Education and Science

Vol 51 (2026) No 227 605-623

Original Article

Predicting mathematics achievement through SEM: the role of mathematics familiarity, self-efficacy, and anxiety in mathematical achievement

Fatmir Mehmeti [1], Vedat Bajrami [2]

Abstract

This study examines the structural relationships among subjective familiarity with mathematical concepts, mathematics self-efficacy, mathematics anxiety, and academic achievement among students in Kosovo. Using data from PISA 2022, which includes a nationally representative sample of 6,027 students from 229 schools, the study employs structural equation modeling (SEM) in Mplus to test both direct and indirect effects among latent variables. The proposed model assesses how subjective familiarity influences mathematics achievement (as measured by PISA scores) through mediating pathways involving self-efficacy and anxiety. The results indicate that subjective familiarity with mathematical concepts positively predicts mathematics self-efficacy, which in turn reduces mathematics anxiety and enhances academic performance. Although mathematics anxiety negatively affects achievement, its impact is partially mediated by students' self-beliefs and prior familiarity with mathematical content. These findings underline the importance of fostering conceptual understanding and confidence in students as part of a comprehensive approach to improving mathematics achievement.

Keywords

Achievement

Mathematics anxiety

Mathematics self-efficacy

Subjective familiarity

PISA 2022

Article Info

Received: 04.30.2025

Accepted: 03.09.2026

Published Online: 07.07.2026

DOI: 10.15390/ES.2026.2490

Introduction

In an era of rapid scientific and technological advancement, mathematical knowledge is essential for both personal and societal development. Mathematics is no longer merely a school subject; it is a fundamental tool for understanding the world, interpreting complex processes, and making informed decisions in everyday life and across modern professions. Mathematics education plays a crucial role in developing analytical and critical thinking skills (Luczak & Erwin, 2023; Whitney-Smith et al., 2022). Mathematics serves as the foundation for many scientific disciplines, making it a key component of comprehensive education of individuals (Goos et al., 2023; Li & Schoenfeld, 2019). Furthermore, mathematical skills are vital not only for solving everyday problems but also for achieving success in a wide range of professional contexts (Santos-Trigo, 2024). Despite its importance, mathematics achievement remains a significant challenge for many students. Success in mathematics depends on a range of psychological and affective factors that interact closely with the learning process, including students' intellectual understanding of mathematical concepts (Jin et al., 2022), their lack of confidence or self-efficacy in problem-solving (Larsen & Jang, 2021; Živković et al., 2023), and their experience of mathematics anxiety (Ashcraft & Moore, 2009; Ramirez et al., 2013).

[1] Faculty of Education, Ukshin Hoti University, Prizren, Kosovo, fatmir.mehmeti@uni-prizren.com

[2] Faculty of Education, Ukshin Hoti University, Prizren, Kosovo, vedat.bajrami@uni-prizren.com

The present study investigates the complex relationships among subjective familiarity with mathematical concepts, mathematics self-efficacy, mathematics anxiety, and academic achievement. Understanding these relationships is critical, as they jointly influence students' performance in mathematics (Lessani et al., 2014; Reić-Ercegovac et al., 2019; Zeng, 2025). Subjective familiarity with mathematical concepts refers to students' self-assessed knowledge and understanding of mathematical concepts that vary in complexity (OECD, 2024). Rather than measuring actual competence, this construct captures students' perceptions of how well they understand mathematical concepts, providing insight into their confidence in their mathematical abilities. As a component of cognitive regulation, subjective familiarity is recognized as an important variable in research on self-regulated learning. This variable reflects students previously acquired mathematical knowledge, serves as a foundation for teaching mathematics, and supports students' comprehension of mathematics (Jin et al., 2022).

Bandura (1994) defines self-efficacy as individuals' beliefs in their capacity to produce desired outcomes and influence events that affect their lives, shaping cognition, motivation, emotion, and behavior. Pajares (1996a) further elaborates self-efficacy as beliefs about one's capability to organize and execute the actions required to manage prospective situations. Mathematics self-efficacy represents a task-specific judgment of confidence in one's ability to successfully perform mathematical tasks (Hackett & Betz, 1989). It reflects students' perceptions of their competence to perform mathematical tasks efficiently and influences their motivation, level of engagement, and ultimately their academic achievement in mathematics (Street et al., 2024). This concept is foundational to understanding how individuals approach tasks, cope with challenges, and persevere in the face of adversity. In educational settings, self-efficacy significantly influences students' motivation, learning strategies, and academic performance. Students with higher levels of self-efficacy are more likely to engage in challenging tasks and persist longer when confronted with difficulties (Hayat et al., 2020; Honicke & Broadbent, 2016; Zheng et al., 2021). Students with strong self-efficacy in mathematics are more likely to engage with challenging problems, invest sustained effort, and demonstrate resilience when encountering difficulties, whereas those with lower self-efficacy often avoid demanding tasks and experience heightened mathematics anxiety (Huang et al., 2019).

