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Research article

The role of teachers' beliefs and professional development in students' mathematics motivation in primary education

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Abstract: Motivation plays a crucial role in mathematical competence, with motivated students tending to perform better than those who lack motivation. Given that teachers can play a significant role in fostering student motivation, the aim of this study was to investigate teachers' influence on students' motivation to learn mathematics. Alongside the teacher's influence, we also aim to explore the impact of individual factors on students' motivation. This study examines the effects of both individual and teacher-related factors on fostering students' mathematics motivation, at both the student and the classroom levels. We use multilevel modelling for analysis. Student level contains individual factors: grade level, gender, and mathematics achievement. Classroom level contains teacher-related factors: teacher beliefs and professional development. Motivation was addressed through five dimensions: intrinsic value, utility value, attainment value, relative cost and perceived competence. The data is part of the international longitudinal study, MathMot, which examines primary school students' mathematics motivation across six European countries. The data of the present study consists of Finnish students from 3rd (n = 760) and 4th grade (n = 747) and their teachers (N = 95). According to the results, student motivation is most significantly impacted by mathematical achievement at the individual level, and by teachers' in-service training and beliefs about teaching and learning mathematics at the classroom level. Establishing a direct connection between teacher self-efficacy and student motivation is challenging because it affects motivation indirectly, for example, through teaching methods. Additionally, the role of the teacher in fostering motivation is relatively small and unstable in the early years.

Keywords: mathematics motivation, mathematics education, teacher self-efficacy, epistemic beliefs, teaching experience, in-service training

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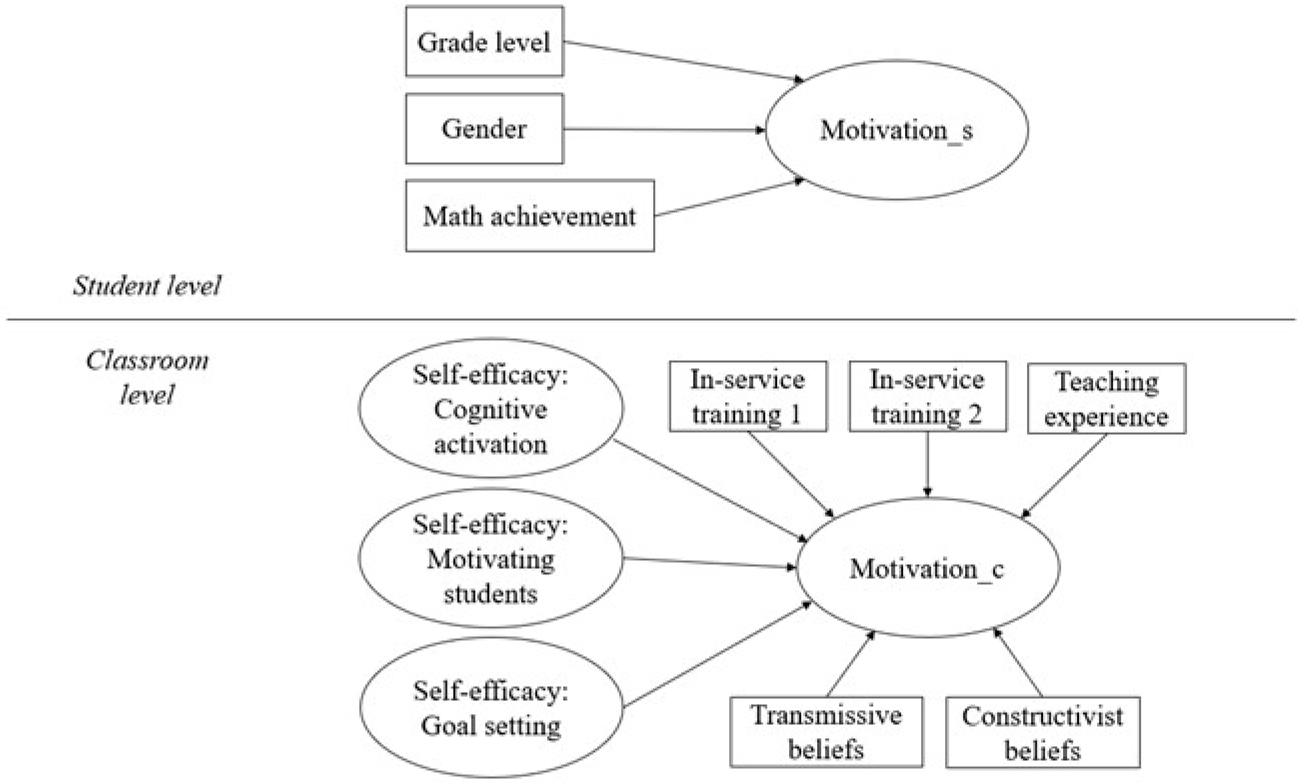


1 Introduction

Several studies have identified students' motivation as one of the most effective domains with a strong association with their mathematical skills (e.g. Lim & Chapman, 2015; Skaalvik et al., 2015). Students with higher expectations of success are more likely to set higher learning goals and they achieve higher performance (Grigg et al., 2018). However, more research is needed to understand what is essential for supporting and enhancing students' mathematics motivation and its various dimensions from the perspective of individual and teacher-related factors. In this study, we address motivation through five dimensions: intrinsic value, utility value, attainment value, relative cost, and perceived competence. These dimensions are based on expectancy-value theory (EVT) (Eccles & Wigfield, 2002, 2020), which highlights the role of expectancies and values in shaping motivation.

