

GETRIIN AAVISTE

Mathematics anxiety
as an obstacle to mathematics learning:
Individual and school-related factors
associated with mathematics anxiety



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LIST OF PUBLICATIONS

This dissertation is based on the following studies, which are referred to in the text by roman numerals.

- I **Aaviste, G.**, Löchner, D., Laas, K., & Täht, K. (2026a). Students' online course activity, together with self-efficacy and test anxiety, predicts mathematics exam results. *LUMAT: International Journal on Math, Science and Technology Education*, 14(2), 1–20.
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- III **Aaviste, G.**, Löchner, D., Laas, K., & Täht, K. (2026b). Understanding mathematics anxiety: The role of social-emotional skills and school support. *Cogent Education*, 13(1), 2609386.
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- IV **Aaviste, G.**, Kolde, A., Gugushvili, N., Kuus, E., & Täht, K. (2026). Õnnestumise valem matemaatikas: parem sotsiaalmajanduslik taust, madalam ärevus ja suurem uudishimu nii õpilase kui kooli tasandil. *Eesti Haridusteaduste Ajakiri. Estonian Journal of Education*, 14(1), 167–194.
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- V **Aaviste, G.**, Kolde, A., Laas, K. & Täht, K. (submitted) Is mathematics anxiety an individual or school-level phenomenon: Multilevel analysis on PISA 2022 Estonian data. *European Journal of Psychology of Education*

The author's contribution to the publications

The author of the present dissertation is the first author of all five publications included in the dissertation. The studies were developed in collaboration with the supervisor and co-authors. The author conducted the literature reviews, carried out the statistical analyses in Studies I–III, and prepared the first drafts of all manuscripts. In Studies IV–V, the author participated in the statistical analyses, including the preparation and preliminary implementation of the multilevel models, while the second author led the multilevel modelling and provided methodological expertise. The author was responsible for revising the manuscripts throughout the publication process and coordinating communication among the co-authors. The interpretation of the findings and the final versions of the manuscripts were developed collaboratively with all co-authors.

INTRODUCTION

Being competent in mathematics plays an increasingly important role in modern society (Geary et al., 2023). Furthermore, longitudinal evidence suggests that childhood mathematical ability is positively associated with adulthood socio-economic status, even after accounting for socio-economic background at birth and intelligence (Ritchie & Bates, 2013). These findings highlight the long-term importance of learning mathematics. Despite the importance of learning mathematics, it is often perceived as a challenging subject for students because mastering its concepts requires sustained cognitive effort and deliberate practice. This is partly because mathematical competence typically requires systematic instruction and continuous engagement rather than developing naturally through environmental exposure (Ashcraft & Krause, 2007). Due to its cumulative nature, difficulties encountered in earlier stages of learning may negatively affect later understanding and performance, potentially leading to frustration, reduced confidence, and fear of making mistakes. Such experiences may contribute to the development of negative emotions toward mathematics, including mathematics anxiety (Q. Li et al., 2021).

Mathematics anxiety has been defined as feelings of tension, apprehension, or fear experienced in situations that involve mathematics (Ashcraft, 2002). It has considerable implications for students' academic and personal development. Higher mathematics anxiety is often associated with lower mathematics achievement, decreased motivation to engage with mathematics, and reduced interest in STEM-related educational and career pathways (Ashcraft & Krause, 2007; Hembree, 1990). At the same time, students cannot easily avoid learning mathematics, as it is a compulsory component at school curricula and mathematical competence plays an important role in educational attainment and access to future career opportunities. Moreover, mathematics learning is shaped not only by cognitive abilities but also by students' psychological and social characteristics, such as interest, values, beliefs, and social and emotional skills (Kankaraš, 2017). Researching how these factors are related to mathematics anxiety is therefore essential for explaining why some students develop negative emotional experiences in mathematics, whereas others do not. Although mathematics anxiety has been widely researched, its complexity and the interplay between individual psychological characteristics and school-related factors remain insufficiently understood. Therefore, a more comprehensive understanding of the individual and contextual factors associated with mathematics anxiety is important for both educational research and educational practice.

Mathematics anxiety

As explained above, learning mathematics can elicit various negative emotions, including mathematics anxiety (Q. Li et al., 2021). Mathematics anxiety has been primarily studied as a unidimensional construct; however, research suggests it

may comprise distinct yet related components. For example, Lukowski et al. (2019) showed that mathematics anxiety may consist of three components: anxiety related to mathematical calculations, classroom situations, and mathematics tests. This perspective highlights the complexity of mathematics anxiety and the need to further examine the concept. In educational settings, mathematics anxiety may therefore emerge not only during mathematical problem-solving, but also in evaluative situations such as tests and examinations. This distinction is particularly relevant in high-stakes academic contexts, where students may specifically experience anxiety related to assessment and performance situations. Mathematics test anxiety refers specifically to anxiety experienced in situations where mathematical knowledge is being evaluated, such as tests or exams. Although some researchers have distinguished mathematics test anxiety from broader mathematics anxiety, they have found that these constructs remain closely related (Dowker & Sheridan, 2022; Kazelskis et al., 2000).

Although some degree of anxiety before evaluations is considered normal (Agius, 2012) and may help students remain attentive and motivated, excessive anxiety can impair both emotional well-being and academic achievement (OECD, 2021). Feeling mathematics anxiety goes beyond just feeling down, as it has been shown to be negatively related to students' mathematics achievement (Ashcraft & Krause, 2007; Barroso et al., 2021). Furthermore, experiencing elevated levels of mathematics anxiety is related to avoidance patterns, lower learning motivation, and overall negative attitudes toward learning (Ashcraft, 2002; Quintero et al., 2022). Over time, repeated negative experiences and lower achievement may also contribute to avoidance behaviours and reduced interest in STEM-related educational and career pathways (Ashcraft & Krause, 2007; Ashcraft & Moore, 2009; Hembree, 1990).

One of the most widely discussed consequences of mathematics anxiety is its negative association with mathematics performance. In educational research, mathematics achievement is commonly assessed as students' performance on mathematics assessments. In the present dissertation, mathematics achievement refers to students' performance on mathematics assessments and is measured using national examination results, mathematics test scores, or PISA mathematics assessment scores. Many studies have shown a negative relationship between mathematics anxiety and mathematics achievement (e.g., Ashcraft & Krause, 2007; Barroso & Ganley, 2021). One possible explanation for this relationship is that students with higher mathematics anxiety may focus primarily on avoiding failure rather than mastering mathematical concepts (Klee et al., 2021), which may help explain why anxiety is negatively associated with achievement. However, Barroso et al. (2021) reported unexplained heterogeneity across studies in their meta-analysis, suggesting that the strength of this relationship may depend on additional psychological and contextual factors that have not yet been fully examined. However, the direction of the relationship between mathematics anxiety and achievement is still unclear. Previously, it has been suggested that a more nuanced relationship exists: lower mathematics achievement may contribute to the development of mathematics anxiety, while mathematics anxiety itself

may subsequently affect later achievement (Carey et al., 2016). Thus, mathematics anxiety may be understood both as a consequence of earlier learning difficulties and as a factor that further hinders mathematics learning.

Self-efficacy

When considering the important role of mathematics anxiety in learning mathematics, it is also important to research and understand the factors that may help to reduce or help to better handle mathematics anxiety. One of the most widely researched psychological constructs in educational psychology is self-efficacy, which has been shown to be related to students' motivation, persistence, achievement, and overall emotional well-being (Usher & Pajares, 2008). Self-efficacy refers to individuals' beliefs in their capability to perform successfully in a particular domain or task, for example, in mathematics (Bandura, 1995). According to Bandura's (1995) social cognitive theory, self-efficacy develops through several sources: previous experiences of success and failure; observing others' performance; encouragement from others, like parents or teachers; and students' individual emotional states. In educational contexts, this means that students' self-efficacy may additionally be shaped by social comparisons, teacher and parental feedback, and emotional experiences such as stress or anxiety (Usher & Pajares, 2008).

In mathematics learning, self-efficacy has consistently been associated with students' achievement and emotional experiences. Students with higher self-efficacy tend to demonstrate greater persistence when facing difficulties, adapt their learning strategies, show stronger intrinsic interest in learning, and demonstrate better self-regulation skills (Mills et al., 2007). They also tend to report lower levels of anxiety and stress, whereas students who feel less confident in their abilities are more likely to experience higher levels of anxiety (Carey et al., 2016; Şanlı, 2021; Živković et al., 2023). One possible explanation for this is that students with higher self-efficacy are better able to manage their work, more efficient at problem-solving, and more persistent (Usher & Pajares, 2008).

Social and emotional skills

Educational research has increasingly recognised the need to examine social and emotional skills and their contributions to achievement, emotional well-being, and students' ability to cope with challenges in learning situations (Chernyshenko et al., 2018; De Fruyt et al., 2015). Furthermore, social and emotional skills are considered fundamental to students' well-being and academic achievement (Cipriano et al., 2023; OECD, 2021). Social and emotional skills are a set of developable competencies that support students' learning, well-being, and the ability to adapt in educational settings. These skills are defined as individual characteristics that develop through a reciprocal relationship between individuals

and their environments, are reflected in consistent thoughts, feelings, and behaviours, and continue to develop through learning experiences (De Fruyt et al., 2015). They are also referred to as non-cognitive skills, soft skills, character skills, or 21st-century skills (De Fruyt et al., 2015; Miyamoto et al., 2015). In addition to cognitive abilities and educational opportunities, these skills have been shown to predict a wide range of important life outcomes, including well-being, health, social relationships, and educational and occupational success (Soto et al., 2024).

Social and emotional skills are grounded in the Big Five personality traits framework (Soto & Tackett, 2015). The key difference between relatively stable personality traits and social and emotional skills is that the latter are malleable and can be developed through learning experiences (Chernyshenko et al., 2018). This makes them particularly relevant in educational settings, as previous research suggests that social and emotional learning programs tend to improve students' social and emotional skills and attitudes, behavioural adjustment, reduced internalising issues (often associated with anxiety), and achievement test scores (e.g., Durlak et al., 2011). Furthermore, social and emotional skills are related to achievement not only directly, by supporting students' behaviour and interactions, but also indirectly by supporting the development of cognitive skills (Chernyshenko et al., 2018). Supporting the development of students' social and emotional skills has also been shown to be associated with better school relationships (OECD, 2021). Thus, students with similar cognitive abilities may differ in their academic performance because they approach learning situations differently.

