Routledge
Taylor & Francis Group

Investigations in Mathematics Learning

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uiml20

An Interplay of Enjoyment, Engagement, and Anxieties: The Characteristics of Upper Secondary School Mathematics Students

Robert Weinhandl, Martin Mayerhofer, Branko Anđić & Cornelia S. Große

To cite this article: Robert Weinhandl, Martin Mayerhofer, Branko Anđić & Cornelia S. Große (03 Nov 2023): An Interplay of Enjoyment, Engagement, and Anxieties: The Characteristics of Upper Secondary School Mathematics Students, Investigations in Mathematics Learning, DOI: 10.1080/19477503.2023.2267936

To link to this article: https://doi.org/10.1080/19477503.2023.2267936

INVESTIGATIONS IN MATHEMATICS LEARNING
https://doi.org/10.1080/19477503.2023.2267936

An Interplay of Enjoyment, Engagement, and Anxieties: The Characteristics of Upper Secondary School Mathematics Students

Robert Weinhandl [a], Martin Mayerhofer [b], Branko Anđić [a], and Cornelia S. Große [c]

[a]Department of STEM Didactics, School of Education, Johannes Kepler University, Linz, Austria; [b]Department of Mathematics, Faculty of Mathematics, University of Vienna, Vienna, Austria; [c]Department of Educational Research, School of Education, Johannes Kepler University, Linz, Austria

ABSTRACT

Our research aimed to identify factors of motivation and affect to best characterize upper secondary mathematics students and correlations between these factors. This work is based on personas, a tool from user experience research for representing the needs and characteristics of users of a system, developed in prior research. In the present study, we conducted an online questionnaire study with questionnaire scales aligned to the previously developed personas. To identify latent factors in the characterization of upper secondary mathematics students, a factor analysis was conducted and correlations were computed. The findings revealed that the factors *Enjoyment*, *Concerns & Anxieties*, *Performance-related confidence*, *Engagement*, *Performance orientation*, and *Persistence* are essential to describe upper secondary mathematics students and that *Enjoyment*, *Concerns & Anxieties*, *Performance-related confidence*, and *Engagement* are highly correlated. We propose that these interdependencies be observed in teacher training as well as in professional development and discuss the implications for the practices of teachers and teacher educators.

KEYWORDS

Factor analysis; mathematics; personas; student characteristics

Introduction

Mathematical instructional materials and tasks are decisive for what students learn and for their engagement in learning processes (Watson & Mason, 2007); improper use of materials can create tension between the intentions of designers, teachers, and students (Johnson et al., 2017). In a recent review, Gallagher et al. (2022) argues that adapting instructional and learning materials to students' characteristics provides all students with an equal opportunity to succeed in mathematics. To this end, teachers need a sound knowledge of their students' characteristics.

Adolescents have different personalities. The design of learning resources needs to consider student characteristics such as self-efficacy, implicit theories of ability, interest, and enjoyment to result in beneficial motivational and learning outcomes (Chao et al., 2016). In fact, knowledge of students and of student learning in mathematics are two of the three elements of subject knowledge required for optimal teaching practice, the third being knowledge of mathematics itself (Frid et al., 2009).

Students' learning outcomes and performance are related to intelligence and self-beliefs. Regarding self-beliefs, task-specific self-efficacy (e.g., Pajares & Graham, 1999) and subject-specific self-concept (e.g., Peteros et al., 2019) are predictors of student performance. Student performance, in turn, is positively related to student well-being (Rodríguez et al., 2020). According to Ignacio et al. (2006), different mathematics students have different beliefs and attitudes toward

CONTACT Martin Mayerhofer martin.mayerhofer@univie.ac.at Department of Mathematics, Faculty of Mathematics, University of Vienna, Oskar-Morgenstern-Platz 1, Vienna 1090, Austria

Supplemental data for this article can be accessed online at https://doi.org/10.1080/19477503.2023.2267936

learning mathematics and experience different emotional responses to learning mathematics. Following Dweck (1986), the goal orientations of mathematics students can be divided into mastery goal orientations and performance goal orientations. Anderson (2007) claims that the identity of mathematics learners can be characterized with the four "faces" engagement, imagination, alignment, and nature. Engagement refers to the "direct experience of the world and [the] active involvement with others" (p. 8), in the context of mathematics education, the connection with learning materials, teachers, and peers. Imagination refers to the "images [learners] have of [them]selves and how mathematics fits into the broader experience of life" (p. 9). Alignment is demonstrated when students "align their energies within institutional boundaries and requirements" (p. 10). The natural component of identification refers to "who we are from what nature gave us at birth" (p. 10). Roesken et al. (2011) identified seven dimensions and three core dimensions of students' beliefs and emotions about mathematics. These seven dimensions are ability, effort, teacher quality, family encouragement, enjoyment of mathematics, difficulty of mathematics, and success. Students' beliefs and emotions about mathematics are partially intertwined with their motivational orientations. In the study of Roesken et al. (2011), the aspects ability and success are described as students' beliefs about themselves related to self-confidence and self-efficacy, and the construct difficulty of mathematics is described as beliefs about mathematics and learning mathematics. Liston and O'Donoghue (2009) take a similar approach in characterizing essential aspects to describe mathematics learners and use constructs concerning enjoyment of mathematics, mathematical self-concept, value of mathematics, fragmented conceptions of mathematics, as well as surface and deep approaches to learning, respectively. Research results of Birgin et al. (2010) indicate that the perceived enjoyment of mathematics, but also the enjoyment of the teaching method had a significant effect on students' mathematics anxiety.

This brief, inexhaustive survey of characteristics of mathematics learners and their impact on mathematical achievement and well-being shows that there is a large variety of individual student characteristics that are relevant for teaching and learning mathematics. Many of the significant studies on student characteristics are ten years or older (e.g., Anderson, 2007; Nicholls et al., 1990; Roesken et al., 2011). Since the nature of learning mathematics has changed significantly in the past decade, in particular due to the increased use of digital technologies in mathematics education, it is reasonable to re-examine relations between characteristics of mathematics students within these new circumstances. Therefore, we investigate whether the findings of prior research regarding the motivational and affective beliefs of learners who are used to traditional learning settings are also found in learners who are frequently exposed to technology-enhanced learning settings. This leads us to pose the following research question: *Which factors describe mathematics student characteristics, and how are they intercorrelated?*

In order to investigate the characteristics of mathematics learners and the relations between these characteristics, we conducted an online questionnaire study in two upper secondary schools. To increase the willingness to participate and decrease the likelihood of a positive selection of conscientious students, students were allowed time to complete the questionnaire on-site. The scale of our study is comparable to the study of Petronzi et al. (2019) who surveyed 163 mathematics students from two schools and, based on this sample, provided vital information concerning mathematics anxiety. The knowledge we aim to gain from our study can help adapt the design of modern learning environments and learning resources to mathematics students' needs and characteristics.

Research Background

In order to develop high-quality learning environments and resources for teaching and learning mathematics, it is important, among other things, to know mathematics students and their motivational characteristics (e.g., Chao et al., 2016; Frid et al., 2009). The present study builds upon our previous research (Weinhandl et al., 2022, 2023) in which we developed representatives of mathematics student groups based on qualitative data. To better situate this research within the literature, this section introduces constructs from psychology that are predictive of important aspects of mathematics learning (e.g., persistence, enjoyment). To lay the foundation for evaluating intercorrelations of the motivational and affective beliefs of mathematics learners, we review established psychological constructs. The importance of examining motivational and affective beliefs for mathematics education is supported by previous studies (e.g., Hannula et al., 2016; Reinhold et al., 2021).

Self-competence and self-confidence. Živković et al. (2022) summarize that self-competence is an indicator of a learner's effectiveness in different environments. Self-competence is a mediator between anxiety and performance in different domains (Li et al., 2021; Živković et al., 2022) and is related to performance (Eccles et al., 1998). Self-competence can also influence personal development and well-being; students with high confidence in their mathematical abilities engage highly in mathematical activities (Živković et al., 2022). Similarly, Falco et al. (2008) argue that students' attitudes toward mathematics learning consist largely of their mathematical self-confidence. Efficacy beliefs also regulate motivation; students are more likely to engage in, persevere in, and exert effort on academic tasks if they are confident that they will master them (Schweinle & Mims, 2009).