Leading theories of motivation are linked to socio-cognitive approaches (Wigfield et al., 2015). Socio-cognitive theory (Bandura, 1986), in turn, emphasizes the interplay between individual behaviour, individual factors, and the social environment. People are active agents in relation to their own motivation, and the social environment can enable, limit, or be neutral in relation to an individual's tendencies (Bandura, 1986). We aim to examine how individual factors at the student level and teacher-related factors at the classroom level effect on students' motivation. We are especially interested in teacher's role to affect students' motivation. Teaching-related solutions do not directly contribute to students' mathematical skills, but they are relevant in reinforcing positive attitudes, which are connected to higher skills in mathematics (Niemi, 2022). Teacher self-efficacy, for example, has been shown to help teachers set suitable learning goals for their students, work for cognitive activation in lessons, and be able to face teaching challenges in mathematics education (Liu & Yin, 2024). Additionally, teacher's beliefs about teaching and learning are considered relevant in predicting instructional quality and teaching practises (Fives & Buehl, 2012; Lui & Bonner, 2016). Despite the existing body of research on the effect of teacher self-efficacy on various factors, such as students' achievement and motivation, further research is needed to explore its practical effects on student motivation, especially in primary education (Oppermann & Lazarides, 2021; Reinhold et al., 2021).

2 Motivation for learning mathematics

We approach the motivation concept through a prevalent motivational theory used in educational research: *expectancy-value theory* (EVT) (Eccles & Wigfield, 2002, 2020), more recently, *situational expectancy-value theory* (SEVT) (Eccles & Wigfield, 2023). Students' motivation is formed of two main components, expectations of success and values.

Learning is driven by the student's expectations of success, their perception of their own ability to perform, their perception of the difficulty of the task, and their goals and subjective evaluations of the task (Eccles & Wigfield, 2002, 2020). Different concepts are used to describe these expectations of success. Empirical studies often use self-efficacy and self-concept as synonymous constructs to describe a person's perception of their competence (Anderman, 2020; Nuutila et al., 2018), with self-efficacy referring to the capacity to perform a specific task (Bandura, 1986) and self-concept referring to competence in a more general domain (Eccles & Wigfield, 2020; Schukajlow et al., 2017). In this study, we use the concept of perceived competence, which is also proposed as an alternative to the expectancy of success (Radišić et al., 2024). Perceived competence can be more clearly set apart from self-efficacy and self-concept. It refers to a student's perception of their capacity to perform achievement-related tasks (Pekrun, 2006).

In addition to expectations, learning is driven by values concerning the learning content. Values can be divided into four factors: 1) intrinsic/interest value, 2) utility/extrinsic value, 3) attainment value, and 4) cost (Eccles & Wigfield, 2002). Intrinsic value refers to how much the student enjoys the task while working on it. This can be seen as related to intrinsic motivation as defined by (Ryan & Deci, 2020). Utility value refers to the student's perception that the content being studied will be useful in the future (Eccles & Wigfield, 2002). This concept is close to the concept of extrinsic motivation, according to which an individual acts to receive a reward or to avoid negative consequences, for example (Ryan & Deci, 2020). Attainment value is related to how important it is for the learner to succeed in a given task. Cost value is defined as the negative aspects that result from engaging in a task (Eccles & Wigfield, 2002).

Motivation plays a central role in engaging students in learning mathematics and improving their mathematical skills. Expectations have a strong reciprocal connection to performance in mathematics (Luo et al., 2014; Skaalvik et al., 2015; Williams & Williams, 2010). Students with higher expectations of success are more likely to have the confidence to set higher learning goals and achieve higher performance (Grigg et al., 2018). Within the values, studies (e.g. Murayama et al., 2013) show that intrinsic value predicts higher performance in mathematics than utility value. Numerous studies have shown a strong connection between students' expectancies of success and task values to the continuous involvement with mathematics tasks (Eccles & Wigfield, 2020) and later career choices (e.g. Wang, 2012; Watt et al., 2012).

3 Teacher's beliefs and professional development in the context of mathematics education

Teachers have a crucial role in helping students to develop mathematical skills (Hiebert & Grouws, 2007). It has also been observed that teachers' beliefs and instructional practices are linked to students' attitudes towards mathematics (Muis & Foy, 2010). The teacher is responsible for creating opportunities for learning and this is influenced by the teacher's self-efficacy beliefs and their beliefs about teaching and learning mathematics (Hoy et al., 2006). Learning opportunities also depend on the teacher's expertise, which develops as an ongoing process through pre-service teacher education, work experience, and in-service training.

3.1 Teachers' beliefs about mathematics education

Teachers' beliefs about mathematics education consist of their beliefs about themselves as teachers and on the subject of teaching, that is, teacher self-efficacy beliefs and epistemic beliefs (Ekmekci et al., 2019; Leijen et al., 2024). Epistemic beliefs refer to teachers' perceptions and experiences of mathematical knowledge and of mathematics teaching and learning (Thompson, 1992). The teachers use mathematical knowledge with an intention to help students learn (Hill et al., 2008). Thus, these beliefs about mathematical knowledge affect their beliefs about teaching and learning.