Different social and emotional skills support students' learning through complementary mechanisms. For example, curiosity and perseverance help to primarily support students' motivation and engagement in learning. More specifically, curiosity encourages intellectual exploration and engagement with learning (Chernyshenko et al., 2018; Peterson & Cohen, 2019), whereas perseverance supports sustained effort when facing difficult tasks (Duckworth et al., 2007). In contrast, emotional control and stress resistance help students regulate emotions and cope more effectively with academic stress (Amstadter, 2008; Feder et al., 2009; Wirtz et al., 2014). Accordingly, students with stronger emotional regulation and greater open-mindedness tend to achieve better results in mathematics (Sert & Arıkan, 2025). Taken together, these findings suggest that social and emotional skills may help students manage both the cognitive and emotional demands of mathematics learning.

Because social and emotional skills influence learning experiences, emotional regulation, and adaptation to challenging situations, they may also play an important role in students' experiences of mathematics anxiety. However, compared with constructs such as self-efficacy or motivation, the relationship between social and emotional skills and mathematics anxiety has received relatively little research attention. As learning mathematics often involves making mistakes, uncertainty, and evaluation, students with stronger emotion regulation skills may interpret these situations as more manageable challenges rather than threats,

whereas students with weaker emotion regulation skills may experience greater anxiety (Folkman, 2008). Within the educational settings, the development of these competencies is commonly addressed through social and emotional learning (SEL), which aims to foster students' ability to recognise and regulate emotions, solve problems, establish positive relationships, and make responsible decisions (Zins & Elias, 2007). Previous research has shown that participating in such programs is associated with improvements in students' social and emotional skills, attitudes, behaviour, and achievement (Durlak et al., 2011). A more recent study suggests that stronger social and emotional skills are associated with higher achievement in mathematics, with this association more pronounced among girls and students from lower socio-economic backgrounds (Sert & Arıkan, 2025).

Although research examining the relationship between mathematics anxiety and social and emotional skills remains relatively limited, analyses of the PISA 2022 data indicate that these skills are associated with students' mathematics achievement (Schleicher, 2023). The present dissertation focuses on seven social and emotional skills included in the PISA 2022 assessment: curiosity, perseverance, emotional control, stress resistance, assertiveness, empathy, and cooperation. Among these, curiosity and perseverance primarily reflect motivational aspects of learning, whereas emotional control and stress resistance are closely related to students' ability to regulate emotions and cope with academic stress. Successful mathematics learning involves more than memorising procedures; it requires students to explore ideas, solve unfamiliar problems, and formulate conjectures (Schoenfeld, 2016). Such learning situations may require students to persist through difficulties and regulate their emotional responses when solutions are not immediately apparent (Lazarus & Folkman, 1984; Pekrun, 2006).

Gender differences

Gender differences have been an important topic in research on mathematics learning and mathematics anxiety. Previous research has shown that girls tend to report having higher levels of mathematics anxiety (Devine et al., 2012; Dowker, 2026). This pattern has also been observed across other STEM subjects, where girls consistently report higher levels of anxiety than boys (Rozgonjuk et al., 2024). Furthermore, it has been shown that girls tend to experience less positive emotions when learning mathematics (Lichtenfeld et al., 2023). However, findings regarding gender differences in mathematics achievement have been less consistent. Some studies have reported slightly lower mathematics achievement among girls (Reilly et al., 2015), whereas others have found no significant gender differences in overall mathematics performance (Barroso & Ganley, 2021; Geary et al., 2023; Ross et al., 2012; Vos et al., 2023). Similarly, recent evidence from Estonia has been mixed. While girls have demonstrated either comparable or slightly higher mathematics achievement than boys despite reporting higher levels of mathematics anxiety (Kilp-Kabel et al., 2025; Mädamürk & Kikas, 2024), the PISA 2022 results showed higher mathematics performance among

boys (Tire et al., 2023). Together, these findings suggest that gender differences in mathematics may be more strongly reflected in students' emotional experiences than in their achievement. This highlights the need to consider both mathematics anxiety and achievement when examining gender differences in mathematics learning.

Socio-economic background

Students' socio-economic background refers to the educational, occupational, and economic position of a student's family and reflects the educational resources and opportunities available to support students' learning (Sirin, 2005). In this dissertation, socio-economic background is measured using the PISA Economic, Social, and Cultural Status (ESCS) index, a composite of parental education, occupation, and home educational resources (OECD, 2023a, 2024). Previous international research has shown socio-economic background to be an important predictor of students' academic achievement, including in mathematics (OECD, 2019, 2023b; Selvitopu & Kaya, 2023; Sirin, 2005). In Estonia, socio-economic background explained about 13% of the variation in mathematics achievement in PISA 2022, which is comparable to the OECD average of 15 % (OECD, 2023b; Tire et al., 2023). Furthermore, multilevel analyses have shown that higher student- and school-level socio-economic status are both associated with higher mathematics achievement (Rozgonjuk et al., 2023).

In addition to achievement, previous research has shown that students from more advantaged socio-economic backgrounds tend to report lower levels of mathematics anxiety (Adimora et al., 2015; Huang & Liu, 2025; Svraka et al., 2024). Taken together, these findings indicate that socio-economic background represents an important contextual factor when examining both mathematics learning and mathematics anxiety. Greater access to educational resources, supportive learning environments, and academic opportunities may contribute to both higher achievement in mathematics and more positive emotional experiences in mathematics.

School-related factors

Students' experiences in learning mathematics are shaped not only by individual characteristics but also by the environments in which learning takes place. Because students who are attending the same schools share common educational experiences and therefore tend to be more similar to each other than students attending different schools (Hox, 2010). Since students spend the majority of their day in school, the school environment should be considered, as it affects students' learning (Goldstein, 2003). Previously, it has been highlighted that students' academic development is shaped by various personal, pedagogical, structural, and sociocultural factors at school and at home (Skinner et al., 2022).

As school attendance is compulsory, students cannot easily avoid either academic challenges or the social interactions that accompany learning. Consequently, students must engage with teachers and classmates, as well as with learning tasks, making the school environment an important context to consider not only for academic achievement but also for emotional experiences such as mathematics anxiety. The classroom or school environment, therefore, represents an important context in which students' motivation, achievement, and emotional experiences, including mathematics anxiety, may be shaped.

Among various school-related factors, perceived teacher support and teaching quality have received attention in educational research, as they may affect students' learning experiences and their emotional responses to learning mathematics. Teachers play an important role in shaping students' daily experiences by planning lessons, giving feedback, and responding to students' academic and emotional needs. Through these interactions, teachers' behaviour may help to reduce or strengthen students' mathematics anxiety levels. A previous meta-analysis has shown that good student-teacher relationships are particularly beneficial for students experiencing academic difficulties, those from lower socioeconomic backgrounds, or those with learning difficulties (Roorda et al., 2011).

Student-teacher relationships are also related to students' perceptions of lesson quality (Arthur et al., 2022; Roorda et al., 2011). Students who feel more supported by their teachers also tend to have lower levels of mathematics anxiety (Lazarides & Buchholz, 2019; H. Li et al., 2021), while higher perceived teaching quality is associated with better achievement (Arthur et al., 2022). The present dissertation focuses on two aspects of perceived school environment included in the PISA 2022 assessment: perceived mathematics teacher support and perceived mathematics lesson quality.

Another school-related factor that has received increasing attention in educational research is students' sense of school belonging. School belonging refers to students' feelings of being accepted, valued, and included within the school community and has been associated with both academic and psychological outcomes (Goodenow, 1993). Students with a stronger sense of school belonging may perceive the learning environment that the school offers as safe and more supportive, whereas those who feel more excluded may experience higher levels of negative emotions, such as anxiety. Previous research has shown that students with a stronger sense of school belonging tend to report lower levels of mathematics anxiety (Asanjarani et al., 2024; Wang, 2024).

Taken together, these findings suggest that mathematics anxiety should not be understood solely as an individual characteristic but also as a product of students' interactions with their school environment. Therefore, examining school-related factors alongside individual characteristics provides a more comprehensive understanding of mathematics anxiety and mathematics achievement.

An overview of relevant theories

These theories were chosen based on the aims of the dissertations and the multifaceted nature of mathematics anxiety, as each theory provides a complementary perspective on the individual, motivational, emotional, or contextual factors associated with mathematics anxiety and mathematics learning. Understanding the factors associated with mathematics learning and mathematics anxiety requires the consideration of multiple psychological and educational perspectives. As discussed above, mathematics anxiety is related to multiple individual and contextual factors, including students' beliefs, their social and emotional skills, and school environments. Thus, no single theoretical framework can explain all the relationships examined in this dissertation. The studies included in this dissertation draw from several theoretical frameworks that help to explain different aspects of mathematics anxiety and mathematics learning. The following section provides a brief overview of the theories used.

Social cognitive theory

According to social cognitive theory (Bandura, 1986), human functioning is explained by interactions among personal, behavioural, and environmental factors. More precisely, people and their environments are closely interrelated. Personal factors, behaviours, and environmental factors are continuously related to one another through a triadic reciprocal interaction. From this perspective, mathematics anxiety is not merely an individual emotional response but rather emerges from ongoing interactions among students' beliefs about their mathematical capabilities, their experiences in mathematics-related activities, and the social contexts in which learning occurs.

One of the main concepts of social cognitive theory is self-efficacy, which refers to one's beliefs about one's ability to successfully perform tasks and overcome difficulties, and is developed through mastery experiences, vicarious experiences, verbal persuasion, and physiological and emotional states (Bandura, 1995). Moreover, mastery experiences are considered particularly influential, as repeated successes or failures shape individuals' beliefs about their capabilities (Usher & Pajares, 2008). Students with higher self-efficacy levels are more willing to challenge themselves and show greater persistence when facing difficulties (Mills et al., 2007). Consequently, higher self-efficacy has been shown to be associated with higher achievement in mathematics (Arens et al., 2022). Furthermore, students with higher self-efficacy tend to doubt their abilities less and experience lower levels of mathematics anxiety (Hiller et al., 2022; Şanlı, 2021; Živković et al., 2023). As self-efficacy develops partly through social experiences and verbal persuasion, support from teachers may contribute to students' beliefs about their capabilities (Usher & Pajares, 2008).

Taken together, these findings highlight the importance of self-efficacy for understanding students' emotional and academic experiences in mathematics. From a social cognitive theory perspective, self-efficacy is therefore a relevant

concept for explaining mathematics anxiety, achievement, and school-related outcomes. Thus, this theory is useful for better understanding students' beliefs about their capabilities and how these beliefs might influence their emotional experiences and achievement in mathematics.

While social cognitive theory primarily explains students' beliefs about their abilities, it does not fully account for why students differ in their motivation and willingness to engage with mathematics in the first place. This perspective is addressed by situational expectancy theory, which helps to explain how students' expectations of success and the value they assign to learning activities shape their motivation and engagement.

