSEA = 0.09 (for grade 9).



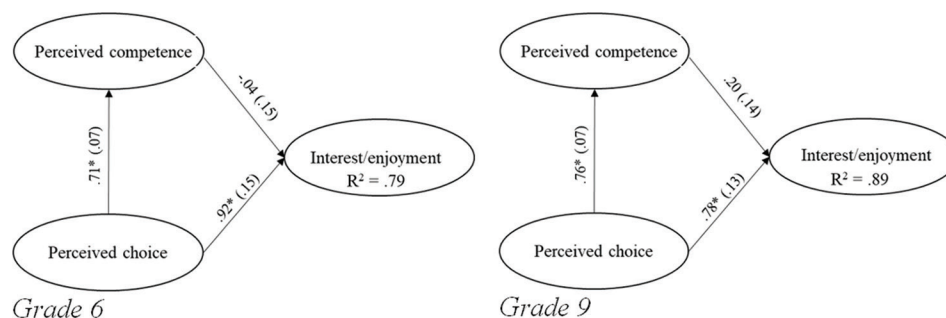
**Figure 2:** Mean values for Interest/Enjoyment, Perceived Competence and Perceived Choice Comparing Students Perceptions in Grades 6 and 9. \*\* $p < 0.001$

## DISCUSSION

The present study explored the Estonian science education context and sought to determine changes in, and associations among students' intrinsic motivation factors (interest/enjoyment, perceived competence, and perceived choice), through comparing the same students' perceptions in grades 6 and 9, grounded on SDT (Deci et al., 1991; Deci and Ryan, 1985). The findings from the current study extended an understanding toward an increasingly important role of perceived competence and choice on influencing lower secondary school students' interest/enjoyment in science learning.

### Changes in Students' Perceptions of Interest/Enjoyment, Perceived Competence, Perceived Choice in Science Learning Going from Grade 6 to 9

With respect to the first research question, it was predicted that students' perceptions of interest/enjoyment, perceived competence, and perceived choice in science learning would decrease, as they progressed from grade 6 to grade 9. The results revealed a significant decrease in perceived competence and interest/enjoyment, but, however, no significant decrease in perceived choice toward science learning (Figure 2). Thus, the results partly supported the prediction of declining interest/enjoyment, perceived competence, and perceived choice in science learning with age.



**Figure 3:** Structural models indicating relationships between interest/enjoyment, perceived choice, perceived competence within Grade 6 (on left) and Grade 9 (on right). Standardised regression coefficients ( $\beta$ ) are presented. Standard errors are in parentheses. \* $p < 0.001$ .

This expected finding was in line with the existing literature regarding declining feelings of competence during adolescence (Spinath and Steinmayr, 2008). In grade 9, students perceived themselves as less competent in science learning, compared with grade 6, perceiving science as more difficult and abstract for students with advancing age (Johnstone, 1991; Millar, 1991). On the other hand, this declining trend could also be explained by subject specificity, as in grade 9, four science subjects were taught separately in Estonia, and hence physics and chemistry were considered generally more difficult and less favorable subjects compared with biology and geography (Lamanauskas et al., 2004; Mullis et al., 2020). According to SDT, the need for competence was satisfied if a student had optimal challenges to achieve, a feeling of self-efficacy when performing and completing the task and also gained positive feedback from peers or teachers (Ryan and Deci, 2017; 2020). Taking into consideration previous research results (Elliot et al., 2002; Niemiec and Ryan, 2009; Patall et al., 2014; Patrick et al., 2007; Wood, 2019), it is important in science teaching that teachers provide students with tasks that require sufficient effort (challenges) in learning, give meaningful feedback, facilitate students feelings of being competent as well as support students' autonomy to foster interest and motivation. For example, the selection of science content presented in different contexts needed to be carefully determined with respect to the students, or the levels of abstraction and the use of a variety of assessment and teaching methods were considered in such a way that students' need for competence were supported and maintained (Teppo, 2021).

The declining trend with respect to interest/enjoyment was predicted and was in line with a large number of longitudinal and cross-sectional studies, which also indicated a decrease in students' motivation toward science learning with age (Liou et al., 2020; Logan and Skamp, 2008; Potvin and Hasni, 2014a; Vedder-Weiss and Fortus, 2011; Vedder-Weiss and Fortus, 2012), including in mathematics and reading (Gottfried et al., 2001). Going from elementary to secondary school was seen as leaving less time and opportunities to incorporate everyday life situations, or social, context-based approaches (e.g. project-based learning), which had been shown to promote interest and motivation in learning (e.g. Broman et al., 2020; Walkington and Bernacki, 2014). While it was important to

recognize that all students were not necessarily intrinsically motivated in learning science subjects at school, on the contrary, they might have more interest toward learning other subjects, it was important in addressing, or even increasing interest and hence motivation, to use relevant approaches, topics or methods that fascinated students and enhanced their engagement. This necessitated a student-centered approach to science learning that prioritizes students' individual interests, emphasizing broader personal and social contexts over abstract scientific content.