Seeing mathematics as a static discipline consisting of a collection of facts is in close relation to transmissive view of teaching (Voss et al., 2013). Transmissive pedagogical beliefs refer to a teacher-centred approach, where students are seen as passive recipients of information that is learned through repetition and automatization (Lui & Bonner, 2016; Voss et al., 2013). On the contrary, teachers with dynamic beliefs on mathematical knowledge tend to have constructivist beliefs on teaching and learning. This means that they see students as actively constructing their own understanding through engaging in mathematical problem solving and deep conceptual pondering (Voss et al., 2013).

Teachers' beliefs about teaching and learning are considered relevant in predicting instructional quality and teaching practices (Fives & Buehl, 2012; Lui & Bonner, 2016). A constructivist perspective, or a less transmissive approach to learning, has been found to be particularly associated with high cognitive activation (Voss et al., 2013) and primary school students' self-efficacy in mathematics (Haataja et al., 2024), whereas transmissive approach may lead to better student achievement in high-stakes mathematics exams (Ekmekci et al., 2019). The relation between primary school teachers' beliefs and students' learning outcomes is a complex phenomenon, and statistical studies cannot always demonstrate a direct connection between these constructs (Haataja et al., 2024; Lauermann & ten Hagen, 2021; Leijen et al., 2024). Teachers' epistemic beliefs are also in connection to their self-efficacy, constructivist beliefs significantly predicting efficacy in instructional strategies to activate students and adapt the instruction to meet their learning needs (Alt, 2018).

Teachers' self-efficacy refers to their self-perception of being able to execute the tasks and duties related to their profession. Originally introduced by Bandura (1977), self-efficacy is a concept that has been widely used to investigate teachers' goals, efforts, and well-being in their working lives (Leavy et al., 2023). The concept of teacher self-efficacy is a multidimensional construct that has been defined and measured in various ways by different researchers (e.g. Bong & Skaalvik, 2003; Tschannen-Moran & Hoy, 2001). Teacher self-efficacy is more than an innate characteristic of an individual but affected by the teachers' school community (Liu & Yin, 2024) and their students (Lauermann & ten Hagen, 2021).

Teachers with high self-efficacy are found to set suitable learning goals for their students, work for cognitive activation in lessons, and be able to face teaching challenges in mathematics education (Liu & Yin, 2024). From 3rd to 5th grades, high teacher self-efficacy has been found to improve students' experiences of receiving support from the teacher, their interest in mathematics, and mathematical self-efficacy (Chang, 2015; Oppermann & Lazarides, 2021; Perera & John, 2020). 4th grade teachers' self-efficacy for teaching mathematics affects positively how students in class level experience the interaction and learn mathematical contents in math lessons (Perera & John, 2020). Similarly, in secondary school, mathematics teachers' self-efficacy enhances the goal-oriented climate in their classrooms, and consequently their students' motivation for mathematics, especially regarding the attainment and utility values (Lazarides et al., 2018). Despite the body of research on the effect of teacher self-efficacy on various factors, such as student achievements and motivation, more studies in authentic classrooms are needed (Lauermann & ten Hagen, 2021).

3.2 Teacher professional development

Teachers' self-efficacy beliefs about teaching mathematics are shaped by their teacher education and work experiences and are implemented in their teaching practices and their views of children as learners (Leavy et al., 2023). Teacher self-efficacy tends to increase with the teaching experience gained (Täht et al., 2023), and can be improved with suitable in-service training (Lazarides et al., 2018; Oppermann & Lazarides, 2021).

In Finland, teacher's professional development is seen as an ongoing process, that begins with pre-service education and continues throughout their entire career (Feiman-Nemser, 2001; Niemi, 2015). The aim of the Finnish pre-service teacher education is to educate pedagogically thinking teachers who can integrate research insights on teaching with the practical challenges (Tirri, 2014). A research-based model of teacher professional competences is seen as a multidimensional adapted process model of teaching (MAP), which identifies the skills required in a teacher's work (Metsäpelto et al., 2022). This comprehensive model supports the phases of student selection of teacher education, pre-service training, and in-service training.

The teaching experience can be considered a necessary part of professional development and teacher expertise (Palmer et al., 2005; Ropo, 2004; Winkler, 2001). Studies underline multiple components in teacher expertise, and the definition of teacher expertise is still unclear (Raduan & Na, 2020). According to Palmer et al. (2005, p. 21) expertise in teaching is a complex construct that has been associated with instructional effectiveness, teaching experience, what and how teachers think, and how teachers act. Teacher expertise can be considered to contain two key components: teacher's ability to build relationships with students and teacher's subject-matter expertise of the teaching content (Lentillon-Kaestner et al., 2024)

In-service training provides continuous education and training throughout the whole teacher career. In Finland, all teachers participate mandatory in-service training for a two to three days annually, but Finnish teachers also have the autonomy to choose among optional in-service training options those that best meet their needs and the needs of their students (Niemi, 2015). More research is needed to know more specifically what kind of in-service training best supports teachers in fostering students' mathematics motivation.