Situated expectancy-value theory

Situated expectancy-value theory is based on expectancy-value theory (Eccles & Wigfield, 2020; Wigfield & Eccles, 2000), which states that one's motivation and behaviour are shaped by one's expectations of success and the values one assigns to performing the tasks. Situated expectancy theory emphasises that students' expectations and values are shaped by contextual processes and may change over time (Eccles & Wigfield, 2020). Additionally, the idea that mathematics demands cognitive effort and carries the potential risk of failure can further contribute to the perceptions of cost. This theory helps explain the connection between mathematics anxiety and students' expectations of success, as well as their perceptions of cost. Having doubts about mathematical ability can lead to anticipated failure and increase anxiety during mathematics tasks. Therefore, from the situated expectancy-value theory perspective, mathematics anxiety could be both an outcome and a contributor to motivational beliefs. Mathematics anxiety may arise when students expect low achievement or perceive mathematics as highly costly, and, in turn, anxiety may further reduce expectations of future success and the perceived benefits of engaging with mathematics.

The theory considers interest as a value indicator for students' learning activities, meaning that students who perceive mathematics as interesting, useful, or important to them are more likely to participate more actively and face challenges head-on (Eccles & Wigfield, 2020). Situated expectancy-value theory also highlights the perceived cost of learning. Negative emotions, such as anxiety, may increase the perceived cost of learning mathematics, thereby decreasing students' motivation and willingness to persist in learning mathematics (Eccles & Wigfield, 2020; Reeve, 2018).

Although situated expectancy-value theory complements social cognitive theory by explaining why students engage in learning mathematics, these theories do not fully account for how achievement-related emotions, such as mathematics anxiety, arise. This aspect is addressed by control-value theory, which proposes that students' emotions depend on their perceived control over learning and the value they attach to the academic tasks.

Control-value theory

According to the control value theory of achievement emotions (Pekrun, 2006; Pekrun et al., 2017), mathematics anxiety is conceptualised as an achievement emotion, as it arises in relation to achievement-related activities and outcomes such as learning mathematics, solving mathematical problems, or taking tests (Schukajlow et al., 2023). Achievement emotions can be classified into two types: state-achievement emotions, which are feelings that occur in specific situations (e.g., anxiety before an exam); and trait-achievement emotions, which are stable feelings that are repeatedly experienced over longer periods (e.g., anxiety towards mathematics-related tasks) (Peixoto et al., 2017).

According to the theory, students' emotional experiences in academic settings result from the interaction between perceived control (such as self-efficacy) and the value attached to the task, both of which are influenced by contextual factors and individual traits (Pekrun, 2006; Pekrun et al., 2017). These processes may be particularly relevant in mathematics, where students frequently receive immediate feedback about the correctness of their responses, strengthening the relationship between emotions and achievement (Schoenherr et al., 2025). Furthermore, the subjective value students assign to a task is related to anxiety. When students perceive an achievement as important but feel a low sense of control, they are more likely to feel anxiety; conversely, if the outcome is considered not important, anxiety is less likely to occur (Pekrun, 2006, 2024).

An important characteristic of control-value theory is that it emphasises domain specificity, meaning that students' emotional experiences may differ across different subjects (Schukajlow et al., 2023). Thus, mathematics anxiety should be examined as a domain-specific achievement emotion rather than just researching anxiety in general. Mathematics anxiety often has negative consequences for learning by reducing intrinsic motivation and diverting working memory resources to worry, hindering the cognitive performance needed to successfully manage mathematics tasks (Schukajlow et al., 2023).

Control-value theory also helps to understand mathematics anxiety by explaining how characteristics of the learning environment, such as teacher support, instructional quality, task demands, goals, and feedback, are related to students' perceptions of control and value, which in turn may shape their emotional experiences and achievement (Holm et al., 2020; Klee et al., 2021). This suggests that mathematics anxiety is not just related to students' individual characteristics but also to the learning environments. This view is relevant to the dissertation, as it provides a basis for examining how psychological characteristics (e.g., self-efficacy) and school-related factors (e.g., perceived teacher support) are associated with mathematics anxiety and mathematics achievement.

Although control-value theory explains why students experience achievement emotions, it does not fully account for how they respond to stressful, challenging situations. This aspect is addressed by the transactional model, which explains how students assess potentially stressful situations and evaluate their ability to cope with them.

Transactional model of stress and coping

The transactional model of stress and coping (Lazarus & Folkman, 1984) offers a useful framework for understanding mathematics anxiety as a stress response that results from individuals' appraisals of mathematical situations and their perceived ability to cope with them. According to the model, students evaluate situations through two processes: first, they assess whether the situation is relevant or threatening to them; second, they assess whether they have sufficient resources to cope with it (Lazarus & Folkman, 1984). When students feel like the situation is threatening to them and do not have enough resources to deal with that, they may feel increased negative emotions, such as anxiety (Folkman, 2008). The transactional model, therefore, provides a useful framework for understanding why students differ in their emotional responses to mathematics and why stronger emotional regulation skills may protect against mathematics anxiety. An important contribution of the transactional model is its emphasis on the subjective nature of stress (Lazarus & Folkman, 1984). Students may experience different levels of mathematics anxiety in the same situation depending on how they appraise the demands of the task and their ability to cope with it. This helps explain why mathematics anxiety is often only moderately related to actual mathematical ability.

While these theories primarily explain individual psychological processes, students' learning does not occur in isolation. The bioecological model of academic functioning extends this perspective by situating these processes within broader educational and social contexts.

Bioecological model of academic functioning

Rather than viewing mathematics anxiety as solely an individual characteristic, this perspective suggests that it emerges through interactions among students and the multiple social systems in which they participate, including families, classrooms, peer groups, schools, and broader sociocultural contexts. The bioecological model of human development (Bronfenbrenner & Morris, 2006) provides a comprehensive framework for understanding how development is shaped by individuals and their environments. Building on this perspective, Skinner et al. (2022) provide a bioecological model of academic functioning for understanding how students' academic development is shaped by the interaction between individual characteristics and their broader educational environment. The model proposes that students' academic functioning develops through ongoing interactions between the individual and various environmental systems operating at different levels. First, the microsystem, which consists of students' immediate learning environments (e.g. relationships with teachers, peers, parents); second, the mesosystem, which reflects the relations between these settings, and third, the exosystem, which comprises a broader context that indirectly influences students (e.g. school policies, parental workplaces), and lastly the macrosystem, which

represent the wider cultural, societal, and educational context in which learning takes place (Skinner et al., 2022).

The model further emphasises that students' academic functioning should not be understood solely in terms of individual characteristics but rather as the result of continuous interactions among contextual factors, individual processes, and developmental change over time (Skinner et al., 2022). Consequently, students' motivation, achievement, and emotional experiences are shaped simultaneously by their own psychological resources and by the environments in which learning occurs.

The bioecological perspective is particularly relevant to the present dissertation because it provides a theoretical foundation for examining mathematics anxiety from both individual and contextual perspectives. In addition to students' psychological characteristics, such as mathematics self-efficacy and social and emotional skills, the dissertation considers school-related factors, including teacher support, lesson quality, school belonging, and socio-economic background.

Table 1. Overview of the theoretical frameworks used to explain mathematics anxiety

Theory name	Core premise	Relation to mathematics anxiety
Social cognitive theory (Bandura, 1986)	Behaviour, personal, and environmental factors interact reciprocally.	Mathematics anxiety develops through interactions among students' beliefs, experiences, and learning environments.
Situated expectancy-value theory (Eccles & Wigfield, 2020)	Motivation depends on expectations of success and the perceived task value.	Mathematics anxiety may both result from and contribute to students' expectations of success and perceived task value.
Control-value theory (Pekrun, 2006)	Achievement emotions arise from perceived control and value.	Mathematics anxiety occurs when achievement is important, but the perceived sense of control is low.
Transactional model of stress and coping (Lazarus & Folkman, 1984)	Stress depends on how students appraise demands and coping resources.	Mathematics anxiety reflects appraisals that mathematical demands exceed perceived coping resources.
Bioecological model of academic functioning (Skinner et al., 2022)	Functioning is shaped by interactions between individuals and their environments.	Mathematics anxiety is related to school, family, peers, and broader educational contexts.

Although each of these theories is relevant regarding different aspects of learning and learning-related beliefs and emotions, they complement one another in explaining the relationships examined in this dissertation. Table 1 summarises the core premise of each theoretical perspective and its relevance to understanding

mathematics anxiety. Taken together, these theories suggest that mathematics anxiety develops through the interaction among students' beliefs about themselves, their motivation to engage in mathematics, and the way they appraise and cope with mathematical challenges. Social cognitive theory and situated expectancy-value theory primarily help to explain students' beliefs about their capabilities and their motivation to engage in mathematics. In turn, control-value theory and the transactional model help to explain the development of achievement emotions and students' responses to mathematical challenges, whereas the bioecological model of academic functioning situates these processes within the broader learning environment.

AIMS OF THE DISSERTATION

The main aim of the dissertation is to investigate mathematics anxiety as an obstacle to mathematics learning and to examine the various factors associated with it. More specifically, the aim is to explore how mathematics anxiety relates to students' mathematics achievement and to identify psychological, social and emotional, and school-related factors associated with mathematics anxiety. Particular attention is given to the roles of self-efficacy, social and emotional skills, socio-economic background, and perceived school environment factors, such as perceived teacher support and lesson quality.

Although the primary focus of the dissertation is mathematics anxiety, mathematics achievement is also examined because anxiety should be understood within the broader mathematics learning process. Previous research has shown that mathematics anxiety and mathematics achievement are reciprocal, with anxiety predicting achievement, while achievement may also contribute to the development of anxiety (Carey et al., 2016). Thus, examining both constructs helps to better understand mathematics learning and the factors associated with mathematics anxiety.

In addition, the dissertation aims to contribute to a more nuanced understanding of mathematics anxiety by examining different forms of anxiety and by investigating these relationships at both the student and school levels. In particular, the dissertation combines student- and school-level analyses to examine how individual psychological characteristics and broader educational contexts are associated with mathematics anxiety and mathematics achievement. By combining results from multiple studies and methodological approaches, and incorporating students across different age groups, this dissertation seeks to provide a broader understanding of mathematics anxiety as an obstacle to mathematics learning.

OVERVIEW OF THE INCLUDED STUDIES AND THEIR CONTRIBUTION TO THE DISSERTATION

To provide an overview of how the five studies in this dissertation collectively address their aims, Table 2 summarises each study's methodological characteristics and offers a brief overview of their contributions to the overall research.