Goals. Students' goals in achievement-related contexts comprise mastery goals, performance goals, and work avoidance goals. Students with a high mastery goal orientation learn for the sake of improvement and understanding mathematics (Gilbert et al., 2014; Ng, 2016). Students in the pursuit of mastery goals seek to be challenged, persist despite difficulties, see mistakes as learning opportunities, and are more intrinsically motivated (Furner & Gonzalez-DeHass, 2011).

Students with high mathematical performance goals want to prove their abilities and outperform others (performance approach) or avoid negative events and failures (performance avoidance) (Furner & Gonzalez-DeHass, 2011). In this context, performance approach goals have been found to be positively related to, for example, exam performance or perseverance in learning. In contrast, performance avoidance goals are associated with test anxiety, fear of failure, or viewing tasks as a threat (Furner & Gonzalez-DeHass, 2011). Performance goals are negatively related to performance avoidance goals and positively related to mastery goals (Ng, 2016). Ng (2016) summarizes that favorable behavior of mathematics learners who pursue both mastery and performance approach goals has been well documented.

Work avoidance goals are related to tasks which students consciously avoid to engage in or which lead them to minimizing the effort to complete academic tasks (Dowson & McInerney, 2001). Emotionally, students' work avoidance goals are often associated with feelings of laziness, boredom or anger; cognitively, they are associated with reduced engagement in learning. King and McInerney (2014) summarize that work avoidance goals have been found to be negatively related to satisfaction with learning, perceived ability, student academic achievement, depth of processing, and grades.

Interest. Interest is a highly context-specific construct. For this reason, some studies have found significant connections between mathematics-related interest and, for example, learning achievement, while other studies have not (Ufer et al., 2017). One consistent finding is that the interest of learners in mathematics and fields related to mathematics tends to decrease over time; it should be noted that when interest is measured, the specific context should always be clarified (Ufer et al., 2017).

Anxiety & worry. In addition to hostile teacher behavior, test anxiety is counted among the worst mathematics experiences of learners (Bekdemir, 2010). In the study of Stacey (2017), more than half of the learners surveyed reported being "anxious" or "very anxious" about mathematics and exams. Learners who identify as female are likely to exhibit higher anxiety and test anxiety levels (e.g., Fuller et al., 2016).

Academic performance anxiety is the tendency of students to perceive certain performance-related challenging situations as threatening and to respond to them mentally, physically, and behaviorally with states of arousal and affect (Beilock et al., 2017; Schwarzer, 2000). Thus, performance anxiety is linked to fear and apprehension with the completion of a task (e.g., test) or engagement with a particular domain (e.g., mathematics). Performance anxiety differs from general anxiety in that performance anxiety relates to a specific domain and focuses on performance. In this case, students experience the loss of control and the ability to act in the face of critical teaching demands. Thus, performance anxiety can lead to despair, the degradation of the emotional state, and the ability to perform (Chow & Mercado, 2020). According to many empirical studies, performance anxiety can have negative impact on students' learning behavior, cognitive-motivational orientations, and psycho-emotional state (e.g., Ahmed et al., 2012; Grover et al., 2007; Schnabel & Gruehn, 1994) or lead to negative attitudes, avoidance behavior, and reduction of the resources that individuals need to successfully complete a task (Beilock et al., 2017). It should be noted in this context that the detrimental effect of performance anxiety on task performance leads to a negative feedback loop.

Mathematical worries differ from anxiety in that they are "negative effects on learning which disturb a person's mind from focusing on relevant issues" (Sengodan & Iksan, 2012, p. 18). According to Karing and Artelt (2014), worry refers to task-irrelevant considerations before and during students' engagement with tasks. Various studies (e.g., Karing & Artelt, 2014) reported low to moderate negative correlations between worry and student performance.

Participation & engagement. Classroom participation is defined as co-constructive classroom interactions resulting in co-constructive knowledge acquisition (Jansen et al., 2022). Participation in this context is understood as active behavior in class with the aim to acquire knowledge or demonstrate academic achievement; raising questions for the clarification of content is not sufficient to meet this definition (Galyon et al., 2012). Green et al. (2007) and Jansen et al. (2022) summarize that there is a positive relationship between the students' cognitive activation, classroom participation, and learning outcomes. Students' classroom participation is mainly related to the learning strategies of the representatives of mathematics student groups in our study.

Cognitive engagement typically refers to the mental effort invested in academic work and emphasizes the inner psychological and personal investment and use of the mind in learning, including self-regulatory strategies and the desire to be challenged (Lin et al., 2018; Watt et al., 2017). Cognitive engagement is the conscious task-specific thinking that a student undertakes while participating in an instructional activity; cognitive engagement in mathematics education can be identified by specific linguistic and behavioral indicators (Helme & Clarke, 2001). Moreover, it can be fostered by certain aspects of the instructional situation, task, and person. Active cognitive engagement means that the student acts to maintain or extend contact with the subject matter (Ainley, 2001). According to Corno and Mandinach (1983), four forms of cognitive engagement can be distinguished: self-directed learning, task focus, resource management, and reciprocity. Teaching practices play an essential role in shaping cognitive engagement (Helme & Clarke, 2001).

Emotional engagement refers to students' affective responses to their learning environment, which is typically linked to interest; emotional engagement encompasses students' positive and negative reactions to peers, teachers, and school and promotes eagerness to learn (Cevikbas & Kaiser, 2022; Watt et al., 2017). Emotional engagement predicts cognitive engagement (Hong et al., 2020), the amount of resources students invest in learning mathematics (Singh et al., 2002), and student learning outcomes (Reinhold et al., 2021).

Self-efficacy. The authoritative work of Bandura (1977) defines self-efficacy as the conviction that specific actions and problems can be mastered successfully. Consequently, self-efficacy always refers to a concrete objective (Siefer et al., 2020) and is related to students' motivation and willingness to exert effort (Klassen & Usher, 2010). It is considered essential to distinguish between general school self-efficacy and mathematical self-efficacy (Siefer et al., 2020). For mathematical self-efficacy, we use the definition of Hackett and Betz (1989) in this study, according to which mathematical self-efficacy expectancy is "a situational or problem-specific assessment of an individual's confidence in her or his ability to successfully perform or accomplish a particular task or problem" (p. 262). Regarding the connection between mathematical self-efficacy and mathematics learning in school, the studies by Schiepe-Tiska et al. (2016) and Siefer et al. (2020) show a moderate correlation between student performance and self-efficacy in mathematics, indicating that at least some high-performing students show only low self-efficacy. In addition, Schiepe-Tiska et al. (2016) found a positive correlation between social background and students' mathematical self-efficacy. Regarding differences between male and female students, the studies by Palomares-Ruiz and García-Perales (2020) and Siefer et al.

(2020) show that, in general, male students have higher self-efficacy than female students. For these reasons, mathematical self-efficacy is an important dimension to consider when representing groups of mathematics learners.

Instrumentality. Instrumentality describes how young people assess the importance, relevance, and value of mathematics for their personal future (Schiepe-Tiska & Schmidtner, 2013). However, high assessment of relevance is not necessarily associated with a high level of enjoyment or interest in mathematics. According to PISA (Schiepe-Tiska & Schmidtner, 2013), the instrumentality of mathematics in the OECD countries can be regarded as relatively high; a significantly higher instrumentality can be seen in participants who identify as male than those who identify as female.

Control beliefs. Control beliefs are described by many experts (e.g., Bishara & Kaplan, 2018; Villa & Sebastian, 2021) as the way individuals perceive their ability to control events and an individual's beliefs about the causes of good or bad events in their life in general and at school in particular. They are divided into internal and external control beliefs. Internal locus of control refers to an individual's belief that their abilities and efforts are fundamental causes of success or failure. Individuals with external control beliefs consider external factors such as luck, chance, or teacher influence as responsible for success or failure. There is empirical evidence for a positive correlation between internal locus of control beliefs and achievement (e.g., Anakwe, 2018).