4 Research questions

This study explores the effect of individual and teacher-related factors on fostering students' mathematics motivation on both the student and the classroom level. Student level contains individual factors, including grade level, gender, and mathematics achievement. Classroom level contains teacher-related factors, including teacher beliefs (*self-efficacy and beliefs about teaching and learning mathematics*) and professional development (*teaching experience and participation in in-service training*). Motivation is addressed through five dimensions: *intrinsic value, utility value, attainment value, relative cost* and *perceived competence*. Our research questions are:

1. How do students' individual factors – grade level, gender, and mathematics achievement – affect their mathematics motivation?
2. How do teacher-related factors – beliefs and professional development – affect students' mathematics motivation at the classroom level?
   (a) What is the role of teacher beliefs?
   (b) What is the role of professional development?

5 Methods

This study draws on the Finnish data collected from students and teachers participating in the international research project MathMot: *Co-constructing mathematics motivation in primary education – A longitudinal study in six European countries* (Research Council of Norway, grant number 301033). The aim of the MathMot project is to deepen understanding of how mathematics motivation develops during the early years of primary school and which classroom practices support the development of motivation. The teaching and learning of mathematics have been studied in 50 schools across each country participating in the research, focusing on grades 3 and 4.

5.1 Participants

The Finnish data were collected during spring 2022 in 50 schools in Southern Finland. The sample consisted of 3rd grade (n = 760) and 4th grade (n = 747) students and their teachers (N = 95). Schools from three municipalities from Southern Finland were included in the sample based on their accessibility. The participating schools have a diverse socioeconomic population base.

5.2 Measures

All the data were collected by trained research assistants during regular school hours. Both students and teachers answered a set of demographic questions. For the students, we utilised *grade (3rd and 4th) and gender (0 =female, 1 =male)*, and for the teachers, we utilised professional development, which included *years of teaching experience and in-service training*. In-service training was examined from two perspectives: a) *in-service training related to mathematics content, pedagogy, and motivation,* and b) *in-service training addressing individual needs and teaching in multicultural settings*. Teachers answered their participation in various forms of in-service training over the past two years (0 = *no*, 1 = *yes*).

Student motivation was measured using the EVS instrument (see Peixoto et al., 2023). The scale aligns with the EVT dimensions and comprises five dimensions: *intrinsic value* (e.g., “Math is one of my favourite subjects”), *utility value* (e.g., “I can learn many useful things by doing math”), *attainment value* (e.g., “I'm determined to understand the things we learn in mathematics class”), *relative cost* (e.g., “When I do math, I would rather be doing other things”), and *perceived competence* (e.g., “I can easily solve different math problems”) – 28 items in total, distributed on a 4-point Likert scale (1= frequently – 4=never). This scale was reversed for analyses. The motivation scale included practice items and graphical representation of the 4-point scale to ensure that the students understood how to use the scale (Mellor & Moore, 2014).

Students’ mathematical achievement was measured with a mathematics test that consisted of 12 questions in the 3rd grade and 14 questions in the 4th grade. The problems were retrieved from the released items of the TIMSS 2011 (*Trends in international mathematics and science*, approval IEA 22-2022) study and assessed to correspond with the Finnish mathematics curriculum for the 3rd and 4th grades. Students’ test scores were converted to the TIMSS scale. The mean of the scale is set at 500 and the standard deviation at 100.

Teachers’ self-efficacy was examined using a 20-item scale (Laschke & Blömeke, 2013) comprising dimensions: cognitive activation, motivating students, and goal setting for student learning. These dimensions are based on the results of confirmatory factor analysis and can be seen as a combination of findings from previous studies (Reinhold et al., 2021; Skaalvik & Skaalvik, 2007).

Teachers' epistemological beliefs about teaching and learning mathematics were examined using the *TEDS-M Capturing Beliefs* scale (Laschke & Blömeke, 2013), which consists of 14 items. The scale comprises two dimensions: teacher-centred (*transmissive*) teaching beliefs and student-centred/active learning (*constructivist*) beliefs.

5.3 Data analysis

The data analysis began with a confirmatory factor analysis (CFA) to examine the fit of the measurement models to the data and to assess the structural validity of the measures. We used the chi-square (χ^2), the comparative fit index (CFI), the Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA) as model fit indicators for the models. CFI and TLI values greater than .90 and RMSEA values up to 0.08 indicated an acceptable fit with the data (Marsh et al., 2004). Following the CFA, we calculated the composite reliability (CR) to evaluate the internal consistency of the measurement factors (Geldhof et al., 2014). Reliability values between 0.60 and 0.70 are considered acceptable (Hair et al., 2021).