Table 2. Overview of the included studies and their contribution to the dissertation

	Study I	Study II	Study III	Study IV	Study V
Main focus	Online learning and test anxiety	Subject-specific anxiety	Social and emotional skills	Mathematics achievement	Mathematics anxiety
Sample	High school graduates	Grades 3 and 5	PISA 2022 Estonian sample	PISA 2022 Estonian sample	PISA 2022 Estonian sample
Outcome variable	Mathematics exam results	Grade 5 mathematics achievement	Mathematics anxiety	Mathematics achievement	Mathematics anxiety
Main variables	Test anxiety, self-efficacy, and online course activity	Mathematics anxiety, interest, and Grade 3 achievement	Social and emotional skills, socio-economic background, perceived mathematics teacher support, perceived lesson quality	Mathematics anxiety, socio-economic background, curiosity, and perceived lesson quality	Socio-economic background, stress resistance, self-efficacy, school belonging, perceived mathematics teacher support
Method	Linear regression model, correlations	Linear regression model, Mann-Whitney U test, correlations	Hierarchical regression model, t-test, correlations	Multilevel regression model, correlations	Multilevel regression model, correlations
Analytical perspective	Individual	Individual	Individual	Multilevel (student and school)	Multilevel (student and school)
Main theoretical lens	Social cognitive theory (Bandura, 1995)	Situated expectancy-value theory (Eccles & Wigfield, 2020)	Social cognitive theory (Bandura, 1995) Transactional model (Lazarus & Folkman, 1984)	Bioecological model (Skinner et al., 2022)	Bioecological model (Skinner et al., 2022) Social-cognitive theory (Bandura, 1995) Control-value theory (Pekrun, 2006)
Main contributions	Demonstrated the importance of self-efficacy and test anxiety for mathematics learning in an online learning context	Showed the importance of mathematics-specific anxiety and interest for explaining mathematics achievement	Introduced social and emotional skills as an important dimension in understanding mathematics anxiety, highlighting the roles of stress resistance and emotional control	Integrated a multilevel perspective, demonstrating that mathematics achievement is shaped by both student- and school-level factors	Integrated a multilevel perspective, demonstrated that mathematics anxiety is shaped by both student- and school-level factors

METHOD

Study I

In Study I, the sample consisted of high school students who took a voluntary mathematics exam preparation course in 2021. In Estonia, the national mathematics exam is split into two different exams, with students able to choose one: the more comprehensive “wide” exam or the “narrow” exam. In total, 1430 signed up for that course.

As the course was held during the COVID-19 pandemic and schools were on distance learning, the national exam was not mandatory in 2021, meaning that not all students who participated in the course had to take the mathematics exam. During the course, students had the opportunity to answer a voluntary survey used in Study I. Out of the 213 students who responded to the survey, 195 took the national mathematics exam: 51 (26.2%) completed the narrow exam, and 144 (73.8%) completed the wide exam. The main analyses focused on students who completed the wide mathematics examination, given differences in examination content and difficulty levels. This resulted in an effective sample size of 144 (81.9% girls) for the analyses. Study I included descriptive statistics, correlation analyses, and a regression model. In the regression model, mathematics examination results were predicted by gender, test anxiety, self-efficacy, and online course activity.

Mathematics test anxiety and self-efficacy were assessed using scales adapted from Liu & Lin (2010). Responses were provided on a five-point Likert scale ranging from 1 (“completely disagree”) to 5 (“completely agree”). Composite scores for both constructs were calculated by summing the respective item responses. Online course activity data were retrieved directly from the online course environment and included webinar views, file downloads, video views, and forum views. These indicators were standardised and combined into a single composite measure of online course activity using principal component analysis (PCA).

Study II

Study II used two different data collections from 2019 and 2021. The first data collection used the Grade 3 students’ mathematical competence test, which was administered in Estonian schools as part of the national examination system. The Education and Youth Board (previously SA Innove), which was responsible for organising educational development and assisting schools, used to contact schools two years later. The same schools were approached once again for the follow-up research. For both data collection rounds, after completing the online self-report questionnaire, students took the mathematics test. An ethics committee authorised all study methods, and parents and students provided informed consent.

846 students (55.3% girls) participated in Grade 3, while 317 students (50.5% girls) completed all tests in Grade 5. A total of 126 students participated in both data collection waves. External factors, such as illness and periods of distance learning, were the main reasons for the smaller longitudinal sample size.

Study II included descriptive statistics, correlation analysis, the Mann-Whitney U test, and regression analysis. A stepwise multiple regression analysis was conducted to predict Grade 5 mathematics achievement. The final model included Grade 3 mathematics achievement, mathematics anxiety, and mathematics interest as significant predictors, whereas gender, general academic anxiety, and general academic interest were excluded from the final model.

General academic anxiety and mathematics anxiety were measured using modified items from the Abbreviated Math Anxiety Scale (mAMAS; Carey et al., 2017). Learning interest and mathematics learning interest were measured using adapted items from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1993). Mathematics achievement was measured using tests developed in accordance with the Estonian national curriculum. The tests followed the same overall structure across Grade 3 and Grade 5 but were adjusted to reflect age-appropriate difficulty levels for each grade.

Studies III–V

Studies III–V used data from the large-scale Programme for International Students Assessment (PISA) survey conducted by the Organisation for Economic Co-operation and Development (OECD) in 2022. Study III used the entire Estonian sample, comprising an effective sample size of 6392 15-year-old students (48.81% girls, 51.19% boys) from 196 schools. As Studies IV and V included analyses at both the student and school levels, schools with fewer than 10 students were excluded from the sample, resulting in an effective sample size of 6232 students (48.72% girls, 51.28% boys) from 166 schools. During the PISA survey, students were assessed in reading comprehension, science, and mathematics. Study III used mathematics achievement together with measures of mathematics anxiety, social and emotional skills, socio-economic background, perceived mathematics lesson quality, and perceived mathematics teacher support. Study III analyses included descriptive statistics, correlation analyses, t-test analyses, and a hierarchical regression model to predict mathematics anxiety. The analysis was done in three steps: first, gender and socio-economic status were added as control variables (Model 1); secondly, social and emotional skills were added to the model (Model 2), and finally, school-related factors (perceived lesson quality and perceived teacher support) were added to the model (Model 3).

Studies IV and V analyses included descriptive statistics and correlation analyses at both the student and school levels, as well as a two-level regression model predicting mathematics test results in Study IV and mathematics anxiety in Study V. School-level predictors were specified as school means, which were then grand-mean-centred, whereas student-level variables (socio-economic background,

mathematics anxiety, curiosity, perceived lesson quality, stress resistance, self-efficacy, school belonging, perceived teacher support) were group-mean-centred. This centring technique allows to determine whether associations result from differences among students within schools or between schools. In Study IV, random intercepts for schools and random slopes for mathematics anxiety and curiosity were added to the final multilevel model. In Study V, random intercepts for schools and random slopes for stress resistance and self-efficacy were added to the final multilevel model.

RESULTS

Study I

In Study I, the relationships among online course activity, mathematics test anxiety, self-efficacy, and mathematics exam results were investigated. During the study, students' online course activity logs and self-reported data from a voluntary survey were combined with mathematics examination results obtained from the national examination registry after the exam. The results showed that online course activity was positively associated with mathematics exam results, although it was not significantly related to either students' self-efficacy or test anxiety. Regression analysis further demonstrated that self-efficacy (standardised regression coefficient, $\beta = .41$) was the strongest predictor of mathematics exam results, while online course activity ($\beta = .16$) was also a positive predictor, and test anxiety ($\beta = -.19$) was a negative predictor. These findings suggest that supporting students' self-efficacy and addressing test anxiety may be important components of effective preparation for mathematics examinations.

Study II

Study II investigated whether mathematics achievement is better explained by general academic anxiety and interest or by mathematics-specific anxiety and interest. More specifically, Study II aimed to determine whether general or mathematics-specific factors predict Grade 5 mathematics achievement more strongly, while accounting for prior Grade 3 mathematics achievement and gender.

The results indicated that girls reported higher levels of both mathematics anxiety ($\delta = .42$) and general academic anxiety ($\delta = .35$), as well as lower mathematics interest ($\delta = -.32$), compared to boys, despite no gender differences in mathematics achievement or general learning interest. Furthermore, stepwise regression analysis showed that mathematics-specific anxiety ($\beta = -.16$) was a significant negative predictor of Grade 5 mathematics achievement, and prior Grade 3 mathematics achievement ($\beta = .64$) was a significant positive predictor. In contrast, general academic anxiety and interest did not add explanatory value beyond subject-specific factors. Study II demonstrates that even after controlling for prior achievement, mathematics-specific anxiety and interest are unique and significant predictors of elementary school mathematics achievement.

Study III

Study III investigated whether mathematics anxiety is associated with students' social and emotional skills (curiosity, perseverance, emotional control, stress resistance, assertiveness, empathy, and co-operation), school-related factors (per-

ceived teacher support and mathematics lesson quality), and demographic predictors (gender and socio-economic status).

Correlation analyses demonstrated that higher mathematics anxiety was associated with lower mathematics achievement, a lower socio-economic background, and weaker social and emotional skills. In particular, perseverance, emotional control, and stress resistance demonstrated the strongest negative associations with mathematics anxiety. Additionally, perceived lesson quality was positively correlated with mathematics test results and negatively correlated with mathematics anxiety. The strongest correlations were between emotional control and stress resistance ($r = .58$) and between perceived teacher support and perceived lesson quality ($r = .47$), both of which were positively related. T-test analysis further showed that girls reported higher levels of mathematics anxiety, curiosity, and empathy and lower levels of emotional control and stress resistance than boys. Despite these differences, no gender differences emerged in mathematics achievement.

Hierarchical regression analysis for predicting mathematics anxiety was conducted in three steps: first, gender and socio-economic status were entered as control variables; then, social and emotional skills were added; and finally, school-related factors were added. The results demonstrated that among social and emotional skills, higher stress resistance ($\beta = -.17$), perseverance ($\beta = -.15$), and emotional control ($\beta = -.11$) are negative predictors for mathematics anxiety. Perceived lesson quality, teacher support, and socio-economic background were also significant negative predictors. Interactions between gender and perseverance ($\beta = -.06$), stress resistance ($\beta = -.06$), and lesson quality ($\beta = .07$), as well as between socio-economic status and perseverance ($\beta = -.05$), were also added to the model and were statistically significant.

Study IV

Building on Study III, which focused on predictors of mathematics anxiety, Study IV extended the analysis by examining factors associated with mathematics achievement at both the student and school levels. More precisely, Study IV investigated how student- and school-level factors are related to students' mathematics performance.

Correlation analyses showed positive relationships among mathematics achievement, socio-economic background, curiosity, and perceived lesson quality. Negative correlations were found between mathematics achievement and mathematics anxiety. All of the correlations were significant at both the student and school levels.

The multilevel regression model revealed that, at the student level, higher socio-economic status (unstandardised regression coefficient, $B = 20.13$), curiosity ($B = 12.67$), and perceived lesson quality ($B = 5.17$) predicted higher mathematics achievement, whereas mathematics anxiety ($B = -17.76$) predicted lower achievement. At the school level, socio-economic status ($B = 55.04$) and curiosity

($\beta = 20.24$) were positive predictors, and mathematics anxiety ($B = -42.45$) was a negative predictor of mathematics achievement. In addition, mathematics anxiety and curiosity varied across schools, suggesting that the school environment may play a role in how these factors relate to students' mathematics achievement. The intraclass correlation ($ICC = .057$) indicated that approximately 5.7% of the variance in mathematics achievement was attributable to the differences between schools, whereas the remaining variance reflected differences between students.