Reactions to Errors

Affective-motivational adaptivity and *action-adaptivity* of reactions to errors have emerged from research on students' emotional and actional responses in the face of failure at a task. Affective-motivational adaptivity of reactions to errors is associated with how emotions and motivation are regulated when falling short of success (Dresel et al., 2013). Such reactions are related to motivational aspects of learning (e.g., self-concept) and come along with attributions of errors to one's self. Action-adaptive reactions to errors are triggered by motivational beliefs oriented toward the task and are positively related to effort and developing strategies for rectification of errors (Dresel et al., 2013). Correspondingly, a mastery goal orientation fosters action-adaptive reactions to errors while a performance goal orientation promotes affective-motivational adaptive reactions (Dresel et al., 2013). The task orientation of high-achieving students and their tendency toward action-adaptive reactions to errors (Dresel et al., 2013) is also supported by an experimental study of Große and Renkl (2007), which suggests that the discussion of both correct and incorrect solutions to mathematical problems in worked examples improves the learning outcomes compared to when focussing on correct solutions only.

The findings of existing works related to the constructs which we have summarized above show that students' attitudes toward learning mathematics are complex and influenced by several factors such as their self-competence and confidence, self-efficacy, control beliefs, interest and the perceived value of mathematics, participation and engagement, fears and concerns, as well as reactions to errors. Some of these beliefs, such as high level of anxiety about mathematics, may negatively affect students' learning behavior, cognitive-motivational orientations, and psycho-emotional state. By contrast, students will achieve better learning outcomes of the learning process and learning resources are compatible with their goals and beliefs. This underlines the importance of students' beliefs and attitudes about mathematics, as they significantly affect students' learning success in mathematics.

Methodological Background

In a previous qualitative study (Weinhandl et al., 2022), we developed profiles of representatives of academic upper secondary school mathematics students based on data from teachers. These profiles were then presented to mathematics school students. They were asked to screen the profiles and make suggestions on how to improve them. Personas, i.e., profiles of prototypical representatives of mathematics students, emerged from this process. These personas showed different characteristics concerning the categories of goals, needs, challenges, joys, fears, feelings and emotions, and strategies.

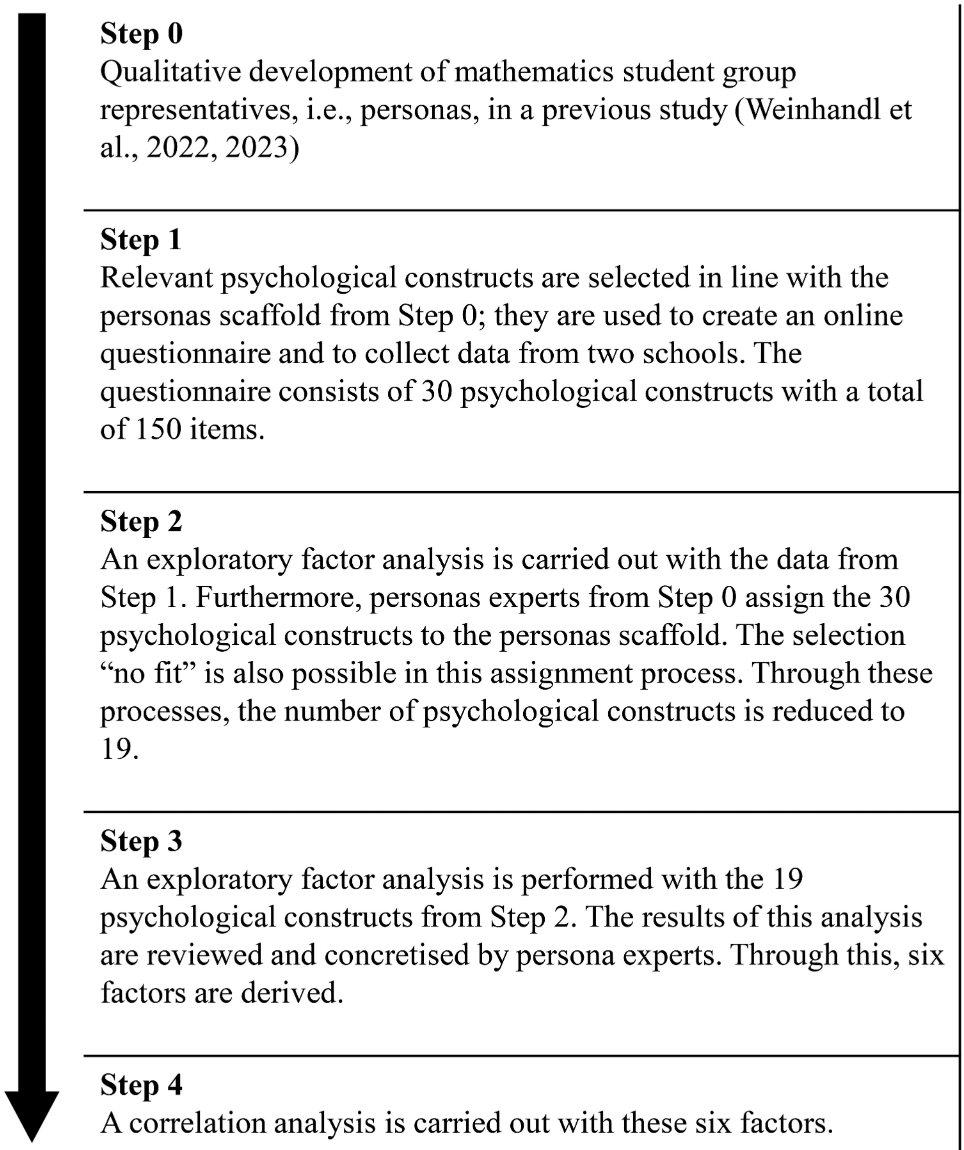

Figure 1. Research steps of our study.

According to these categories and characteristics of the personas, suitable psychological constructs were identified to underpin the dimensions of these personas. For example, in our previous research (Weinhandl et al., 2022), we discovered that in the goal category of one persona, "making best possible progress in mathematics" is a major aspect. To cover this aspect, we use the construct of mastery approach goals (Harackiewicz et al., 1997). Overall, we identified 30 psychological constructs to cover all major aspects of our personas.

The individual research steps (see Figure 1) are described in further detail in the following paragraphs.

To develop the personas, we used a digital open-ended questionnaire to obtain detailed information from in-service and pre-service mathematics teachers on the characteristics of – in their view – typical upper secondary school mathematics students (step 0). The data obtained from these teachers were used to create the personas. They were then subjected to a validation and improvement process involving mathematics school students, mathematics teachers, and university staff. Furthermore, the personas were used in school contexts to test their practicability and to improve the quality of the personas (Weinhandl et al., 2022, 2023).

Measures

To cover all categories and their manifesations in our mathematics student personas, we identified established psychological constructs and scales to measure them in our study (see Supplementary Material). The items of the scales were translated into German where necessary and adapted to fit the mathematics context. We developed an online questionnaire using 30 scales with a total of 150 items, each measured on a 5-point Likert scale (1 = "do not agree," 5 = "strongly agree") (step 1).

Sample

This questionnaire was employed in two academic upper secondary schools, each of them comprising grades 9 to 12 and students between 14 to 18 years of age. An academic upper secondary school is a school that aims to prepare students for tertiary education. Of the two academic upper secondary schools in our study, one is a public school in an urban area ($n = 121$) and the other one a private school in a rural area ($n = 23$). Students from grades 9 to 11 participated in our online questionnaire study in May and June 2022. Students in grade 12, the final grade, had already finished the school year, which is why this age group was not included in our sample. In total, 144 students participated in our study. The questionnaire was distributed to the students via QR code during class time. At the time of answering the questions, a teacher and a researcher were always present in the classroom. Before the data collection started, the aim of our study was explained to each class, and the students were made aware of the voluntary nature of their participation. The internal consistency of the individual constructs was high for all constructs (Cronbach's $\alpha = .74$ to $.96$; see Supplementary Material).