Mathematics anxiety is a complex and multifaceted phenomenon affecting students across different educational levels. Richardson and Suinn (1972) define mathematics anxiety as feelings of tension and apprehension that interfere with the ability to manipulate numbers and solve mathematical problems in academic and everyday situations. Extensive research has shown that higher levels of mathematics anxiety are consistently associated with poorer mathematical performance (Barroso et al., 2021; Chang & Beilock, 2016; Namkung et al., 2019; Zhang et al., 2019). This negative relationship between mathematics anxiety and performance is evident across diverse domains and educational contexts, with students experiencing significant declines in mathematics achievement as their anxiety levels increase (Zhang et al., 2019). In addition, studies have shown that students with higher levels of mathematics anxiety are more likely to avoid challenging mathematical problems, even when they possess the ability to solve them. This avoidance further exacerbates the issue by limiting their exposure to mathematical practice, ultimately reinforcing anxiety and negatively affecting their long-term academic success (Jenifer et al., 2023). Moreover, the cognitive effects of mathematics anxiety include impaired working memory, reduced problem-solving capacity, and an overall decline in cognitive functioning during mathematics-related tasks (Ashcraft & Krause, 2007). These cognitive deficits further perpetuate the negative cycle of anxiety and poor performance, making it increasingly difficult for students to overcome mathematics-related challenges.

This study places key variables - subjective familiarity with mathematical concepts, mathematics self-efficacy, mathematics anxiety, and academic achievement - within an integrated theoretical framework drawing on metacognitive theory and social cognitive theory. From a metacognitive perspective, subjective familiarity is conceptualized as a key metacognitive experience known as the "feeling of knowing," which reflects learners' perceptions of their understanding of concepts (Dorsch, 2023; Dunlosky & Metcalfe, 2008; Fernández Velasco & Loev, 2024). This feeling of familiarity serves as a key mechanism in self-regulated learning processes (Zimmerman, 2002), directly influencing strategy selection, monitoring of understanding, and decision-making in problem-solving tasks (Rach & Ufer, 2020). According to social cognitive theory (Bandura & National Inst of Mental Health, 1986), such metacognitive experiences contribute to the development of mathematics self-efficacy, as efficacy beliefs are grounded in perceived competence (Schunk & DiBenedetto, 2020). The interaction between these two constructs indicates that students who feel more familiar with mathematical concepts develop stronger beliefs in their ability to successfully perform specific tasks (Pajares, 1996b). According to Pekrun's (2006) Control-Value Theory, high self-efficacy, which reflects a strong perception of control, directly predicts lower levels of mathematics anxiety, a negative achievement-related emotion. This negative relationship is widely documented in the literature (Ashcraft & Moore, 2009; Barroso et al., 2021; Ramirez et al., 2016; Zhang et al., 2019), with strong self-efficacy beliefs disrupting the negative cycle of fear and avoidance. Building on this theoretical framework, the proposed model suggests that these psychological interactions enhance academic achievement: students who combine clear metacognitive awareness of their knowledge with high confidence in their abilities and reduced anxiety are more likely to engage effectively and persistently with complex mathematical content (Hayat & Shateri, 2019; Shen et al., 2025; Syaiful et al., 2022; Usher, 2012; Varveris et al., 2023; Zeng, 2025).

Although previous research has examined the effects of familiarity with mathematical concepts (Almuna Salgado, 2017; Jin et al., 2022; Rach & Ufer, 2020; Voica et al., 2020), mathematics self-efficacy (Hera et al., 2023; Larsen & Jang, 2021; Nicolaidou & Philippou, 2003), and mathematics anxiety (Al Mutawah, 2015; Ashcraft & Moore, 2009; Sad et al., 2016; Živanović et al., 2024) on academic achievement, integrated models that consider these variables simultaneously remain limited. This gap in literature highlights the need for in-depth research that examines the complex relationships among these factors and their combined impact on mathematical achievement. Such research is essential not only for addressing theoretical gaps but also for informing educational practice by enabling teachers and policymakers to develop evidence-based strategies to enhance students' mathematical performance. Furthermore, this study contributes to the fields of educational psychology and mathematics education by providing a comprehensive analysis of the factors influencing mathematical achievement. Specifically, it seeks to deepen understanding of these relationships and explore their implications for mathematics education.