Study V

Building on Studies III and IV, Study V examined mathematics anxiety from a multilevel perspective. More specifically, Study V investigated how student- and school-level factors are related to students' mathematics anxiety. The selection of the individual-level predictors was informed by the findings of Study III, which identified the strongest psychological predictors of mathematics anxiety, whereas the multilevel analytical approach was based on the modelling strategy used in Study IV.

Correlation analyses showed that at the student level, the strongest correlation was between self-efficacy and mathematics anxiety. At the school level, the strongest correlations were between self-efficacy and socio-economic background and between self-efficacy and mathematics anxiety. Overall, these correlations suggest that self-efficacy was consistently associated with mathematics anxiety at both the student and school levels.

The multilevel regression model revealed that, at both the student and school level, mathematics self-efficacy ($\beta = -.40$ and $\beta = -.43$, respectively) was the strongest predictor of mathematics anxiety. Other variables, such as stress resistance ($\beta = -.25$ and $\beta = -.26$, respectively) and perceived teacher support ($\beta = -.12$ and $\beta = -.15$, respectively), were also significant negative predictors of mathematics anxiety at both levels. Although school belonging ($\beta = -.07$) was a significant negative predictor for mathematics anxiety at the student level, it remained non-significant at the school level. However, socio-economic background was the only non-significant predictor of mathematics anxiety at either level.

Overall, the findings of Study V suggest that individual psychological factors explain a larger proportion of differences in mathematics anxiety than school-level factors, although school context also contributes to students' mathematics anxiety.

DISCUSSION

Each of the five studies included in this dissertation helps to broaden the understanding of mathematics anxiety and its role in mathematics learning. Study I focused on individual psychological factors by examining the roles of mathematics test anxiety and self-efficacy in the mathematics national exam results at the end of high school. Study II extended this perspective by comparing mathematics-specific and general academic anxiety and interest, highlighting the importance of domain-specific emotions. Study III broadened further the view by including students' social and emotional skills and school-related factors, such as perceived teacher support and lesson quality, to predict mathematics anxiety. Finally, Studies IV and V applied a multilevel perspective, demonstrating that both mathematics achievement and mathematics anxiety are associated with student- and school-level factors. Taken together, the studies demonstrate that mathematics anxiety cannot be understood solely in terms of isolated individual characteristics but should be viewed as part of a broader learning process shaped by psychological, social, and contextual factors.

Mathematics anxiety as an obstacle to mathematics learning

Across studies examining mathematics achievement, anxiety consistently emerged as an important factor associated with it. Higher levels of mathematics or test anxiety were consistently related to lower mathematics achievement. These results are in line with previous research, which has found a negative relationship between mathematics anxiety and achievement (Ashcraft & Krause, 2007; Barroso et al., 2021; Brunner et al., 2026; Caviola et al., 2022). More precisely, Study I found that test anxiety negatively predicted mathematics exam results. Similarly, Study II showed that mathematics-specific anxiety predicted achievement, even after controlling for prior achievement. Studies III and IV further confirmed that mathematics anxiety was negatively associated with achievement. Given that these studies encompass students from Grade 3 through the end of high school, the findings provide evidence that the negative relation between mathematics anxiety and achievement is robust across a wide age range and educational contexts, suggesting that this association is a persistent feature of students' mathematical development. A review of previous studies by Dowker (2026) suggests that mathematics anxiety exists across age groups and increases with age, and that its negative relationship with mathematics achievement will also grow stronger over the years. Although the present dissertation includes students from primary school through the end of high school, the studies cannot determine whether the association between mathematics anxiety and achievement strengthens over the years. Nevertheless, the consistent negative association observed across the studies does suggest that this relationship remains robust

across different educational stages. The robustness of negative correlations between mathematics anxiety and achievement is also consistent with the transactional model (Lazarus & Folkman, 1984), which suggests that students' emotional responses may depend on how they evaluate academic situations and their perceived ability to cope with them. This means that students who perceive given mathematics tasks as threatening and believe that they lack sufficient coping skills may therefore be more likely to experience higher levels of mathematics anxiety. Pekrun (2024) further suggests that anxiety is likely to arise when students perceive important academic outcomes as uncertain rather than certain, highlighting the role of uncertainty in the experience of anxiety.

One additional explanation for this consistent negative relationship between mathematics anxiety and mathematics achievement is that mathematics anxiety may interfere with cognitive processing during mathematics tasks, consistent with previous work showing that mathematics anxiety occupies working memory resources that would otherwise be available for mathematics problem-solving (Ashcraft & Krause, 2007; Finell et al., 2022). Thus, more anxious students may shift their focus from problem-solving to worrying about their performance.

Moreover, in Study II, mathematics-specific anxiety emerged as a stronger predictor of mathematics achievement than general academic anxiety. This suggests that although mathematics anxiety and general academic anxiety are closely related to each other, they remain distinct constructs. Because the relationships between those forms of anxiety have received relatively little attention, future research should further examine whether mathematics anxiety is just confined to mathematics learning or whether its association with broader academic anxiety also affects students' experiences and achievement in other subjects as well. From a practical perspective, these findings suggest that efforts to improve mathematics achievement should not focus solely on cognitive skills and content knowledge, but also address students' emotional experiences in mathematics. More precisely, Study II's results suggest that, in addition to addressing general academic anxiety, interventions should also target mathematics-specific emotions, as these represent related but distinct aspects of students' emotional experiences.

However, the findings of these studies should not be interpreted as evidence that mathematics anxiety causes lower achievement. As suggested by Carey et al. (2016), mathematics anxiety and mathematics achievement may have reciprocal relationship with each other, thus creating a cycle in which higher anxiety impairs achievement and which, in turn, further causes higher anxiety levels. Mathematics anxiety may therefore be understood both as a consequence of prior learning difficulties and as a factor contributing to subsequent difficulties in mathematics learning.

Given the complex relationship between mathematics anxiety and achievement, it is important to examine various factors that may be associated with these constructs. The findings from the studies conducted show the potential role of psychological factors, such as self-efficacy and social-emotional skills, in ex-

plaining individual differences in mathematics anxiety. These factors are discussed in the following section.

Psychological factors related to mathematics anxiety

The findings of the studies conducted suggest that mathematics anxiety should not be viewed as an isolated factor in explaining students' experiences of learning mathematics. Rather, it is systematically associated with students' self-efficacy and their social and emotional skills, indicating that mathematics anxiety is rooted in a broader network of psychological resources that help support learning and achievement. More specifically, self-efficacy and social-emotional skills emerged as important factors related to mathematics anxiety.

Self-efficacy

One of the most noteworthy factors related to mathematics anxiety across the studies is self-efficacy. Study I demonstrated that self-efficacy was negatively correlated with mathematics anxiety and was the strongest predictor of mathematics achievement. This is in line with previous research that has shown negative relationships between self-efficacy and mathematics anxiety (Akin & Kurbanoğlu, 2011; Rozgonjuk et al., 2020). These findings are consistent with both social cognitive theory (Bandura, 1986, 1995) and the transactional model of stress and coping (Lazarus & Folkman, 1984). According to social cognitive theory (Bandura, 1986, 1995), students with stronger self-efficacy are more likely to persist when facing challenges because they believe in their mathematical capabilities. From the perspective of the transactional model (Lazarus & Folkman, 1984), these self-beliefs are also related to how students appraise challenging situations. More precisely, students who perceive themselves as having sufficient resources to cope with the challenges of learning mathematics are more likely to view these situations as more manageable, and consequently, less likely to experience heightened levels of mathematics anxiety. This interpretation is also consistent with Li et al. (2021), who have highlighted that increasing students' self-efficacy is a key factor in reducing their anxiety levels. Nevertheless, an overview of past research suggests that the relationship between mathematics anxiety and students' beliefs about their abilities is reciprocal (Dowker et al., 2016). This means that while stronger self-efficacy may reduce students' mathematics anxiety, repeated experiences of heightened anxiety may also undermine students' beliefs in their mathematical capabilities.

Another explanation for the negative relationship between mathematics anxiety and self-efficacy is how students evaluate their own mathematical ability. Mathematics is a multifaceted field comprising multiple domains and competencies. Previously, it has been discussed that students may not distinguish between aspects of mathematics and thus generalise difficulties in one area to their overall mathematical ability (Dowker et al., 2016). As Bandura (1986, 1995) pointed out,

one of the most effective ways to increase self-efficacy is through mastery experiences. Previous successes in mathematics strengthen students' beliefs about their abilities, whereas previous negative experiences may weaken them. Consequently, when students experience difficulties with a single topic in mathematics, they may begin to perceive themselves as having low mathematical ability, rather than recognising that their difficulties may be limited to a specific topic, which can lead to decreased self-efficacy and increased mathematics anxiety.

Self-efficacy does not develop in isolation. According to Bandura (1995), verbal persuasion and social experiences are important sources of efficacy beliefs, suggesting that supportive teachers may also help strengthen students' confidence in mathematics. From an educational standpoint, one way teachers might support students in developing a more differentiated understanding of mathematics. Teachers could more effectively communicate that mathematics comprises diverse topics that require different knowledge and skill sets, thus helping students avoid generalising difficulties in one topic to their overall ability in mathematics. Such an approach may support the development of more accurate self-efficacy beliefs by encouraging students to evaluate their mathematics abilities across different domains rather than generalising difficulties from a single topic. In turn, this may help to reduce the risk of developing mathematics anxiety.

Taking these results together, the findings suggest that self-efficacy represents one of the central psychological factors associated with mathematics anxiety. It is necessary to simultaneously help students to increase their self-efficacy levels as well as support finding strategies to lower their anxiety levels. As students' emotional experiences are also influenced by their broader social and emotional skills, the next section considers the role of these skills in mathematics anxiety.

Social and emotional skills

Although self-efficacy emerged as one of the strongest psychological factors associated with mathematics anxiety, the findings suggest that students' broader social and emotional skills may provide an additional perspective for understanding why some students experience higher levels of mathematics anxiety than others.

Study III examined how students' social and emotional skills predict mathematics anxiety and showed stress resistance, emotional control, and perseverance as key protective factors against mathematics anxiety. These results highlight that students with stronger emotional regulation skills may be better equipped to manage stressful situations that may arise during learning mathematics without developing higher levels of anxiety. This interpretation is supported by the growing recognition that social and emotional skills represent an important foundation for students' learning and well-being (Durlak et al., 2011; OECD, 2021). In particular, these skills may influence not only mathematics achievement

but also students' ability to cope with the emotional demands of learning mathematics.