An exploratory factor analysis was performed to examine the factorial structure of the items describing mathematics learners and to reduce the number of constructs needed to cover the persona scaffold (step 2). In line with Roesken et al. (2011), we used the maximum likelihood estimator with oblique rotation.

Furthermore, three experts, each with more than five years of research experience, from our qualitative study used the constructs and items related to the representatives of mathematics students to improve and refine the personas. Additional experts in the use of personas supported the improvement process. These experts ($n_{female} = 7$, $n_{male} = 4$; age range: 23–42; experienced teachers with more than ten years of classroom experience as well as early-career teachers with less than five years of classroom experience) matched the psychological constructs and items with the categories of the personas developed in the first phase of our study (intercoder reliability: Cohen's $k = .664$; substantial agreement according to Greve and Wentura, 1997). The matching also revealed several redundancies of scales or items. For example, the original questionnaire included several scales related to interest, self-concept, and work avoidance; out of these, we selected one scale for each construct. Moreover, we excluded scales that did not fit the focus of our analysis, e.g., perceived competence or social engagement. This resulted in 19 scales with a total of 82 items (see Table 1).

We carried out a second exploratory factor analysis with this reduced set of psychological constructs, following the same process as described above (step 3). To determine the number of factors, we followed a recommendation of Hu and Bentler (1999) to accept a model when RMSEA $< .06$ as well as a recommendation of Finch (2020) to choose the model with fewer factors when comparing two models with adjacent numbers of factors whose RMSEAs differ by less than 0.015. The fit indices of the models resulting from our analysis (see Table 2) show that the six-factor model and the seven-factor model are good fits.

Considering also the conceptual coherence of the included factors, we opted to use the seven-factor model.

Table 1. Constructs selected for our study.

Construct	Source	Items
Mastery approach goals	Harackiewicz et al. (1997)	4
Performance approach goals	Harackiewicz et al. (1997)	5
Work avoidance goals	Spinath et al. (2002)	5
Fear of exams	Jonberg et al. (2021)	4
Concerns	Hodapp et al. (1982)	5
Fear of performance	Bos and Pietsch (2006)	4
Affective-motivational adaptivity of reactions to errors	Dresel et al. (2013)	4
Interest	Harackiewicz et al. (1997)	4
Emotional engagement	Rimm-Kaufman et al. (2015)	5
Subject-specific self-concept	Bos et al. (2012)	5
Instrumentality	Rakoczy et al. (2013)	4
Self-efficacy	Jerusalem and Satow (1999)	4
Locus of control	Levenson and Krampen (1981)	6
Helplessness	Jerusalem and Schwarzer (1993)	5
Proactive participation in class	Kuhl (1984, 1998); Trautwein (2003)	4
Cognitive engagement	Rimm-Kaufman et al. (2015)	4
Social reference norm	Schöne et al. (2004)	3
Individual reference norm	Schöne et al. (2004)	3
Action-adaptivity of reactions to errors	Dresel et al. (2013)	4

Table 2. Fit indices for alternative models.

Factors	RMSEA (90% CI)	TLI	BIC
5	0.076 [0.058; 0.095]	0.918	−268.979
6	0.057 [0.032; 0.080]	0.953	−251.401
7	**0.046 [0.000; 0.073]**	**0.969**	**−215.601**
8	0.030 [0.000; 0.065]	0.987	−180.311
9	0.000 [0.000; 0.056]	1.004	−144.347

Table 3. Factor loadings based on an exploratory factor analysis.

Construct	F1	F2	F3	F4	F5	F6	F7
Fear of exams	**0.980**						
Concerns	**0.801**						
Fear ofperformance	**0.792**						
Affective-motivational adaptivity of reactions to errors	**0.588**						
Interest		**1.032**					
Emotional engagement		**0.871**					
Subject-specific self-concept		**0.667**					
Work avoidance goals		**−0.612**					
Instrumentality		**0.566**					
Self-efficacy	−0.317	**0.537**					0.610
Mastery approach goals		**0.519**					
Locus of control			**0.851**				
Helplessness			**−0.708**				
Proactive participation in class				**0.787**			
Cognitive engagement				**0.802**			
Performance approach goals					**0.867**		
Social reference norm					**0.830**		
Individual reference norm						**0.331**	
Action-adaptivity of reactions to errors						**1.029**	

Note. Factor loadings with absolute values greater than .3 are displayed. The bold factor loadings indicate the allocation of the construct to the respective factor (F1-F7) in the final model.

The factors were determined based on factor loadings greater than .5. Since the construct *Individual reference norm* had its highest factor loading on factor 6 (= F6 in Table 3) and is conceptually related to *Action-adaptivity of reactions to errors*, we merged these two constructs into one factor. *Self-efficacy* had high factor loadings both on factor 2 and on factor 7; for conceptual reasons, it was included in factor 2. Therefore, our factor analysis finally resulted in six distinct factors (see Table 4).

Table 4. Factors of the final model.

Factor	Items	Cronbach's α
Concerns & Anxieties (F1)	8	.893
Enjoyment (F2)	14	.831
Performance-related confidence (F3)	4	.890
Engagement (F4)	4	.739
Performance orientation (F5)	4	.834
Persistence (F6)	4	.627

Furthermore, the individual items of the factors were examined concerning redundancies. This further investigation should make the individual factors more concise. Conceptually equivalent items were removed from the factors. We checked the resulting factors for reliability. This resulted in factors with 4 to 14 items, each with sufficient to good reliability (see Table 4).

We calculated the Pearson correlation coefficient for pairwise correlations between the six factors (step 4). Although the sample size in our study is relatively small ($n = 144$) and Likert-scaled data were collected, according to Norman (2010), this analysis can be carried out *without concern*. Furthermore, Bujang and Baharum (2016) explain that 78 is the minimum sample size to detect a difference of .1 in a correlation analysis (power: .90, $\alpha = .05$).

Results

The goal of this study was to identify factors suitable to describe mathematics learners and to examine correlations between these factors. The analysis of the factorial structure of the items considered relevant for describing mathematics learners has resulted in 19 factors (see Section "Methodological background"). Using exploratory factor analysis, these have been condensed into six factors. In this section, we describe the resulting factors qualitatively and report bivariate correlations.

Factor Analysis

A factor analysis based on the persona scaffold of upper secondary mathematics students and subsequent qualitative improvement and reduction of the factorial structure led to six central factors to capture the needs and characteristics of this group of learners. We labeled these six factors *Enjoyment*, *Concerns & Anxieties*, *Performance-related confidence*, *Engagement*, *Performance orientation*, and *Persistence*. In this section, we describe these factors in detail.

Enjoyment captures the degree to which students like mathematics for itself and enjoy related activities such as problem-solving. This factor also includes whether students value the utility of mathematics and consider it essential for their future. It is characteristic for students who enjoy mathematical problem solving that they pick up new content quickly and are able to solve demanding problems through effort.

Concerns & Anxieties related to mathematics can arise both interpersonally and intrapersonally. On the interpersonal level, they are often related to embarrassment in front of others, e.g., in front of the teacher during a test or in front of classmates while solving a problem on the blackboard. Test anxiety is another important component of interpersonal concerns and anxieties. On the intrapersonal level, concerns and anxieties are often related to making mistakes or giving wrong answers, which may lower the self-image or self-esteem and can cause students to worry about their future.

Performance-related confidence captures whether students are convinced of their ability to solve mathematical problems and to fulfil requirements set by their teachers or the national school-leaving exam by effort.

Engagement captures whether students are attentive and actively participate in class to learn as much as possible.

Table 5. Bivariate correlations (Pearson correlation coefficient r).