The findings regarding perceived choice (i.e., having the opportunity to choose how to learn) showed no significant decline from grades 6–9. In other words, students felt a similar perceived choice level toward science learning in both grades (Figure 2). The findings also indicated that the mean values of perceived choice were above average, which could be interpreted, from one point of view, as - Estonian students felt sufficient autonomy in terms of perceived choice. From another point of view, the result could also be interpreted as - students didn't really have choices how and what to learn in science lessons. For example, as the teacher provided the materials and guided the teaching, and the students could not imagine any other way. Thus, there was no significant change in students' perceptions of choice in science lessons, i.e., regarding how they study and their reasons for studying science. However, on the teachers' side, they were able to decide how, what, and when to teach, which reflects the high level of autonomy in Estonian schools. According to SDT, autonomy was a key factor for the development and maintenance of intrinsic motivation, which needed to be supported by having choices related to how students could learn and had a feeling of self-control and initiative while engaging in activities (Ryan and Deci, 2000b; 2017). For example, one way to foster the satisfaction of the need for autonomy was to offer students choices regarding the content and/or the methods while studying (Reeve et al., 2004). Overall, the findings suggest that while students perceived a consistent level of choice in science learning across grades 6 and 9, the interpretation of perceived choice varies. On one hand, the above-average perceived choice could indicate that students felt a certain degree of autonomy. On the other hand, it may also reflect limited opportunities for real choice, as teachers controlled much of the teaching content and methods.

## Relationships between Interest/Enjoyment, Perceived Competence and Perceived Choice towards Science Learning - Predicting Students' Intrinsic Motivation in Grades 6 and 9

With respect to the second research question, it was expected that intrinsic motivation could be predicted by students' perceived competence and perceived choice. SDT highlighted the critical, supportive roles played by competence and autonomy in fostering intrinsic motivation (Deci and Ryan, 1985; Ryan and Deci, 2000b). Consistent with SDT, findings from the current study indicated that both students' perceptions of choice in grades 6 and 9 had a positive significant effect on their perceived competence and intrinsic motivation in science learning. The structural models (Figure 3), which had an adequately fit with the sample data from this study, explained accordingly 79% and 89% of the variance among grades 6 and 9 students' intrinsic motivation. The models suggested that students' perceptions of choice would influence students' intrinsic motivation and perceived competence in science learning in both grades. These findings were in line with previous studies, which also indicated positive associations between the effect of choices on intrinsic motivation (Mayer, 1994; Patall et al., 2010b).

Regarding the relationship between perceived competence and intrinsic motivation, findings from the present study indicated that perceived competence had no significant effect on intrinsic motivation in either grade. This finding was in contradiction with SDT, according to which both perceived autonomy and perceived competence were theorized to be positive predictors of intrinsic motivation (Deci and Ryan, 1985; Ryan and Deci, 2000b). However, in line with SDT, numerous empirical studies found positive associations between perceived competence and intrinsic motivation in science (Painter, 2011; Spinath and Steinmayr, 2008). Taking into account the Estonian science learning context, it could be hypothesized that intrinsic motivation was seen as a subject-specific phenomenon, i.e., students had different preferences for learning biology, geography, chemistry, or physics at school (Teppo, 2021), whereas 6<sup>th</sup> graders learned only science as one subject. Such separate teaching of science subjects could influence students' perceptions of competence in each science subject, and hence influence subject-related intrinsic motivation. To confirm this assumption, future studies would need to conduct analyses predicting intrinsic motivation within each science subject. In addition, it could also be hypothesized that perceived competence might have an indirect effect through perceived choice on intrinsic motivation, as well as perceived choice and also competence might have effects in both ways, not just one way as hypothesized (see path a), but this was not explored during this study. For example, the interplay between perceived competence and perceived choice may not only act as a direct influence on intrinsic motivation but also interact in ways that amplify or diminish motivation. Future studies could explore these reciprocal effects using more complex structural models or longitudinal designs, examining

how such indirect relationships evolve over time and vary across different science subjects and grade levels.