The finding that stress resistance emerged as one of the strongest predictors of mathematics anxiety is also consistent with the transactional model (Lazarus & Folkman, 1984), suggesting that stronger emotional regulation skills may influence how students appraise stressful mathematical situations and the coping strategies they employ (Lazarus & Folkman, 1984). This interpretation is further supported by previous research, which highlighted that having good social and emotional skills can significantly help to navigate life: from academic achievement to overall well-being and occupational success (Chernyshenko et al., 2018).

Building on these findings from Study III, Study V examined mathematics anxiety at both the student and school level. The results confirmed that, similarly to Study III, stress resistance remained as one of the strongest predictors of mathematics anxiety at both levels. Moreover, curiosity is also an important factor related to mathematics anxiety and achievement. Study III found that curiosity is a negative predictor of mathematics anxiety. Furthermore, Study IV found that curiosity is a significant positive predictor for mathematics achievement at both the student and school level. Study IV also indicated that both mathematics anxiety and curiosity are significant predictors of mathematics achievement, but the strength of these associations varied across schools. This suggests that some schools may be more successful than others in reducing the negative relationship between mathematics anxiety and achievement, or more successful in strengthening the positive relationship between curiosity and achievement. One possible explanation is that differences in school climate, instructional practices, or teacher support may affect how students experience and engage with mathematics learning. This perspective is consistent with the bioecological model (Skinner et al., 2022), which emphasises that students' academic development is shaped not only by individual characteristics but also by the broader educational environment. Although previous studies have consistently demonstrated negative associations between mathematics anxiety and achievement (Ashcraft & Krause, 2007; Barroso & Ganley, 2021; Dowker et al., 2016), relatively few studies have examined whether this relationship also differs across schools. The present findings suggest that the school context may influence the extent to which mathematics anxiety is associated with achievement, highlighting the importance of considering contextual factors alongside individual characteristics.

Motivational factors

In addition to self-efficacy and social and emotional skills, motivational factors also play a role in mathematics learning. Study II showed that mathematics-specific interest was more strongly related to mathematics achievement than general academic interest. Studies III and IV further highlighted the role of curiosity in mathematics anxiety and achievement. The results of these studies show that students who are more interested in and curious about mathematics tend to have lower anxiety and better achievement in mathematics. Research has

shown that previous success supports the development of later positive attitudes toward the subject (Du et al., 2021; Jōgi et al., 2015). These results align with the perspective of situated expectancy-value theory (Eccles & Wigfield, 2020), which suggests that students who perceive mathematics as interesting and valuable are more likely to engage with mathematical tasks and persist when challenges arise. Furthermore, control-value theory (Pekrun, 2006) posits that emotions influence students' interest and motivation to learn. For example, anxiety may sometimes motivate students to invest effort to avoid failure, but it is generally expected to undermine intrinsic motivation in learning (Pekrun, 2006). This interpretation is consistent with the findings of the present dissertation, where students with higher curiosity and interest tend to report lower mathematics anxiety and better mathematics achievement.

Gender differences

Although gender differences were not the main aim of the current dissertation, gender was included in several models, and significant gender differences consistently emerged across the studies. Study II showed that girls tended to report higher levels of anxiety (academic and mathematics) than boys, despite showing no gender differences in mathematics achievement. One possible explanation is that girls may think mathematics is important while at the same time thinking they have no high ability in mathematics, which may contribute to higher anxiety levels (Rodríguez et al., 2020). At the same time, boys' greater interest in mathematics (Evans et al., 2002; Geary et al., 2023) may not necessarily translate into better achievement in mathematics. It has also been shown that girls are often socialised to be more emotionally expressive and thus may internalise stress more than boys do; however, boys are more frequently encouraged to show emotional control and resilience (Chaplin & Aldao, 2013). These results about gender differences in mathematics anxiety are in line with previous research, which has shown that girls report having higher levels of anxiety (Devine et al., 2012; Dowker et al., 2012; Hembree, 1990; Lichtenfeld et al., 2023).

Study III further demonstrates that gender differences did not emerge just in mathematics anxiety. Consistent with the OECD (2021) report, girls tend to report higher levels of empathy and co-operation but lower levels of stress resistance, emotional control, and assertiveness than boys. In addition, Study III found that girls tended to have higher levels of curiosity and empathy, whereas boys reported higher levels of emotional control and stress resistance. These findings suggest that gender differences in mathematics learning may involve different combinations of motivational and emotional characteristics rather than differences in mathematical ability alone.

Taken together, the above-described results about gender differences show the complex nature of mathematics anxiety and its crucial role in learning mathematics. The findings suggest that mathematics anxiety should not be viewed solely as part of mathematics achievement, but rather as an individual difference

that can be explained by various psychological and motivational factors. Given that different psychological and motivational factors appear to play important roles in mathematics learning, it is necessary to consider these to better understand mathematics anxiety. Although individual factors play an important role, the findings of Studies III and IV also suggest that specific indicators of school environment and contextual factors are important, as discussed further in the next section.

School environment and contextual factors

Students spend a substantial proportion of their waking hours in school environments. As schools differ in their environmental characteristics, students' experiences may also vary, potentially shaping their motivational and emotional characteristics. School environments comprise a range of contextual factors, such as teacher support, lesson quality, and students' sense of belonging, all of which may be related to students' experience of learning mathematics. Students' sense of belonging at school and the quality of student-teacher relationships are also positively related to social and emotional skills (OECD, 2021), suggesting that school-related factors should be considered when researching mathematics anxiety and achievement. The findings of studies III and IV suggest that students' perceptions of their learning environment, such as perceived teacher support and mathematics lesson quality, are negatively associated with mathematics anxiety and positively associated with mathematics achievement.

Study III showed that students' perceived support from mathematics teachers and the quality of mathematics lessons are negatively related to mathematics anxiety at the student level. Furthermore, Study IV revealed that although mathematics achievement can be explained by both student and school-level characteristics, the predictive power of perceived mathematics lesson quality for mathematics achievement emerged only at the student level. These results suggest that students' individual perceptions of the quality of mathematics lessons may be more important for understanding achievement than the differences in average lesson quality between schools. In other words, students attending the same school may experience lesson quality differently, and these individual perceptions appear to be more closely associated with mathematics anxiety than school-level averages are.

Study V also highlighted the role of perceived mathematics teacher support at both student and school levels while predicting mathematics anxiety. More precisely, higher perceived teacher support predicted lower levels of mathematics anxiety. One possible explanation for these findings is that teachers may influence students' mathematics anxiety levels indirectly through students' self-efficacy levels. As discussed earlier, self-efficacy emerged as one of the most important psychological factors associated with mathematics anxiety. Previous research has also shown that individual, clear, and constructive feedback supports the development of students' self-efficacy (Margolis & McCabe, 2006). This interpretation is also consistent with social cognitive theory (Bandura, 1986,

1995), according to which supportive interactions with teachers represent an important source of students' self-efficacy beliefs. These findings align with the bioecological model (Skinner et al., 2022) and control-value theory (Pekrun, 2006), which suggest that supportive student-teacher relationships may help develop students' perceived control, thereby reducing their negative emotions.

An important factor to consider is that different teachers may teach students within the same school, and perceptions of lesson quality may reflect differences between classrooms rather than between schools. This interpretation is also supported by the OECD (2021) report, which found that most of the variation in students' social and emotional skills occurs within schools rather than between schools. One possible explanation is that the development of social and emotional skills may depend more on students' immediate classroom experiences and the teachers they interact with than on school-wide policies and practices (OECD, 2021). Supportive teachers may help to increase students' confidence, provide constructive feedback, and create a more supportive learning environment. Thus, teachers may play an important role in supporting students' mathematics learning not only through high-quality instruction, but also by shaping students' mathematical learning and emotional experiences through the development of their social and emotional skills.

Study V showed that school belonging was a significant negative predictor of mathematics anxiety at the student level but not at the school level. This suggests that students' individual perceptions of school belonging may be more relevant to understanding mathematics anxiety than school-level differences in belonging. Similar to the results on perceived mathematics teacher support, these findings indicate that students within the same school may differ in how connected and supported they feel in their school environments.

The results also suggest that school belonging should not be viewed separately from other school-related factors. At the school level, school belonging was strongly correlated with mathematics self-efficacy and socio-economic background, which indicates that these factors may co-occur within schools. This aligns with previous research from the Estonian PISA 2022 report, which shows that students from better socio-economic backgrounds tend to report a stronger sense of school belonging (Tire et al., 2023). Overall, these results suggest that students' sense of belonging may reflect broader educational and socio-economic contexts, even though their association with mathematics anxiety appears to be prevalent primarily at the student level.

Overall, the findings regarding school-level factors suggest that mathematics anxiety is shaped not only by students' individual characteristics but also by the broader educational environment in which they spend their learning time. The multilevel analyses suggest that school-level factors help explain mathematics anxiety beyond what student-level factors alone can. Thus, future studies should examine which school practices and learning environments are most supportive of the development of social and emotional skills and for reducing mathematics anxiety. Understanding these contextual factors better is particularly important

when considering the differences in students' socio-economic backgrounds, which are discussed in the following section.

Socio-economic background

In addition to school-related factors, socio-economic background also emerged as an important predictor for both mathematics anxiety and mathematics achievement. The results from studies III and IV suggest that students from more advantaged socio-economic backgrounds tend to report lower levels of mathematics anxiety and higher levels of mathematics achievement. Furthermore, at the school level, average socio-economic background was also a positive predictor for mathematics achievement, further highlighting that socio-economic background is relevant at multiple levels. These results highlight the important role of socio-economic background in learning. These findings suggest that differences in students' learning opportunities associated with socio-economic backgrounds extend beyond the classroom and may contribute to differences in achievement. Previous research has shown that, in many countries participating in PISA surveys, including Estonia, the relationship between socio-economic background and achievement has strengthened over the past 20 years (Enchikova et al., 2024). This trend raises important questions about equal educational opportunities and the extent to which students' and schools' backgrounds continue to affect learning outcomes.

Although correlation analyses in studies IV and V found significant negative relationships at both student and school levels between mathematical anxiety and socio-economic background, in Study IV, socio-economic background did not emerge as a significant predictor for mathematical anxiety at either level. This suggests that the relationship between socio-economic background and mathematics anxiety may be accounted for by other psychological and educational factors included in the model, such as mathematics self-efficacy and perceived mathematics teacher support.

Socio-economic background does not just directly associate with mathematics anxiety and achievement, but they have a strong link to social and emotional skills as well. Previously, it has been found that students from better socio-economic backgrounds tend to report stronger social and emotional skills (OECD, 2021). Consistent with these findings, Study III showed that students from higher socio-economic backgrounds tended to report higher levels of all measured social and emotional skills, although these relationships were generally modest. One possible explanation proposed by the OECD (2021) is that students from more advantaged backgrounds may have greater opportunities to develop these competencies through both family and educational experiences.