	Factor	M	SD	1	2	3	4	5	6
1	Enjoyment	3.13	0.83	-	−.448**	.472**	.493**	.393**	.300**
2	Concerns & Anxieties	3.14	1.09		-	−.494**	−.224**	−.039	−.094
3	Performance-related confidence	3.45	0.63			-	.206*	.222**	.262**
4	Engagement	3.06	0.98				-	.256**	.417**
5	Performance orientation	3.21	1.08					-	.335**
6	Persistence	3.55	0.85						-

Note. n = 144. * The correlation is significant at the .05 level (2-sided). ** = The correlation is significant at the .01 level (2-sided).

Performance orientation captures whether students aspire to improve their performance (intrapersonal) or to outperform their peers (interpersonal). Possible performance indicators are grades or the ability to solve certain problems.

Persistence is about how consistently students pursue their goals and how they manage setbacks. Students with high persistence tend to view mistakes as learning opportunities that they take on.

Factor Correlations

The Pearson correlation coefficients of bivariate correlations between the factors were computed. Following Cohen et al. (2007), we interpret the effect size of the correlations as small for $|r| = .1$, as medium for $|r| = .3$, and as large for $|r| = .5$.

The correlations between the factors can be found in Table 5. We highlight that *Enjoyment* correlates with large effect size with *Concerns & Anxieties*, *Performance-related confidence*, and *Engagement* and of *Concerns & Anxieties* with *Performance-related confidence*. Interestingly, there are statistically not significant correlations of *Concerns & Anxieties* with *Performance orientation* and *Persistence*.

Discussion

The goal of our study was to identify suitable factors that capture the characteristics and needs of mathematics students and investigate their correlations. The factors *Enjoyment*, *Concerns & Anxieties*, *Performance-related confidence*, *Engagement*, *Performance orientation*, and *Persistence* resulted as a suitable set of factors from our analysis of data from upper secondary school mathematics students. We highlight the strong positive correlation between *Enjoyment* and *Performance-related confidence* as well as the negative correlation between *Concerns & Anxieties* and these two factors.

Factor Analysis

We now compare the seven dimensions of student beliefs and emotions about mathematics that have been identified by Roesken et al. (2011), i.e., *Ability*, *Effort*, *Teacher quality*, *Family encouragement*, *Enjoyment of mathematics*, *Difficulty of mathematics*, and *Success*, with the factors found in our study. Enjoyment plays a central role both in Roesken et al. (2011) and in our study. Furthermore, there are clear overlaps in the dimensions *Ability*, *Effort*, and *Success* in Roesken et al. (2011) and the factors *Performance-related confidence*, *Engagement*, *Performance orientation*, and *Persistence* in our study. We could not identify the dimensions *Teacher quality* and *Family encouragement* of Roesken et al. (2011). In fact, these two dimensions did not arise in the qualitative data collected in our previous research. We also note that the factor *Concerns & Anxieties* figured prominently in our data, while it is not emphasized by Roesken et al. (2011).

Comparing the results of our study with the four faces of the identity of mathematics learners of Anderson (2007), i.e., *Engagement*, *Imagination*, *Alignment*, and *Nature*, there is a significant overlap with *Engagement*. Both Anderson (2007) and our study focus on how students engage in mathematics learning in the classroom. This overlap is particularly interesting given Anderson's (2007) conclusion that students who actively participate in mathematics classes develop their identities through engagement.

According to Ignacio et al. (2006), confidence, "liking or disliking mathematics," the desire to master the subject, and expectations of success are central when describing mathematics students. Confidence is implicitly included in different factors of our study. There is a clear connection between "liking or disliking mathematics" (Ignacio et al., 2006) and the factor *Enjoyment* in our study. There is also an overlap between the desire to master the subject and expectations of success (Ignacio et al., 2006) and *Performance-related confidence*, *Performance orientation*, and *Persistence* in our study.

Task-specific self-efficacy (Pajares & Graham, 1999) and mathematical self-concept (Peteros et al., 2019) are suitable predictors of student performance in mathematics. Self-efficacy and self-concept are also central in our study and included in *Enjoyment* and *Performance-related confidence*.

Correlation Analysis

Prior research has shown that the dimensions of *Ability*, *Difficulty of mathematics*, and *Success* correlate strongly (Roesken et al., 2011). The results of our study indicate that the factors *Enjoyment*, *Engagement*, *Concerns & Anxieties*, and *Performance-related confidence* correlate strongly. This suggests that, to the extent that mathematical instructional materials and tasks are designed to allow for active participation, students will enjoy engaging in mathematics. This is consistent with Swan's (2006) findings, which indicate that the more actively students participate in mathematics instruction, the more they enjoy learning and achieve better learning outcomes.

Similarly, the construct *Grit* consisting of the two dimensions *Persistence of effort* and *Consistency of interests* accentuates the relevance of non-cognitive characteristics for academic learning outcomes; for a recent overview and discussion, see for example Weinhandl et al. (2023). Specifically, the dimensions of student characteristics proposed in this study indicate strong correlations between the factors *Enjoyment*, *Engagement*, and *Persistence*, which in turn all show a large overlap with the dimensions of *Grit*. As *Grit* has repeatedly shown to be highly predictive of learning outcomes (e.g., Muenks et al., 2017), it can be assumed that the factors *Enjoyment*, *Engagement*, and *Persistence* identified in our study are crucial for beneficial learning outcomes.

Liston and O'Donoghue (2009) were able to demonstrate in their study that there are particularly strong correlations between enjoyment of mathematics and mathematical self-concept ($r = .73$), between enjoyment of mathematics and value of mathematics ($r = .57$), between enjoyment of mathematics and cohesive conception of mathematics ($r = .42$) and between cohesive conception of mathematics and value of mathematics ($r = .62$) among mathematics learners. These results are very much in line with the results of our study, which indicated that *Enjoyment*, *Engagement*, *Concerns & Anxieties* and *Performance-related confidence* are strongly correlated.

The negative correlation between the factors *Concerns & Anxieties* with *Enjoyment* and *Performance-related confidence* observed in our study is noteworthy, since it indicates that students who are confident about solving mathematical problems and who enjoy the process of solving mathematical tasks are less worried and anxious about mathematics. This is in line with the findings of Birgin et al. (2010), who found a negative correlation between mathematics students' enjoyment and their anxiety.

Conclusion

Analyzing data collected from upper secondary school students, we have identified *Enjoyment*, *Concerns & Anxieties*, *Performance-related confidence*, *Engagement*, *Performance orientation*, and *Persistence* as key factors for characterizing mathematics learners. On the one hand, we have found strong positive correlations between *Enjoyment*, *Engagement*, and *Performance-related confidence*. On the other hand, the factor *Concerns & Anxieties* is strongly negatively correlated with all other factors. This supports the assumption that the more a student is involved in the educational process and the more they enjoy the class, the more confident and perseverant and the less anxious they will be with regard to learning mathematics.

Our work contributes a six-factor model to the literature that is suitable to characterize mathematics learners and which may be used to identify subgroups of mathematics learners in data sets of future studies. As an immediate application, the results of our study may be integrated into the training and professional development of mathematics teachers. Indeed, knowledge of how specific attributes of mathematics learners are independent or related to one another helps teachers understand how fostering a specific attribute such as confidence may affect the development of other attributes.

Limitations and Further Research

The results of our study may lead to a better understanding of mathematics learners but must be viewed under certain limiting conditions. They are based on a qualitative investigation and a subsequent quantitative study with a non-representative sample (n = 144). The sample includes students from two schools, one in an urban area and one in a rural area. The size of the sample is too small for further inspection of disparities between students from urban and rural areas. However, this work can guide further, more extensive data collection.

We highlight that we used the same sample to cluster items from 30 different scales that are considered relevant for describing mathematics learners and to cluster the resulting factors. We have used quantitative model fit indices and consideration of conceptual coherence to decide on the number of factors of the final model. We point out the large cross loading of self-efficacy on factor F7 (see Table 3) which lacks noteworthy factor loadings of other constructs. Since self-efficacy is conceptually coherent with constructs such as self-concept or interest, we included self-efficacy in factor F2 (see Table 3) rather than considering it as a factor of its own. For further validation of the resulting factorial structure, structural equation modeling with data from a new sample should be used.