Literature review

Familiarity with mathematics concepts, mathematics self-efficacy, and academic success

Familiarity with mathematical concepts is a key determinant of academic success, particularly in mathematics. Students who are well acquainted with both foundational and advanced mathematical ideas are more likely to develop strong mathematics self-efficacy, the belief in their ability to successfully engage in and solve mathematical problems, which, in turn, contributes to improved academic achievement (Yang et al., 2024). Mathematics self-efficacy plays a critical motivational role, as it encourages students to confront challenging tasks, persist in the face of obstacles, and ultimately achieve higher academic outcomes (Verešová & Foglová, 2018). Empirical research consistently demonstrates that students with greater familiarity with mathematical concepts tend to perform better academically. A solid conceptual foundation enables learners to connect prior knowledge with new material, thereby promoting deeper understanding and more effective problem-solving skills (Al-Hilal, 2024). In contrast, students who lack such familiarity often struggle to develop adequate self-efficacy, which can lead to heightened anxiety and avoidance behaviours that further impede academic progress (Huang et al., 2019). Moreover, studies suggest that instructional approaches integrating cognitive skill development with affective components, such as strengthening self-efficacy, can significantly enhance students' mathematical reasoning and overall achievement by reducing anxiety and increasing confidence (Mukuka et al., 2021). These findings highlight the importance of targeted instructional strategies designed to reinforce students' understanding of key mathematical concepts.

The role of mathematics anxiety in shaping students' performance.

Familiarity with mathematical concepts and mathematics anxiety are critical factors influencing academic success, particularly in mathematics-related fields. When students discuss and justify their problem-solving processes with peers, they develop a deeper familiarity with mathematical concepts. Such interactions enhance students' confidence and reduce mathematics anxiety, ultimately leading to improved academic performance (Pizzie & Kraemer, 2023). Conversely, insufficient familiarity with mathematical concepts often exacerbates mathematics anxiety, which can hinder academic performance by creating mental barriers that prevent students from fully engaging with the material (Huang et al., 2019). The interplay between these factors is particularly significant, as high levels of mathematics anxiety have been shown to negatively affect test performance, classroom participation, and overall academic achievement (Barroso et al., 2021; Gonzalez-DeHass et al., 2024). Furthermore, Li et al. (2021) emphasize that interventions aimed at enhancing students' understanding of mathematical concepts not only strengthen their confidence but also reduce anxiety levels, which is essential for improving academic performance and overall achievement in mathematics.

Interactions among familiarity with mathematical concepts, self-efficacy, and anxiety in predicting academic success

Close relationships exist among familiarity with mathematical concepts, mathematics self-efficacy, mathematics anxiety, and academic success, all of which significantly influence students' educational outcomes. Research indicates that students with a strong understanding of mathematical concepts are more likely to develop high levels of mathematics self-efficacy, defined as confidence in one's ability to perform mathematical tasks successfully (Yıldız et al., 2019; Zakariya, 2022). Mathematics self-efficacy is critical because it directly affects students' willingness to engage in and persist with challenging mathematical activities, ultimately leading to improved academic performance (Skaalvik & Skaalvik, 2006). Moreover, higher levels of self-efficacy are often associated with lower levels of mathematics anxiety, which refers to the emotional distress or fear experienced by some students when engaging with mathematics (Rozgonjuk et al., 2020). Reduced mathematics anxiety has consistently been linked to improved academic outcomes, as less anxious students are more likely to approach learning with a positive attitude and engage more fully with the material. Furthermore, positive emotions toward mathematics are associated with greater academic engagement and stronger self-regulation, both of which contribute to enhanced academic achievement (Villavicencio & Bernardo, 2016).

In this study, we propose a serial mediation model grounded in the existing literature to examine how subjective familiarity with mathematical concepts relates to mathematics self-efficacy and, in turn, influences students' mathematics anxiety and mathematics achievement. Specifically, this study contributes to literature by investigating the mediating roles of mathematics self-efficacy and mathematics anxiety in the relationship between subjective familiarity with mathematical concepts and mathematics achievement (see Figure 1). The following research hypotheses are proposed for testing.