The five-factor model of intrinsic motivation, utility, attainment, cost, and perceived competence showed a good fit for this data ($\chi^2(242) = 1089.79$, $p < 0.001$, CFI = .99, TLI = .99, RMSEA = 0.05). The composite reliability of the five factors was acceptable: intrinsic motivation (CR = .89), utility (CR = .82), attainment (CR = .84), cost (CR = .71), and perceived competence (CR = .83). The three-factor model of self-efficacy (cognitive, motivating, and goal setting) indicated a sufficient fit ($\chi^2(87) = 1086.72$, $p < 0.001$, CFI = .91, TLI = .90, RMSEA = 0.08). Additionally, the composite reliability of these three factors was acceptable: cognitive (CR = .73), motivating (CR = .70), and goal setting (CR = .67). Finally, the two-factor model of transmissive beliefs and constructive beliefs indicated an acceptable fit for this data ($\chi^2(34) = 346.57$, $p < 0.001$, CFI = .92, TLI = .90, RMSEA = 0.08). The reliability of the two factors was also acceptable (transmissive beliefs: CR = .67; constructive beliefs: CR = .81).

We used multilevel modeling (MLM) to investigate how individual factors—grade level, gender, and math achievement—affect individual students' mathematics motivation (1), and how teacher-related factors – beliefs and professional development – affect students' mathematics motivation at the classroom level (2). Table 1 describes the outcome and predictor variables used in the multilevel model. All outcome variables, specifically the motivation variables (intrinsic, utility, attainment, cost, and perceived competence), are latent variables. The predictors include both latent variables (teacher self-efficacy and epistemological belief variables) and observed variables (grade level, gender, math achievement, teaching experience, and in-service training).

The data were hierarchically structured, with students nested within classes taught by teachers. We used MLM because it allows the simultaneous analysis of both individual (i.e., student) and classroom-level data (Hox et al., 2017), and multilevel structural equation modelling was performed using the R package lavaan 0.6-5 (Rosseel & De Wilde, 2024). We utilized a complete case analysis to address the missing data. Imputation was not applied because the results did not differ significantly when the analyses in these studies were conducted with either non-imputed or imputed data.

Table 1. Variables used in the multilevel model.

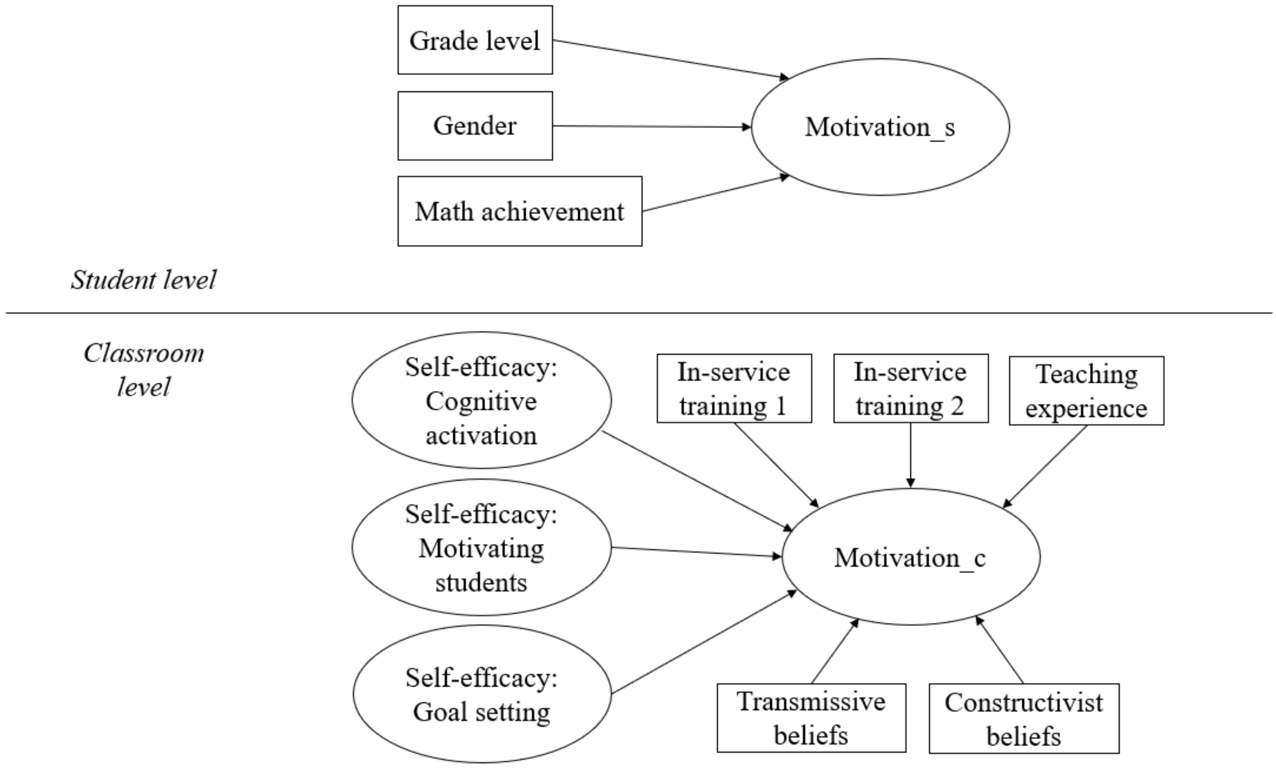
Outcome variables	**Type**	**Level (student/classroom)**
Intrinsic	Latent	Student/Classroom
Utility	Latent	Student/Classroom
Attainment	Laten	Student/Classroom
Cost	Latent	Student/Classroom
Perceived competence	Latent	Student/Classroom
Predictors	**Type**	**Level (student/classroom)**
Grade level (3rd /4th)	Observed, categorical	Student
Gender (males/females)	Observed, categorical	Student
Math achievement	Observed, continuous	Students
Teaching experience	Observed, categorical	Classroom
In-service training 1	Observed, categorical	Classroom
In-service training 2	Observed, categorical	Classroom
Self-efficacy: Cognitive activation	Latent	Classroom
Self-efficacy: Motivating students	Latent	Classroom
Self-efficacy: Goal setting	Latent	Classroom
Transmissive beliefs	Latent	Classroom
Constructivist beliefs	Latent	Classroom

Note. In-service training 1 = Mathematics content, pedagogy, and motivation; In-service training 2 = Addressing individual needs and teaching in multicultural settings.