Since our study was conducted in a country with a high socio-economic standard, the validity of our results is limited to this context. Indeed, self-efficacy and related aspects are positively correlated with learners' socio-economic background (e.g., Merritt & Buboltz, 2015). Our study may provide the basis for conducting similar research in other socio-economic or socio-cultural settings.

Our study provides a snapshot of the dimensions central to mathematics students and how these dimensions relate to each other. Collecting data across several measurement points would enable tracking the development of mathematics learners.

Disclosure Statement

No potential conflict of interest was reported by the authors.

ORCID

Robert Weinhandl http://orcid.org/0000-0002-5525-6404
Martin Mayerhofer http://orcid.org/0000-0002-2978-4385
Branko Anđić http://orcid.org/0000-0003-2691-8357
Cornelia S. Große http://orcid.org/0000-0001-5851-4678

References

Ahmed, W., Minnaert, A., Kuyper, H., & Van der Werf, G. (2012). Reciprocal relationships between math self-concept and math anxiety. *Learning and Individual Differences*, *22*(3), 385–389. https://doi.org/10.1016/j.lindif.2011.12.004

Ainley, M. D. (2001). Interest in learning and classroom interactions. In D. Clarke (Ed.), *Perspectives on practice and meaning in mathematics and science classrooms*. Springer. https://doi.org/10.1007/0-306-47228-7_6

Anakwe, A. I. (2018). Adolescents and academic achievement in Nigeria today. *International Journal of Education & Research*, *6*(1), 69–76.

Anderson, R. (2007). Being a mathematics learner: Four faces of identity. *The Mathematics Educator*, *17*(1), 7–14.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Beilock, S. L., Schaeffer, M. W., & Rozek, C. S. (2017). Understanding and addressing performance anxiety. In A. J. Elliot, C. S. Dweck, & D. S. Yeager (Eds.), *Handbook of competence and motivation: Theory and application* (pp. 155–172). The Guilford Press.

Bekdemir, M. (2010). The pre-service teachers' mathematics anxiety related to depth of negative experiences in mathematics classroom while they were students. *Educational Studies in Mathematics*, *75*(3), 311–328. https://doi.org/10.1007/s10649-010-9260-7

Birgin, O., Baloğlu, M., Çatlıoğlu, H., & Gürbüz, R. (2010). An investigation of mathematics anxiety among sixth through eighth grade students in Turkey. *Learning and Individual Differences*, *20*(6), 654–658. https://doi.org/10.1016/j.lindif.2010.04.006

Bishara, S., & Kaplan, S. (2018). The relationship of locus of control and metacognitive knowledge of math with math achievements. *International Journal of Disability, Development and Education*, *65*(6), 631–648. https://doi.org/10.1080/1034912X.2018.1432033

Bos, W., Bonsen, M., Kummer, N., Lintorf, K., & Frey, K. (2012). Fachbezogenes Selbstkonzept Mathematik - Schüler [Fragebogenskala: Version 1.0]. In Trends in International Mathematics and Science Study *(2007) - Fragebogenerhebung (TIMSS 2007) [Skalenkollektion: Version 1.0]*. Datenerhebung 2007. Forschungsdatenzentrum Bildung am DIPF. https://doi.org/10.7477/12:23:1

Bos, W., & Pietsch, M. (2006). *KESS 4 – Kompetenzen und Einstellungen von Schülerinnen und Schülern am Ende der Jahrgangsstufe 4 in Hamburger Grundschulen*. Waxmann.

Bujang, M. A., & Baharum, N. (2016). Sample size guideline for correlation analysis. *World Journal of Social Science Research*, *3*(1), 37. https://doi.org/10.22158/wjssr.v3n1p37

Cevikbas, M., & Kaiser, G. (2022). Student engagement in a flipped secondary mathematics classroom. *International Journal of Science and Mathematics Education*, *20*(7), 1455–1480. https://doi.org/10.1007/s10763-021-10213-x

Chao, T., Chen, J., Star, J. R., & Dede, C. (2016). Using digital resources for motivation and engagement in learning mathematics: Reflections from teachers and students. *Digital Experiences in Mathematics Education*, *2*(3), 253–277. https://doi.org/10.1007/s40751-016-0024-6

Chow, K., & Mercado, E., III. (2020). Performance anxiety and the plasticity of emotional responses. *Cognition and Emotion*, *34*(7), 1309–1325. https://doi.org/10.1080/02699931.2020.1749568

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). Routledge.

Corno, L., & Mandinach, E. B. (1983). The role of cognitive engagement in classroom learning and motivation. *Educational Psychologist*, *18*(2), 88–108. https://doi.org/10.1080/00461528309529266

Dowson, M., & McInerney, D. M. (2001). Psychological parameters of students' social and work avoidance goals: A qualitative investigation. *Journal of Educational Psychology*, *93*(1), 35–42. https://doi.org/10.1037/0022-0663.93.1.35

Dresel, M., Schober, B., Ziegler, A., Grassinger, R., & Steuer, G. (2013). Affektiv-motivational adaptive und handlungsadaptive Reaktionen auf Fehler im Lernprozess. *Zeitschrift Für Pädagogische Psychologie*, *27*(4), 255–271. https://doi.org/10.1024/1010-0652/a000111

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist*, *41*(10), 1040–1048. https://doi.org/10.1037/0003-066X.41.10.1040

Eccles, J. S., Wigfield, A., & Schiefele, U. (1998). Motivation to succeed. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology: Social, emotional, and personality development* (pp. 1017–1095). John Wiley & Sons, Inc.

Falco, L. D., Crethar, H., & Bauman, S. (2008). Skill-builders: Improving middle school students' self-beliefs for learning mathematics. *Professional School Counseling*, *11*(4). https://doi.org/10.1177/2156759X0801100403

Finch, W. H. (2020). Using fit statistic differences to determine the optimal number of factors to retain in an exploratory factor analysis. *Educational and Psychological Measurement*, *80*(2), 217–241. https://doi.org/10.1177/0013164419865769

Frid, S., Goos, M., & Sparrow, L. (2009). What knowledge is needed for effective teaching of mathematics. *Mathematics Teacher Education & Development*, *10*, 1–3. https://mted.merga.net.au/index.php/mted/article/view/72

Fuller, E., Deshler, J., Darrah, M., Trujillo, M., & Wu, X. (2016). Anxiety and personality factors influencing the completion rates of developmental mathematics students. *Proceedings of the First Conference of International Network for Didactic Research in University Mathematics*, France.

Furner, J. M., & Gonzalez-DeHass, A. (2011). How do students' mastery and performance goals relate to math anxiety? *Eurasia Journal of Mathematics, Science and Technology Education*, *7*(4), 227–242. https://doi.org/10.12973/ejmste/75209

Gallagher, M. A., Parsons, S. A., & Vaughn, M. (2022). Adaptive teaching in mathematics: A review of the literature. *Educational Review*, *74*(2), 298–320. https://doi.org/10.1080/00131911.2020.1722065

Galyon, C. E., Blondin, C. A., Yaw, J. S., Nalls, M. L., & Williams, R. L. (2012). The relationship of academic self-efficacy to class participation and exam performance. *Social Psychology of Education*, *15*(2), 233–249. https://doi.org/10.1007/s11218-011-9175-x

Gilbert, M. C., Musu-Gillette, L. E., Woolley, M. E., Karabenick, S. A., Strutchens, M. E., & Martin, W. G. (2014). Student perceptions of the classroom environment: Relations to motivation and achievement in mathematics. *Learning Environments Research*, *17*(2), 287–304. https://doi.org/10.1007/s10984-013-9151-9

Green, J., Martin, A. J., & Marsh, H. W. (2007). Motivation and engagement in English, mathematics and science high school subjects: Towards an understanding of multidimensional domain specificity. *Learning and Individual Differences*, *17*(3), 269–279. https://doi.org/10.1016/j.lindif.2006.12.003