H1a: Subjective familiarity with mathematical concepts has a direct positive effect on mathematics achievement.

H1b: Mathematics self-efficacy has a direct positive effect on mathematics achievement.

H1c: Mathematics anxiety has a direct negative effect on mathematics achievement.

H2a: Subjective familiarity with mathematical concepts has a positive effect on mathematics self-efficacy.

H2b: Subjective familiarity with mathematical concepts has a negative effect on mathematics anxiety.

H3: Mathematics self-efficacy has a negative effect on mathematics anxiety.

H4a: Mathematics self-efficacy mediates the relationship between subjective familiarity with mathematical concepts and mathematics achievement.

H4b: Mathematics anxiety mediates the relationship between subjective familiarity with mathematical concepts and mathematics achievement.

H5: Subjective familiarity with mathematical concepts has an indirect effect on mathematics achievement through the sequential mediation of mathematics self-efficacy and mathematics anxiety.

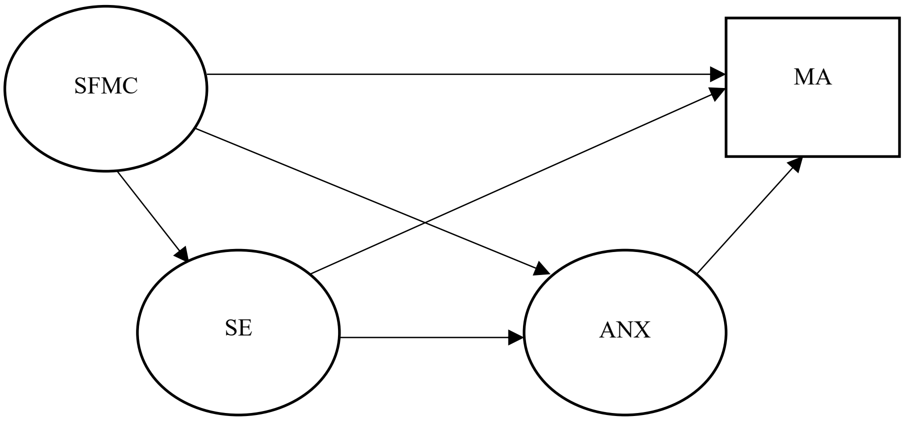


Figure 1. Structural Equation Model Depicting the Serial Mediation Effects of SE (Self-Efficacy) and ANX (Anxiety) on the Relationship Between SFMC (Subjective Familiarity with Mathematical Concepts) and MA (Mathematics Achievement)

Method

This study employed a quantitative, correlational research design to test a predictive model examining the relationships among subjective familiarity with mathematical concepts, mathematics self-efficacy, mathematics anxiety, and mathematics achievement.

Sample

The representative sample comprised 6,027 students (2,928 girls and 3,099 boys) from 229 schools across Kosovo. The sample was designed to represent approximately 21,000 15-year-old students nationwide. Participants ranged from grade 8 to grade 12, reflecting diverse educational experiences and levels of academic development. Data for the analysis was obtained from the PISA 2022 assessment database.

Measures

The dependent variable in this study is students' mathematics achievement in PISA 2022, measured through the PVMATH plausible values provided by the OECD. All statistical analyses were conducted using the ten plausible values for mathematics. The independent variables included in the analysis consist of groups of questionnaire items from PISA 2022 measuring students' "subjective familiarity with mathematical concepts", "mathematics self-efficacy (formal and applied mathematics)", and "mathematics anxiety". Detailed descriptions and explanations of these scales are provided in the following sections.

Subjective familiarity with mathematical concepts

This scale measures the extent to which students perceive themselves as familiar with a range of mathematical concepts spanning basic, intermediate, and advanced levels of mathematical knowledge. Students rate their familiarity with 10 mathematical concepts that represent different levels of mathematical ability and understanding. Example items include "divisor," "area of a circle," "congruent figures,", "linear equation," etc. Each item is rated on a five-point response scale ("Never heard of it," "Heard of it once or twice," "Heard of it a few times," "Heard of it often," and "Know it well, understand the concept") (OECD, 2021, 2024). The composite reliability (ω) of the subjective familiarity with mathematical concepts scale is approximately .88, indicating good internal consistency and that the instrument reliably measures the intended construct.