In the preliminary analysis, we first computed the correlations between outcome variables and predictors at both the classroom and student levels. Second, we tested the unconditional models of each of the latent outcomes separately – intrinsic, utility, attainment, cost, and perceived competence – and defined the latent constructs at the individual and classroom levels using doubly latent multilevel models. In MLM, classroom-level variables are often based on the aggregation of individual-level variables. In the doubly latent multilevel models, latent individual-level variables are modeled as latent constructs at the classroom level, representing latent aggregation (Marsh et al., 2009). We used this doubly latent approach because it accounted for sampling and measurement errors (Marsh et al., 2009). In each unconditional model, to ascertain whether MLM was required, we determined the intraclass correlations (ICCs) to estimate the proportion of variance in each motion variable between classrooms. Analyses at the classroom level were warranted if the ICC was .05 or higher (LeBreton & Senter, 2008).

Finally, in the main analyses, we utilized multilevel models to investigate research questions 1 and 2. Figure 1 illustrates the multilevel models used in the study.

Figure 1. The multilevel model used in the analyses. Students' variables predicted the latent motivation variables at the student level, while the teacher variables predicted the latent aggregated motivation variables at the classroom level.



In-service training 1 = Mathematics content, pedagogy, and motivation; In-service training 2 = Addressing individual needs and teaching in multicultural settings.

In this multilevel model, student variables (i.e., grade level, gender, and math achievement) predicted the latent motivation variables at the student level, and the teacher variables (i.e., teacher experience, two in-service training variables, three self-efficacy variables, transmissive beliefs, and constructivist beliefs) predicted the latent aggregated motivation variables at the classroom level (Figure 1). Due to multicollinearity (i.e., several independent variables in a model are close to each other as concepts and are thus strongly connected), only the predictors that significantly associated with outcomes were taken into the actual MLM one at a time. After this process, we checked that no significant predictors had been omitted from the MLM model.

6 Results

We first present the preliminary results with descriptive statistics for all variables, followed by the correlations between the outcome variables and predictors at both the student and the classroom levels. Subsequently, we present the main results derived from multilevel modelling.

6.1 Preliminary results

Descriptive statistics for all variables are reported in Table 2.

Table 2. Descriptive statistics for student and classroom level variables

	% (n)	**M(SD)**
Student level (Level 1)		
Motivation		
Intrinsic		3.00(.74)
Utility		3.36(.59)
Attainment		3.21(.63)
Cost		1.99(.64)
Perceived competence		3.18(.64)
Grade level		
3rd grade	50.4 % (760)	
4th grade	49.6 % (747)	
Gender		
Female	49.6 % (747)	
Male	50.4 % (760)	
Math achievement		541.4(147.41)
Classroom level (Level 2)		
Professional development		
Teaching experience in years		12.56(9.11)
[a]In-service training 1		.25(.30)
[b]In-service training 2		.36(.39)
Teacher beliefs		
Self-efficacy: Cognitive activation		3.18(.52)
Self-efficacy: Motivating students		3.33(.37)
Self-efficacy: Goal setting		3.45(.36)
Transmissive beliefs		1.64(.32)
Constructivist beliefs		3.47(.45)

[a] Mathematics content, pedagogy, and motivation; [b] Addressing individual needs and teaching in multicultural settings

Descriptive statistics indicate that students' motivation is generally at a good level. The utility value is the highest among the other values. The lowest is the cost, meaning how students feel that learning requires effort. The gender distribution is balanced. Students' average math achievement is relatively high, with the mean of the scale set at 500. Teachers' work experience varies, but on average, they have around 13 years of teaching experience. Participation in in-service trainings varies. Teachers' self-efficacy is relatively high, and their beliefs about teaching and learning are clearly more constructivist. Table 3 presents the correlations between the outcomes and predictors at the student and classroom level.

Table 3. Correlations between outcomes and predictors at the individual and classroom level.