Greve, W., & Wentura, D. (1997). *Wissenschaftliche Beobachtung: Eine Einführung* (2nd ed.). Beltz. https://doi.org/10.22028/D291-27212

Große, C. S., & Renkl, A. (2007). Finding and fixing errors in worked examples: Can this foster learning outcomes? *Learning and Instruction*. https://doi.org/10.1016/J.LEARNINSTRUC.2007.09.008

Grover, R. L., Ginsburg, G. S., & Ialongo, N. (2007). Psychosocial outcomes of anxious first graders: A seven-year follow-up. *Depression and Anxiety*, *24*(6), 410–420. https://doi.org/10.1002/da.20241

Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education*, *20*(3), 261–273. https://doi.org/10.2307/749515

Hannula, M. S., DiMartino, P., Pantziara, M., Zhang, Q., Morselli, F., Heyd-Metzuyanim, E., Lutovac, S., Kaasila, R., Middleton, J. A., Jansen, A., & Goldin, G. A. (2016). *Attitudes, beliefs, motivation and identity in mathematics education: An overview of the field and future directions*. Springer. https://doi.org/10.1007/978-3-319-32811-9

Harackiewicz, J. M., Barron, K. E., Carter, S. M., Lehto, A., & Elliot, A. J. (1997). Predictors and consequences of achievement goals in the college classroom: Maintaining interest and making the grade. *Journal of Personality and Social Psychology*, *73*(6), 1284–1295. https://doi.org/10.1037/0022-3514.73.6.1284

Helme, S., & Clarke, D. (2001). Identifying cognitive engagement in the mathematics classroom. *Mathematics Education Research Journal*, *13*(2), 133–153. https://doi.org/10.1007/BF03217103

Hodapp, V., Laux, L., & Spielberger, C. D. (1982). Theorie und Messung der emotionalen und kognitiven Komponente der Prüfungsangst. *Zeitschrift für Differentielle und Diagnostische Psychologie*, *3*(3), 169–184.

Hong, W., Zhen, R., Liu, R.-D., Wang, M.-T., Ding, Y., & Wang, J. (2020). The longitudinal linkages among Chinese children's behavioural, cognitive, and emotional engagement within a mathematics context. *Educational Psychology*, *40*(6), 666–680. https://doi.org/10.1080/01443410.2020.1719981

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Ignacio, N. G., Nieto, L. J. B., & Barona, E. G. (2006). The affective domain in mathematics learning. *International Electronic Journal of Mathematics Education*, *1*(1), 16–32. https://doi.org/10.29333/iejme/169

Jansen, N. C., Decristan, J., & Fauth, B. (2022). Individuelle Nutzung unterrichtlicher Angebote–Zur Bedeutung von Lernvoraussetzungen und Unterrichtsbeteiligung. *Unterrichtswissenschaft*, *50*(2), 157–183. https://doi.org/10.1007/s42010-021-00141-8

Jerusalem, M., & Satow, L. (1999). Schulbezogene Selbstwirksamkeitserwartung (WIRKSCHUL). In R. Schwarzer & M. Jerusalem (Eds.), *Skalen zur Erfassung von Schüler- und Lehrermerkmalen, Dokumentation der psychometrischen Verfahren im Rahmen der Wissenschaftlichen Begleitung des Modellversuchs Selbstwirksame Schulen* (pp. 15–16). Freie Universität Berlin.

Jerusalem, M., & Schwarzer, R. (1993). Dimensionen der Hilflosigkeit. In G. Westhoff & S. Achtelstetter (Eds.), *Handbuch psychosozialer Meßinstrumente* (pp. 402–404). Hogrefe.

Johnson, H. L., Coles, A., & Clarke, D. (2017). Mathematical tasks and the student: Navigating "tensions of intentions" between designers, teachers, and students. *ZDM*, *49*(6), 813–822. https://doi.org/10.1007/s11858-017-0894-0

Jonberg, A., Kastens, C. P., & Lipowsky, F. (2021). Prüfungsangst in Mathe am Ende der Grundschulzeit: Entwicklung und Interaktionen mit Leistung und Selbstkonzept. *Zeitschrift für Erziehungswissenschaften*, *24*(3), 621–639. https://doi.org/10.1007/s11618-021-01007-6

Karing, C., & Artelt, C. (2014). Urteilsgenauigkeit von Lehrer(inne)n im emotionalmotivationalen Bereich und im Leistungsbereich. In M. Mudiappa & C. Artelt (Eds.), *BiKS - Ergebnisse aus den Längsschnittstudien: Praxisrelevante Befunde aus dem Primar- und Sekundarschulbereich* (pp. 111–118). University of Bamberg Press.

King, R. B., & McInerney, D. M. (2014). The work avoidance goal construct: Examining its structure, antecedents, and consequences. *Contemporary Educational Psychology*, *39*(1), 42–58. https://doi.org/10.1016/j.cedpsych.2013.12.002

Klassen, R. M., & Usher, E. L. (2010). Self-efficacy in educational settings: Recent research and emerging directions. In T. C. Urdan & S.A. Karabenick (Eds.), *The Decade ahead: Theoretical perspectives on motivation and achievement*. https://doi.org/10.1108/S0749-7423(2010)16_Part_A

Kuhl, J. (1984). Tatsächliche und phänomenale Hilflosigkeit: Vermittlung von Leistungsdefiziten nach massiver Misserfolgsinduktion. In F.E. Weinert & R.H. Kluwe (Eds.), *Metakognition, motivation und Lernen* (pp. 192–209). Kohlhammer.

Kuhl, J. (1998). Wille und Persönlichkeit: Funktionsanalyse der Selbststeuerung [Volition and personality: A functional analysis of self-regulation]. *Psychologische Rundschau*, *49*, 61–77.

Levenson, H., & Krampen, G. (1981). *IPC-Fragebogen zu Kontrollüberzeugungen*. Hogrefe.

Li, Q., Cho, H., Cosso, J., & Maeda, Y. (2021). Relations between students' mathematics anxiety and motivation to learn mathematics: A meta-analysis. *Educational Psychology Review*, *33*(3), 1017–1049. https://doi.org/10.1007/s10648-020-09589-z

Lin, F.-L., Wang, T.-Y., & Yang, K.-L. (2018). Description and evaluation of a large-scale project to facilitate student engagement in learning mathematics. *Studies in Educational Evaluation*, *58*, 178–186. https://doi.org/10.1016/j.stueduc.2018.03.001

Liston, M., & O'Donoghue, J. (2009). Factors influencing the transition to university service mathematics: Part 1 a quantitative study. *Teaching Mathematics and Its Applications: An International Journal of the IMA*, *28*(2), 77–87. https://doi.org/10.1093/teamat/hrp006

Merritt, D., & Buboltz, W. (2015). Academic success in college: Socioeconomic status and parental influence as predictors of outcome. *Open Journal of Social Sciences*, *3*(5), 127–135. https://doi.org/10.4236/jss.2015.35018

Muenks, K., Wigfield, A., Yang, J. S., & O'Neal, C. R. (2017). How true is grit? Assessing its relations to high school and college students' personality characteristics, self-regulation, engagement, and achievement. *Journal of Educational Psychology*, *109*(5), 599–620. https://doi.org/10.1037/edu0000153

Ng, C. C. (2016). High school students' motivation to learn mathematics: The role of multiple goals. *International Journal of Science and Mathematics Education*, *16*(2), 357–375. https://doi.org/10.1007/s10763-016-9780-4

Nicholls, J. G., Cobb, P., Wood, T., Yackel, E., & Patashnick, M. (1990). Assessing students' theories of success in mathematics: Individual and classroom differences. *Journal for Research in Mathematics Education*, *21*(2), 109–122. https://doi.org/10.2307/749138

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y

Pajares, F., & Graham, L. (1999). Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. *Contemporary Educational Psychology*, *24*(2), 124–139. https://doi.org/10.1006/ceps.1998.0991