## CONCLUSION

In conclusion, the current research indicated a declining trend in students' perceived competence and interest/enjoyment towards science learning with age, and no significant decline with respect to perceived choice, which remained stable going from grades 6–9. The study demonstrated that perceived choice significantly positively predicted both grades 6 and 9 students' perceived competence and interest/enjoyment in science learning. Contrary to the expectations and considering a general pedagogical approach to learning, perceived competence had no significant predictive effect on interest/enjoyment in either grade.

## Implications

The findings from this study provided some evidence with respect to what conditions were to be created in enhancing student intrinsic motivation in science learning within the classroom, and student engagement in their future studies and career with science. The findings of this study implied that it was important to implement competence-enhancing and autonomy-supportive strategies when aiming to increase students' interest and motivation in science learning. Therefore, science teachers were required to pay greater attention to the need of creating a supportive teaching and learning environment, in a manner which provided students with challenging science content or abstract-level tasks that made use of a variety of motivational, student-centered, teaching and assessment methods. Furthermore, the findings suggested that teachers need to be aware of the differences between controlling and autonomous learning environments and be trained in how to apply autonomy-supportive teaching styles, taking students' choices into account.

## Limitation

The study has several limitations:

1. While the study examines students' science-related intrinsic motivation factors, it doesn't distinguish between different science subjects, such as biology, chemistry, physics, and geography. In the Estonian context, science is taught as separate subjects starting from grade 8, and each subject may have its own specificity in terms of content, teaching methods, and student perceptions (motivation, attitudes, etc). As a result, the lack of differentiation in the analysis may obscure important subject-specific differences in student motivation. Future research should consider exploring motivation across individual science subjects, ensuring a sufficiently large sample to allow for meaningful comparisons, in order to gain a more nuanced understanding of how motivation varies depending on the subject matter.
2. In this study, students' interest/enjoyment, perceived competence, and perceived choice in science learning are assessed through self-reported questionnaires.

However, by relying solely on student self-reports, the relationships between students' perceptions may be subject to bias, as it is unclear what actually occurred in the classroom and how students interpret concepts such as interest, competence, and choice. This introduces the possibility of response bias. Further validation of the research findings is needed, incorporating additional data sources such as teacher assessments and classroom observations. These sources could provide alternative perspectives on classroom teaching and the associated learning environment, helping to corroborate and validate the findings. Future research should consider using a combination of student self-reports and teacher or observational data to offer a more holistic and accurate view of the factors influencing student motivation in science learning.

3. Although in this study relatedness, as one of the three basic psychological needs, is not assessed, it is still considered an important component of the science learning environment which needs to be supported, as social relationships as well as belongingness to a group are known to be significant in developing and enhancing intrinsic motivation, based on SDT. While we acknowledge that social relationships, such as those with peers and teachers, play a significant role in motivation, this aspect was not thoroughly explored in the current study. The absence of relatedness in the analysis limits the understanding of how social contexts influence student motivation in science learning. Future research should consider investigating the role of relatedness, exploring how social interactions and a sense of belonging to a group influence students' intrinsic motivation.
4. As the sample size of the study is limited, it is not possible to make generalizations on the level of the population of Estonian grades 6 and 9 students, nor distinguish between intrinsic motivation factors among the four science subjects. To enhance the applicability of the results, future research should explore larger and more diverse populations, including students from different grade levels, regions, or educational systems. This would allow for more robust comparisons and insights that can be generalized to a wider range of student populations.

### Future Research

Further research is needed to verify whether this pattern can be reproduced using different samples, different measures of intrinsic motivation, and different types of motivation ([Ryan and Deci, 2009]). For example, more research is needed to examine if the current results can be generalized to different science subjects (i.e. biology, geography, chemistry, and physics) as well as mathematics. Thus, future studies are needed, taking into account, for example, STEM subjects and more measurement points when examining changes in students' intrinsic motivation. In addition, future research is needed to identify the transition from lower secondary to upper

secondary, to test whether intrinsic motivation can be fostered with age, and if so, to what extent and which direct and indirect effects may occur when predicting intrinsic motivation. For example, future research should explore student motivation in older adolescents or students from different educational settings, such as upper secondary schools and vocational schools, to enhance the generalizability of the findings and provide a broader understanding of motivational dynamics.

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### Ethics Statement

The present research was conducted as a longitudinal study investigating students' intrinsic motivation in science learning over several school years, using students' dates of birth to align pre- and post-questionnaire data. After data collection, personal information was coded, and further analysis was conducted using anonymized data. Informed consent from parents, permission from school administrators, and approval from the research ethics committee were obtained. The anonymized participant data are securely stored on a password-protected computer.

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### Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

### Data Availability Statement

The data presented in this study are available upon scholarly request.

### Disclose Statement

No potential conflict of interest was reported by the authors.

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