	Intrinsic	**Utility**	**Attainment**	**Cost**	**Perceived competence**
Student level (Level 1)					
Grade level (o)	-.14***	-.06*	-.12***	.00	-.02
Gender (o)	.05	-.01	.01	.00	.20***
Maths achievement (o)	.18***	.11***	.08*	-.42***	.39***
Classroom level (Level 2)					
Teaching experience (o)	.27	.31	.38*	-.13	.20
[a] In-service training 1 (o)	.31*	.41*	.40*	-.07	-.15
[b] In-service training 2 (o)	-.22	-.36*	-.19	.23	-.25
Self-efficacy: Cognitive activation (l)	-.08	-.06	-.02	-.12	.12
Self-efficacy: Motivating students (l)	.15	.01	.12	-.11	.23
Self-efficacy: Goal setting (l)	-.12	-.41*	-.40*	-.04	.23
Transmissive beliefs (l)	.45*	.56**	.42*	-.22	.39*
Constructivist beliefs (l)	.06	-.29	-.22	-.11	.02

Note. o = observed variable; l = latent variable. [a] Mathematics content, pedagogy, and motivation; [b] Addressing individual needs and teaching in multicultural settings, *$p < 0.05$; **$p < .01$; ***$p < 0.001$.

Statistically significant connections are found especially at the student level. Notably, it is more difficult to achieve a significant result at the classroom level as there are fewer observations than at the individual level. The ICCs for intrinsic (.06), utility (.08), attainment (.05), cost (.08), and perceived competence (.14) were acceptable (≥ .05, which indicates a small to medium effect), warranting analysis at the classroom level.

6.2 Main results

Table 4 presents the main results of the MLM. All the multilevel models fitted the data well (Table 4).

Table 4. Standardised effects from the multilevel models.

	Intrinsic	**Utility**	**Attainment**	**Cost**	**Perceived competence**
	β(*SE*)	β(*SE*)	β(*SE*)	β(*SE*)	β(*SE*)
Student (Level 1)					
Grade level (3 = 3rd grade, 4 = 4th grade, [o])	-.21(.03)*	-.08(.03)*	-.15(.04)***	.09(.04)**	-.09(.03)***
Gender (Male=1, Female=0, [o])					.14(.03)***
Math achievement (o)	.21(.03)***	.12(.03)***	.12(.03)***	-.38(.03)***	.40(.03)***
Classroom (Level 2)					
[a]In-service training 1 (o)	.37(.14)**	.36(.17)*	.39(.16)*		
[b]In-service training 2 (o)		-.47(.16)**			
Teaching experience (o)					
Self-efficacy: Cognitive activation (l)					
Self-efficacy: Motivating students (l)					
Self-efficacy: Goal setting (l)		-.53(.19)**	-.39(.21)*		
Transmissive beliefs (l)	.47(.16)**		.47(.18)*		.34(.19)*
Constructivist beliefs (l)					

Note. o = observed variable; l = latent variable. [a] Mathematics content, pedagogy, and motivation; [b] Addressing individual needs and teaching in multicultural settings, *p < 0.05; **p < .01; ***p < 0.001. Interest as outcome variable: $\chi^2(129) = 175.10$, $p = 0.004$, CFI = .99, TLI = .99. RMSEA = 0.02.
Utility as outcome variable: $\chi^2(65) = 83.60$, $p = 0.06$, CFI = 1.00, TLI = 1.00. RMSEA = 0.01.
Attainment as outcome variable: $\chi^2(129) = 187.6$, $p = .001$, CFI = .99, TLI = .99. RMSEA = 0.02.
Cost as outcome variable: $\chi^2(10) = 14.5$, $p = 0.15$, CFI = 1.00, TLI = 1.00. RMSEA = 0.02.
Competence as outcome variable: $\chi^2(45) = 56.55$, $p = 0.12$, CFI = 1.00, TLI = 1.00. RMSEA = 0.01.

At the individual level, the students' grade level (only marginally) and achievement in mathematics were significantly associated with all the students' motivation variables, while gender was only associated with the perceived competence. Thus, the third-grade students had higher motivation than the fourth-grade students (β = -.08 – (-.21) (cost .09)). Students with better achievement in mathematics had higher motivation, particularly lower cost value (*β* = -.38) and higher perceived competence (*β* = .40). Male students had slightly higher perceived competence than females (*β = .14)*.

At the classroom level, higher transmissive teacher beliefs predicted higher class-average in intrinsic value (β = .47), attainment value (β = .47), and perceived competence (β = .34). Additionally, a wider participation in mathematics-related teacher in-service training was significantly linked to higher intrinsic value (β = .37), utility value (β = .36), and attainment value (β = .39) in classes. In turn, higher teacher self-efficacy regarding goal setting was associated with lower utility (β = -.53) and attainment values (β = -.39) in classes. Furthermore, wider teacher in-service training regarding individual needs and teaching in multicultural settings was significantly related to lower utility (β = -.47).

7 Discussion

In this study, we explored the effect of students' individual factors (grade level, gender, and math achievement), and teacher-related factors (teacher beliefs and professional development) on students' mathematics motivation. This motivation included intrinsic value, utility value, attainment value, relative cost, and perceived competence. Our results indicated that both individual factors at the student level, and to some extent teacher-related factors at the classroom level, were associated with student motivation. However, there was no evidence of a direct effect of teacher-related factors on student motivation. This study is significant as it provides valuable insights into mathematics teaching and learning by examining the factors influencing mathematics motivation at both the individual and classroom levels.

The first research question focused on examining the impact of individual factors on student motivation. The results showed that, at the individual level, students' grade level and mathematics achievement significantly predicted all motivation variables. According to the results, 3rd graders exhibited slightly higher motivation than 4th graders. These findings align with previous research. A Finnish longitudinal study has concluded that students' attitudes towards mathematics decline throughout primary school, with the most pronounced decline observed in their liking for mathematics (Metsämuuronen & Tuohilampi, 2014). Additionally, global studies have shown that students report lower values in higher grade levels (Gaspard et al., 2017; Wigfield et al., 2015).