Palomares-Ruiz, A., & García-Perales, R. (2020). Math performance and sex: The predictive capacity of self-efficacy, interest and motivation for learning mathematics. *Frontiers in Psychology*, *11*. Article 1879. https://doi.org/10.3389/fpsyg.2020.01879

Peteros, E., Gamboa, A., Etcuban, J. O., Dinauanao, A., Sitoy, R., & Arcadio, R. (2019). Factors affecting mathematics performance of junior high school students. *International Electronic Journal of Mathematics Education*, *15*(1). Article em0556. https://doi.org/10.29333/iejme/5938

Petronzi, D., Staples, P., Sheffield, D., Hunt, T. E., & Fitton-Wilde, S. (2019). Further development of the Children's Mathematics Anxiety Scale UK (CMAS-UK) for ages 4–7 years. *Educational Studies in Mathematics*, *100*(3), 231–249. https://doi.org/10.1007/s10649-018-9860-1

Rakoczy, K., Buff, A., & Lipowsky, F. (2013). Wahrgenommene Autonomieunterstützung – Schüler [Fragebogenskala: Version 1.0]. In *Unterrichtsqualität und mathematisches Verständnis in verschiedenen Unterrichtskulturen – Fragebogenerhebung Eingangsbefragung (Pythagoras) [Skalenkollektion: Version 1.0]*. Datenerhebung 2002-2003. Forschungsdatenzentrum Bildung am DIPF. https://doi.org/10.7477/1:3:0

Reinhold, F., Hoch, S., Schiepe-Tiska, A., Strohmaier, A. R., & Reiss, K. (2021). Motivational and emotional orientation, engagement, and achievement in mathematics. A case study with one sixth-grade classroom working with an electronic textbook on fractions. *Frontiers in Education*, *6*. Article 588472. https://doi.org/10.3389/feduc.2021.588472

Rimm-Kaufman, S. E., Baroody, A. E., Larsen, R. A. A., Curby, T. W., & Abry, T. (2015). To what extent do teacher–student interaction quality and student gender contribute to fifth graders' engagement in mathematics learning? *Journal of Educational Psychology*, *107*(1), 170–185. https://doi.org/10.1037/a0037252

Rodríguez, S., Regueiro, B., Piñeiro, I., Valle, A., Sánchez, B., Vieites, T., & Rodríguez-Llorente, C. (2020). Success in mathematics and academic wellbeing in primary-school students. *Sustainability*, *12*(9), 3796. Article 3796. https://doi.org/10.3390/su12093796

Roesken, B., Hannula, M. S., & Pehkonen, E. (2011). Dimensions of students' views of themselves as learners of mathematics. *ZDM*, *43*(4), 497–506. https://doi.org/10.1007/s11858-011-0315-8

Schiepe-Tiska, A., Heine, J.-H., Lüdtke, O., Seidel, T., & Prenzel, M. (2016). Mehrdimensionale Bildungsziele im Mathematikunterricht und ihr Zusammenhang mit den Basisdimensionen der Unterrichtsqualität. *Unterrichtswissenschaft*, *44*(3), 211–225. https://doi.org/10.3262/UW1603211

Schiepe-Tiska, A., & Schmidtner, S. (2013). Mathematikbezogene emotionale und motivationale Orientierungen, Einstellungen und Verhaltensweisen von Jugendlichen in PISA 2012. In M. Prenzel, C. Sälzer, E. Klieme, & O. Köller (Eds.), *PISA 2012. Fortschritte und Herausforderungen in Deutschland* (pp. 99–121). Waxmann.
Schnabel, K., & Gruehn, S. (1994). Fachspezifische Leistungsangst und ihr Einfluß auf die Leistungsentwicklung. In R. Olechowski & B. Rollett (Eds.), *Theorie und Praxis. Aspekte empirisch-pädagogischer Forschung – quantitative und qualitative Methoden* (pp. 169–177). Lang.
Schöne, C., Dickhäuser, O., Spinath, B., & Stiensmeier-Pelster, J. (2004). Zielorientierung und Bezugsnormorientierung: Zum Zusammenhang zweier Konzepte. *Zeitschrift Für Pädagogische Psychologie*, *18*(2), 93–99. https://doi.org/10.1024/1010-0652.18.2.93
Schwarzer, R. (2000). *Stress, Angst und Handlungsregulation* (4th ed.). Kohlhammer.
Schweinle, A., & Mims, G. A. (2009). Mathematics self-efficacy: Stereotype threat versus resilience. *Social Psychology of Education*, *12*(4), 501–514. https://doi.org/10.1007/s11218-009-9094-2
Sengodan, V., & Iksan, Z. H. (2012). Students' learning styles and intrinsic motivation in learning mathematics. *Asian Social Science*, *8*(16), 17–23. https://doi.org/10.5539/ASS.V8N16P17
Siefer, K., Leuders, T., & Obersteiner, A. (2020). Leistung und Selbstwirksamkeitserwartung als Kompetenzdimensionen: Eine Erfassung individueller Ausprägungen im Themenbereich lineare Funktionen. *Journal für Mathematikdidaktik*, *41*(2), 267–299. https://doi.org/10.1007/s13138-019-00147-x
Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research*, *95*(6), 323–332. https://doi.org/10.1080/00220670209596607
Spinath, B., Stiensmeier, J., Schöne, C., & Dickhäuser, O. (2002). *Skalen zur Erfassung der Lern und Leistungsmotivation: SELLMO*. Hogrefe.
Stacey, J. (2017). Mathematics and examination anxiety in adult learners: Findings of surveys of GCSE Mathematics students in a UK Further Education college. *Proceedings of the British Society for Research into Learning Mathematics,* United Kingdom (pp. 1–6). https://bsrlm.org.uk/wp-content/uploads/2017/08/BSRLM-CP-37-2-25.pdf
Swan, M. (2006). *Collaborative learning in mathematics. A challenge to our beliefs and practices*. NRDC.
Trautwein, U. (2003). *Schule und Selbstwert: Entwicklungsverlauf, Bedeutung von Kontextfaktoren und Effekte auf die Verhaltensebene*. Waxmann.
Ufer, S., Rach, S., & Kosiol, T. (2017). Interest in mathematics = interest in mathematics? What general measures of interest reflect when the object of interest changes. *ZDM*, *49*(3), 397–409. https://doi.org/10.1007/s11858-016-0828-2
Villa, E. A., & Sebastian, M. A. (2021). Achievement motivation, locus of control and study habits as predictors of mathematics achievement of new college students. *International Electronic Journal of Mathematics Education*, *16*(3). Article em0661. https://doi.org/10.29333/iejme/11297
Watson, A., & Mason, J. (2007). Taken-as-shared: A review of common assumptions about mathematical tasks in teacher education. *Journal of Mathematics Teachers Education*, *10*(4), 205–215. https://doi.org/10.1007/s10857-007-9059-3
Watt, H. M. G., Carmichael, C., & Callingham, R. (2017). Students' engagement profiles in mathematics according to learning environment dimensions: Developing an evidence base for best practice in mathematics education. *School Psychology International*, *38*(2), 166–183. https://doi.org/10.1177/0143034316688373
Weinhandl, R., Mayerhofer, M., Houghton, T., Lavicza, Z., Eichmair, M., & Hohenwarter, M. (2022). Personas Characterising Secondary School Mathematics Students: Development and Applications to Educational Technology. *Education Sciences, 12*(7). https://doi.org/10.3390/educsci12070447
Weinhandl, R., Mayerhofer, M., Houghton, T., Lavicza, Z., Eichmair, M., Hohenwarter, M. (2023). Mathematics student personas for the design of technology-enhanced learning environments. *Research and Practice in Technology Enhanced Learning, 18.* Article 023. https://doi.org/10.58459/rptel.2023.18032
Živković, M., Pellizzoni, S., Mammarella, I. C., & Passolunghi, M. C. (2022). The relationship between math anxiety and arithmetic reasoning: The mediating role of working memory and self-competence. *Current Psychology*, *42*(17), 14506–14516. https://doi.org/10.1007/s12144-022-02765-0