Implications for preventing mathematics anxiety

The findings of the present dissertation have several implications for educational practice and for reducing mathematics anxiety.

At the individual level, the results indicate that educational practices should aim to support students' psychological resources that may help to prepare them against the development of mathematics anxiety. More precisely, strengthening students' self-efficacy may help them better handle challenges with greater confidence and stronger belief in their abilities. In addition, supporting the development of students' social and emotional skills may help them to cope better with the difficulties and stress that learning mathematics can induce. More precisely, students with higher stress resistance, emotional control, and perseverance tend to experience lower levels of mathematics anxiety. Thus, interventions aimed at strengthening these psychological resources may contribute to more positive mathematics learning experiences.

The results also show the potential importance of supportive student-teacher relationships and high-quality instruction. In particular, students who perceived greater support from mathematics teachers and higher mathematics lesson quality also tended to report lower levels of mathematics anxiety. These findings suggest that learning environments in which students feel supported and receive high-level mathematics instruction may contribute to more positive emotional and learning experiences in mathematics. Thus, teachers may have an important role in creating supportive learning environments that help to reduce mathematics anxiety.

The school-level results suggest that a broader educational context should not be disregarded when examining mathematics anxiety and achievement. The findings suggest that the relationships among mathematics anxiety, curiosity, and mathematics achievement vary across schools, indicating that the school environment may influence the strength of these associations with students' mathematics learning. More precisely, schools with higher average levels of mathematics anxiety tend to have lower mathematics achievement. This may indicate that the overall emotional climate towards mathematics in schools is relevant to supporting students' learning.

Although the dissertation provides a broader understanding of mathematics anxiety, it also highlights several important directions for future research. First, future research should expand these findings by conducting longitudinal studies and interventions. Longitudinal studies would help to better understand how mathematics anxiety and psychological and school-related factors related to it develop over time. Intervention studies would further help identify effective strategies to support the development of students' social and emotional skills and reduce their mathematics anxiety levels. Second, future research should also examine teacher-focused interventions to better equip teachers to create supportive learning environments that foster students' self-efficacy levels and the development of their social and emotional skills. Third, future research should use longitudinal and causal modelling approaches to better understand the

developmental pathways of mathematics anxiety and its relationships with psychological and contextual factors across educational stages. Overall, developing a better understanding of the developmental processes of mathematics anxiety may help schools create learning environments in which students feel supported not only to achieve better in mathematics but also to experience mathematics with greater confidence and less anxiety.

Scientific contribution to the understanding of mathematics anxiety

The findings of this dissertation complement previous research by demonstrating the negative relationship between mathematics anxiety and mathematics achievement while extending this perspective by examining mathematics anxiety as part of a broader mathematics learning process. Previous research has established that mathematics anxiety is associated with lower mathematics achievement (Ashcraft & Krause, 2007; Barroso et al., 2021) and with psychological factors such as lower self-efficacy (Carey et al., 2016; Şanlı, 2021; Živković et al., 2023). The findings across the five studies included in this dissertation support these relationships across different educational stages. Furthermore, the results demonstrate that to better understand mathematics anxiety, it is important to consider psychological, social and emotional, and school-related factors simultaneously. In particular, the consistent role of mathematics self-efficacy and social and emotional skills across the studies further supports the importance of understanding students' emotional experiences in mathematics.

A further contribution of the dissertation is the integration of social and emotional skills into the understanding of mathematics anxiety. Previous research has demonstrated the role of mathematics-specific beliefs and motivational characteristics, such as self-efficacy and mathematics interest, in mathematics anxiety (Carey et al., 2016; Şanlı, 2021; Zhang & Wang, 2020; Živković et al., 2023). The findings of this dissertation demonstrate that broader social and emotional skills, particularly stress resistance, emotional control, and perseverance, help explain individual differences in mathematics anxiety. Importantly, these associations remained relevant alongside mathematics self-efficacy, suggesting that the way students experience mathematics anxiety is related not only to their beliefs about their capabilities but also to broader skills in emotion regulation and coping with challenging situations. These results extend the current understanding of mathematics anxiety beyond mathematics-specific characteristics by adding a broader layer of students' social and emotional functioning.

The dissertation also contributes to a more differentiated understanding of the role of socio-economic background. Previous research has shown that a higher socio-economic background is associated with higher mathematics achievement (Rozgonjuk et al., 2023) and lower mathematics anxiety (Adimora et al., 2015;

Huang & Liu, 2025; Svrika et al., 2024). In the present dissertation, socio-economic background was an important predictor of mathematics achievement at both the student and school levels. However, socio-economic background was not a significant predictor of mathematics anxiety in the multilevel analyses, when psychological and school-related factors were taken into account, despite significant correlations with mathematics anxiety. This suggests that the relationships between socio-economic background and mathematics anxiety may be more complex and partly intertwined with students' psychological characteristics and experiences in the school environment. Thus, the findings do not suggest that socio-economic background is irrelevant to mathematics anxiety, but rather that its association with mathematics anxiety may be partly reflected in or through other individual and contextual factors.

Finally, the dissertation further expands the predominantly individual-level literature by adopting a multilevel approach to examining mathematics anxiety and mathematics achievement. Previous research has demonstrated associations between mathematics anxiety and students' perceptions of teacher support (Lazarides & Buchholz, 2019; H. Li et al., 2021) and school belonging (Asanjarani et al., 2024; Wang, 2024). Studies IV and V extend this perspective by simultaneously distinguishing student- and school-level associations. Moreover, the variation in the associations of self-efficacy and stress resistance with mathematics anxiety across schools suggests that relationships between individual characteristics and mathematics anxiety are not necessarily uniform across educational contexts. These findings complement previous research on the importance of supportive learning environments by demonstrating that students within the same school may experience these environments differently.

STRENGTHS AND LIMITATIONS

The findings of this dissertation should be interpreted with consideration of both the strengths and limitations of the included studies. Together, these strengths and limitations provide important context for understanding the scope, interpretation, and generalisability of the results.

One strength of the dissertation is that it uses results from multiple age groups. As the studies used in this dissertation have examined students from primary school through the end of high school, we have provided a relatively good overview across age groups. A further strength is that the dissertation examined mathematics anxiety from both the student and school level perspectives. While mathematics anxiety and learning have primarily been viewed at the student level, this dissertation incorporates multilevel analyses to provide a broader understanding of how individual- and school-related factors contribute to mathematics anxiety and mathematics achievement. Another strength is the use of multiple studies, datasets, and methodological approaches, which complement one another and enable a more comprehensive understanding of mathematics anxiety that would not have been possible with a single study or dataset.

Although this dissertation has several strengths, it also has limitations that should be considered. First, the dissertation uses mostly cross-sectional designs. Therefore, the results cannot be interpreted with causality in mind. Future research should use longitudinal designs to more precisely determine how mathematics anxiety develops. The studies in this dissertation rely on self-reported measures, which may not provide the most accurate overview of the factors being studied, as students may interpret questions differently. Thus, it is important to view the results as students' feelings toward something rather than as an actual representation of reality. All of the studies in the dissertation are based on Estonian students. Therefore, before generalising the results to the rest of the students, different educational systems and cultures should be taken into account. Future research should include other countries to give a broader overview across different cultures.

Despite these limitations, the dissertation provides a comprehensive overview of mathematics anxiety by integrating results from multiple studies, educational stages and analytical approaches. Taken together, the findings of this dissertation contribute to a better understanding of mathematics anxiety and the variety of individual and contextual factors associated with it.

CONCLUSIONS

The present dissertation examined mathematics anxiety as an obstacle to mathematics learning by investigating the individual and school-related factors associated with it. By integrating evidence from five studies, the dissertation demonstrates that mathematics anxiety is shaped by the interplay of psychological, educational, as well as social and emotional factors operating at both the student and school levels.

The main contribution of this dissertation is to show that mathematics anxiety should not be viewed as an isolated emotional reaction but as a component of the broader mathematics learning process. The present dissertation contributes to the understanding of mathematics anxiety by demonstrating that it is a multi-dimensional phenomenon associated with both individual psychological factors and the broader educational environment. The dissertation integrates self-efficacy, social and emotional skills, and school-related factors to provide a more comprehensive understanding of the factors that are associated with mathematics anxiety and mathematics learning. Together, these factors help explain why students with similar mathematical abilities may experience learning differently. The findings further suggest that mathematics anxiety may be understood both as a consequence of prior learning difficulties and as a factor contributing to subsequent difficulties in mathematics learning.

Across studies that used both student- and school-level analyses, mathematics self-efficacy emerged as one of the strongest and most consistent predictors of mathematics anxiety. Among social and emotional skills, stress resistance, emotional control, and perseverance also help explain mathematics anxiety beyond students' self-beliefs about their abilities. These findings highlight the need to develop students' ability to regulate their emotions, cope with learning challenges, and believe in themselves to reduce mathematics anxiety.

The dissertation also showed that mathematics anxiety is associated with school-related factors, such as perceived mathematics teacher support, mathematics lesson quality, and school belonging. These factors are related to lower levels of mathematics anxiety. Furthermore, multilevel analysis revealed that both student and school-level factors contribute to explaining the differences in mathematics anxiety. These findings highlight that mathematics anxiety should be understood not only as an individual characteristic but also as shaped by the different educational contexts in which students spend their time.

Overall, this dissertation contributes to the understanding of mathematics anxiety by showing that it should be considered an integral part of mathematics learning, not just a negative emotional outcome. By combining psychological, social and emotional, and school-related factors across multiple educational stages and analytical approaches, this dissertation provides a more comprehensive framework for understanding what factors are associated with mathematics anxiety. Examining mathematics anxiety from both student- and school-level perspectives demonstrates that understanding students' emotional

experiences requires consideration of both individual characteristics and the broader educational context. These findings may support educators, schools, and policymakers in creating learning environments that foster both students' mathematical achievement and their emotional well-being. From a practical perspective, these findings suggest that efforts to improve mathematics achievement should not solely focus on cognitive skills and content knowledge but should also address students' emotional experiences in mathematics.

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SUMMARY IN ESTONIAN

Matemaatikaärevus kui takistus matemaatika õppimisel: matemaatikaärevusega seotud individuaalsed ja koolikeskkonnaga seotud tegurid

Head matemaatikaoskused on tänapäeva ühiskonnas üha olulisemad nii haridustee kui ka tööalaste võimaluste seisukohalt (Geary et al., 2023; Ritchie & Bates, 2013). Matemaatika õppimise olulisusest hoolimata, peetakse matemaatikat sageli nõudlikuks õppeaineks, kuna selle omandamine nõuab pidevat kognitiivset pingutust ning järjekindlat ja teadlikku harjutamist. Sellised õppimisega seotud raskused võivad tekitada negatiivseid emotsioone matemaatika suhtes, sealhulgas matemaatikaärevust (Q. Li et al., 2021).