Additionally, aligned with several previous studies (Luo et al., 2014; Skaalvik et al., 2015; Williams & Williams, 2010), our results indicate a positive connection between higher mathematics achievement and increased motivation. In particular, higher achievement affected perceived competence and lower relative cost. In addition, boys had more positive perceived competence than girls. Several studies (e.g. Dowker et al., 2012; Ganley & Lubienski, 2016) have shown that primary school boys are more confident than girls in mathematical skills. These results reinforce the need to develop motivating mathematics education. It is crucial to find teaching solutions that foster mathematics motivation, with particular attention needed already in primary school, especially as students move to higher grade levels. It is also important to focus on how to strengthen girls' perceived competence.

The second research question focused on the role of the teacher from the perspective of teacher beliefs and professional development. Teacher beliefs were examined from the perspective of teachers' epistemological beliefs about teaching and learning mathematics (dimensions of transmissive and constructivist beliefs) and self-efficacy (dimensions of cognitive activation, motivating students, and goal setting for student learning).

According to the results, teachers' transmissive beliefs predicted higher class-average in intrinsic value, attainment value, and perceived competence. This finding was somewhat surprising, as transmissive beliefs have previously been found to be negatively related to instructional quality and student achievement (e.g. Voss et al., 2013). On the other hand, it has been shown that constructivist beliefs may be a less important predictor of teacher effectiveness than other teacher characteristics (Baier et al., 2019). Mathematics instructional quality is a wide phenomenon, with a variety of factors related to the curricula and teacher profession. Thus, the connections between teachers' epistemic beliefs and students' learning outcomes may depend on how the learning or teaching is measured.

The results also indicated that higher teacher self-efficacy in setting goals was associated with lower class-level utility value, and attainment value. This contradicts Lazarides et al. (2018), who suggest that higher teacher self-efficacy and clear learning goals enhance student motivation in secondary schools. Future research could investigate whether this difference stems from the age of the students, or whether class composition factors, such as socio-economic background or academic performance, influence the impact of the teacher's goals on student motivation.

Professional development included years of teaching experience and in-service training from two perspectives: in-service training related to mathematics content, pedagogy, and motivation, and in-service training addressing individual needs and teaching in multicultural settings. Teachers' previous participation in in-service training on mathematics content, pedagogy, and motivation was associated with higher class-level intrinsic, utility, and attainment values. In addition, higher teacher in-service training regarding individual needs and teaching in multicultural settings was associated with lower class-average utility. The data were collected in Southern Finland, and the schools represented a wide range of student backgrounds. It should be investigated more thoroughly how socioeconomic factors are connected to teachers' readiness to participate in different types of in-service training. As one possible explanation for this finding, we suggest that teachers from schools with students from challenging backgrounds and lower motivation participated more often in special education-oriented in-service training, whereas teachers from schools in higher socio-economic neighbourhoods had the opportunity to focus on professional development in mathematics and pedagogy.

The strengths of the study include the relatively valid measures, which demonstrate an acceptable factor structure and internal consistency within this data set. However, in the future, it will be important to establish the validity of the measure more broadly among older students and in datasets from other countries.

In conclusion, student motivation can be seen as a slowly changing feature that is not yet fully formed in primary school. The understanding of motivation becomes clearer as the grade levels proceed. In addition, the role of the teacher in fostering motivation is relatively small and unstable in the early years. It is therefore difficult to establish a direct connection between teacher self-efficacy and student motivation. Teacher self-efficacy is strongly associated with evaluated teaching performance, and moderately with student achievement (Klassen & Tze, 2014). Hence, it can be considered that teacher self-efficacy indirectly influences student motivation through the quality of instruction and students' achieved competence. Further research in this area is duly warranted. Additionally, in the future, more attention should be given to and further research conducted on professional development programs. Our findings suggest that different types of in-service training could be valuable in supporting teachers developing motivating teaching practices that meet the need of students.

Research ethics

Author contributions

L.N.: conceptualisation, methodology, writing – original draft preparation, writing – review and editing

M.H.: conceptualisation, methodology, validation, writing – original draft preparation, formal analysis

E.H.: conceptualisation, methodology, writing – original draft preparation, writing – review and editing

P.I.: conceptualisation, investigation, methodology, validation, writing – original draft preparation, data curation

A.L.: conceptualisation, investigation, methodology, project administration, validation, writing – review and editing, data curation, funding acquisition

All authors have read and approved the published version of the manuscript.

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Institutional review board statement

The ethical principles of research provided by the Finnish National Board on Research Integrity (TENK) have been followed throughout the study.

Informed consent statement

Informed consent was obtained from all research participants. Permission from guardians was obtained to involve children in the study.

Data availability statement

The dataset is currently confidential because it involves ongoing longitudinal data collection. The dataset has been anonymized. The complete dataset will be later made available for research purposes through the Finnish Data Archive. Those interested in the data can contact the authors for further information.

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Conflicts of interest

The authors declare no conflicts of interest.

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