Matemaatikaärevus on tugevalt seotud nii õpilaste akadeemilise kui ka isikliku arenguga. Varasemad uuringud on näidanud, et matemaatikaärevus on seotud madalamate tulemustega, langenud motivatsiooniga matemaatikaga tegelemiseks ja vähenenud huviga tegeleda tulevikus STEM-valdkonnas (Ashcraft & Krause, 2007; Hembree, 1990). Kuigi matemaatikaärevust on põhjalikult uuritud, on vähem tähelepanu pööratud sellele, kuidas erinevad psühholoogilised ja koolikeskkonnaga seotud tegurid on omavahel seotud ning kuidas need ühiselt matemaatikaärevuse ja matemaatika õppimisega seotud on. Seetõttu on oluline paremini mõista nii individuaalseid kui ka keskkondlikke tegureid, mis võivad matemaatikaärevusega seotud olla. Selline laiapõhjaline käsitlus aitab paremini mõista matemaatikaärevuse kujunemist ning toetab nii haridusteaduslikke uuringuid kui ka tõendus põhiste sekkumiste ja õpetamispraktikate arendamist. Käesoleva doktoritöö eesmärk on selgitada matemaatikaärevusega seotud individuaalseid ja koolikeskkonnaga seotud tegureid ning anda terviklikum ülevaade nende seostest matemaatika õppimisega. Doktoritöö keskendub erinevatele psühholoogilistele, motivatsioonilistele ja koolikeskkonnaga seotud teguritele, mis võivad olla seotud õpilaste matemaatikaärevuse ning matemaatika õppimisega.

Matemaatikaärevus on pingetunne, kartus või hirm, mis tekib matemaatikaga tegelemisel (Ashcraft, 2002). Kõrgem matemaatikaärevus on seotud nii madalamate tulemustega (Ashcraft & Krause, 2007; Barroso & Ganley, 2021; Brunner et al., 2026) kui ka vältimiskäitumisega, mistõttu kõrge ärevustasemega õpilased võivad matemaatikaga seotud olukordi vältima hakata (Quintero et al., 2022). Matemaatikaärevus võib tekkida nii arvutuste tegemisel, klassiruumis kui ka testide ajal (Lukowski et al., 2019). Kuigi matemaatikaga seotud testiärevust on ka eraldi uuritud, on leitud, et testiärevus ja matemaatikaärevus on teineteisega tugevalt seotud konstruktid (Dowker & Sheridan, 2022; Kazelskis et al., 2000).

Varasemad uuringud on leidnud, et kõrgema matemaatikaärevusega on seotud mitmed psühholoogilised tegurid, seal hulgas madalam enesetõhusus (Carey et al., 2016; Şanlı, 2021; Živković et al., 2023) ja vähenenud huvi matemaatika vastu (Q. Li et al., 2021; Zhang & Wang, 2020; Živković et al., 2023). Lisaks on varasemad uuringud näidanud seoseid sotsiaalemotsionaalsete oskuste ja ärevuse vahel. Näiteks on emotsioonide reguleerimise raskusi seostatud kõrgema ärevu-

sega (Amstadter, 2008; Wirtz et al., 2014), samas kui parem stressitaluvus aitab ärevuse maandamisega paremini toime tulla (Feder et al., 2009). Need tegurid on seotud sellega, kuidas õpilased tajuvad enda võimeid, tulevad toime keeruliste ja stressirohkete olukordadega ning reageerivad matemaatikaga seotud väljakutsetele.

Lisaks individuaalsetele teguritele, on matemaatikaärevusega seotud ka erinevad koolikeskkonnaga seotud tegurid. Varasemad uuringud on näidanud, et õpilaste arengut kujundavad nii pedagoogilised, struktuursed kui ka sotsiaalsed tegurid nii koolis kui ka kodus (Skinner et al., 2022). Õpetaja toetuse tajumine, matemaatikatundide kvaliteedi hindamine ning kooli kuuluvustunne võivad kujundada õpilaste õppimiskogemusi ja emotsioone, mis omakorda on seotud matemaatikaärevuse ja sooritusega matemaatikas. Näiteks on leitud, et õpilased, kes tunnevad suuremat õpetaja toetust (Lazarides & Buchholz, 2019; H. Li et al., 2021) ja tugevamat kooli kuuluvustunnet (Asanjarani et al., 2024; Wang, 2024) kogevad madalamat matemaatikaärevust. Samuti on kõrgem tajutud matemaatikatundide kvaliteet seotud paremate õpitulemustega (Arthur et al., 2022).

Käesolevas doktoritöös toetutakse mitmele teoreetilisele käsitlusele, mis aitavad selgitada matemaatikaärevuse seoseid nii individuaalsete kui ka koolikeskkonnaga seotud protsessidega. Nende käsitluste kohaselt kujuneb matemaatikaärevus õpilaste uskumuste oma võimate kohta, motivatsiooni, matemaatikaga seotud emotsioonide ning matemaatiliste väljakutsetega toimetuleku vastastikusel koosmõjus, mis on omakorda seotud koolikeskkonnaga. Doktoritöö teoreetilisteks alusteks on sotsiaalkognitiivne teooria (Bandura, 1986), situatiivne ootuste-väärtuste teooria (Eccles & Wigfield, 2020), akadeemilise toimimise bioökoloogiline mudel (Lazarus & Folkman, 1984) ning stressi ja toimetuleku transaktsionaalne mudel (Skinner et al., 2022).

Käesolev doktoritöö koosneb viiest teadusartiklist, mis kõik uurivad matemaatikaärevuse erinevaid tahke. Töös kasutatud uuringud moodustavad terviklikuma ülevaate sellest, kuidas erinevad psühholoogilised ja koolikeskkonnaga seotud tegurid on seotud matemaatikaärevuse ja matemaatika õppimisega.

Doktoritöö esimesed kolm uuringut keskendusid peamiselt õpilase individuaalsetele psühholoogilistele teguritele. Esimene uuring keskendus veebipõhisel matemaatikakursusel osalemise aktiivsuse, matemaatikaga seotud testiärevuse ning enesetõhususe seoseid riigieksami tulemustega. Uuringu tulemused rõhutavad õpilaste enesetõhususe ja matemaatikaga seotud testiärevuse olulist rolli matemaatikaeksami tulemustele veebipõhise kursuse kontekstis. Teine uuring võrdles ainespetsiifilise ärevuse ja huvi ning üldise akadeemilise ärevuse ja huvi seoseid matemaatika testitulemustega. Tulemused näitasid, et matemaatika-tulemuste selgitamisel on olulisemad just ainespetsiifilised ärevus ja huvi kui üldised akadeemilised tegurid. Kolmas uuring keskendus sotsiaal-emotsionaalsetele oskustele ning nende seostele matemaatikaärevusega, rõhutades stressi-kindluse ja emotsioonide kontrolli olulisusele matemaatikaärevuse mõistmisel.

Doktoritöö kaks viimast uuringut laiendasid matemaatikaärevuse ja matemaatika õppimise käsitlust, kaasates lisaks õpilase tasandile ka kooli tasandi näitajad. Neljas artikkel keskendus matemaatikaärevuse, sotsiaalmajandusliku

tausta, uudishimu ning tajutud matemaatikatunni kvaliteedi seostele matemaatikatesti tulemustega nii õpilase kui ka kooli tasandil. Tulemused näitasid, et matemaatikatumuse varieeruvuse selgitamisel mängivad olulist rolli nii individuaalsed kui ka koolikeskkonnaga seotud tegurid, rõhutades mitmetasandilise lähenemise olulisust. Viies uuring rakendas sarnast mudelit, kaasates enesetõhususe, stressikindluse, sotsiaalmajandusliku tausta, tajutud õpetaja toetuse ning kooli kuuluvustunde, et ennustada matemaatikaärevust nii õpilase kui ka kooli tasandil. Uuringu tulemused näitasid, et kuigi matemaatikaärevust selgitavad eelkõige õpilase individuaalsed tegurid, ei saa koolikeskkonna rolli alahinnata.

Kokkuvõttes näitab käesolev doktoritöö, et matemaatikaärevus on mitmetahuline nähtus, mida kujundavad nii õpilase individuaalsed psühholoogilised tegurid kui ka koolikeskkonnaga seotud tegurid. Tulemused näitavad, et matemaatikaärevust ei saa käsitleda üksnes negatiivse emotsionaalse reaktsioonina vaid seda tuleb käsitleda laiemas õppimise kontekstis. Doktoritöös kajastatud viie uuringu tulemused toetavad arusaama, et õpilaste matemaatikaga seotud emotsionaalsete kogemuste mõistmisel tuleb arvestada samaaegselt nii õpilaste enda individuaalsete omaduste kui ka koolikeskkonnaga. Töö tulemused aitavad paremini mõista matemaatikaärevuse kujunemist ning pakuvad teadmisi, mida saab rakendada õppimist ja õpilaste heaolu toetatavate õpetamispraktikate ning sekkumiste kavandamisel.

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Publications

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Projektid

HARTA-S2 “Õpetajate professionaalsele arengule suunatud kutsekompetentsuse hindamine” (01.09.2024–31.08.2027); Vastutav täitja: Katrin Poom-Valickis; Tallinna Ülikool, Haridusteaduste instituut (koordinaator), Tartu Ülikool (partner)
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Publikatsioonid

Aaviste, Getriin; Löchner, Dimitri; Laas, Katriina; Täht, Karin (2026). Understanding Mathematics Anxiety: The Role of Social-Emotional Skills and School Support. Cogent Education, 13 (1), 2609386.
DOI: 10.1080/2331186X.2025.2609386.
Aaviste, Getriin; Kolde, Anastassia; Gugushvili, Nino; Kuus, Erki; Täht, Karin (2026). Õnnestumise valem matemaatikas: parem sotsiaalmajanduslik taust, madalam ärevus ja suurem uudishimu nii õpilase kui kooli tasandil. Eesti

- Haridusteaduste Ajakiri = Estonian Journal of Education, 14 (1), 167–194. DOI: 10.12697/eha.2026.14.1.07.
- Aaviste, Getriin; Löchner, Dimitri; Laas, Kariina; Täht, Karin (2026). Students' online course activity, together with self-efficacy and test anxiety, predicts mathematics exam results. LUMAT International Journal on Math Science and Technology Education, 14 (2). DOI: 10.31129/LUMAT.14.2.3158.
- Täht, Karin; Mikkor, Kristel; Aaviste, Getriin; Rozgonjuk, Dmitri (2024). What motivates and demotivates Estonian mathematics teachers to continue teaching? The roles of self-efficacy, work satisfaction, and work experience. Journal of Mathematics Teacher Education, 27 (6), 961–980. DOI: 10.1007/s10857-023-09587-2.
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