Mathematics self-efficacy: Formal and applied mathematics

This scale assesses students' perceived capability to manage both abstract and real-world mathematical tasks, providing a comprehensive indicator of their confidence across different domains of mathematical literacy. Students rated their confidence in performing a range of formal and applied mathematics tasks using nine items. Example items include "working out how long it would take to get from one place to another," "calculating how much more expensive a computer would be after adding tax," "calculating how many square meters of tiles are needed to cover a floor," etc. Each item was rated on a four-point response scale: ("Not at all confident," "Not very confident," "Confident," and "Very confident") (OECD, 2021, 2024). The composite reliability (ω) of the mathematics self-efficacy scale, encompassing both formal and applied mathematics, is approximately .90, indicating strong internal consistency and that the instrument reliably measures the intended construct.

Mathematics anxiety

This scale measures students' emotional reactions, levels of discomfort, and perceived stress when engaging with mathematics in academic and problem-solving contexts. Questions about mathematics anxiety consist of six items, including statements such as "I often worry that it will be difficult for me in mathematics classes," "I get very tense when I must do mathematics homework," "I get very nervous doing mathematics problems." Etc. Each of the six items included in this scale had four response options ("strongly agree", "agree", "disagree", and "strongly disagree") (OECD, 2021, 2024). The composite reliability (ω) of the mathematics anxiety scale was approximately .86, indicating good internal consistency and that the instrument reliably measures the construct.

Data analysis

The study analyzed PISA 2022 data using structural equation modeling (SEM) in Mplus version 8.13, with missing values coded as -999 and handled using robust maximum likelihood estimation (MLR). The structural model assessed both direct and mediated pathways. Descriptive statistics and bivariate correlations were examined, and confirmatory factor analysis was conducted to validate the measurement model of the latent constructs (subjective familiarity, mathematics self-efficacy, mathematics anxiety, and mathematics achievement). The model tested three mediation pathways: through mathematics self-efficacy, through mathematics anxiety, and a sequential pathway through both self-efficacy and anxiety. In addition, the direct effects of subjective familiarity, self-efficacy, and anxiety on mathematics achievement were evaluated. All analyses incorporated PISA sampling weights, and indirect effects were tested using bias-corrected bootstrapping (10,000 resamples). Model fit was assessed using standard fit indices (CFI > .90, TLI > .90, RMSEA < .05, SRMR < .08).

Results

Primary analysis

Items that did not conform to the expected factor structure were removed during the initial factor analysis, as not all items were deemed suitable for inclusion in the model. Several items associated with the latent variable subjective familiarity with mathematical concepts were eliminated due to low factor loadings. Specifically, the excluded items were Item 3 (.498): *How familiar are you with the following mathematical terms? Congruent numbers (.415);* Item 9 *(.566): How familiar are you with the following mathematical terms? exponential function;* and Item 11 *(.386): How familiar are you with the following mathematical terms? 3-dimensional geometry*.

With respect to the latent variable "*mathematics self-efficacy*", Item 1 (.588) was removed because it did not adequately fit the model. *How confident are you in math tasks? Use a [train schedule] to determine how long it would take to get from one place to another*. For the latent variable "*mathematics anxiety*", only one item was excluded due to poor model fit: Item 1 (.582): *I often worry that it will be difficult for me in math class.*

Table 1 presents the results of the confirmatory factor analysis. The initial analysis yielded a χ^2 of 4332.702 with 296 degrees of freedom, a χ^2/df ratio of 14.637, a CFI of .866, a TLI of .853, an SRMR of .068, and an RMSEA of .054. After removing poorly fitting items, the revised conformity factor analysis demonstrated substantial improvement in fit indices: $\chi^2(186) = 2006.083$, $\chi^2/df = 10.785$, CFI = .925, TLI = .916, SRMR = .049, and RMSEA = .045. The CFI and TLI values exceeded the recommended threshold of .95, indicating a strong model fit. Given that the analysis is based on PISA 2022 data, which includes a very large sample size, the χ^2 statistic—and consequently the χ^2/df ratio—tends to become inflated. Therefore, the elevated χ^2/df ratio observed in the first CFA should not be interpreted as strong evidence of poor model fit. Consequently, alternative fit indices that adjust for sample size, such as RMSEA and SRMR, provide a more appropriate evaluation of model fit in large-scale assessments. In this study, both CFAs produced RMSEA and SRMR values within acceptable ranges, supporting the adequacy of the measurement model despite the inflated χ^2 statistics.

Table 1. Confirmatory factor analysis fit indices for the measurement model

	χ^2	df	χ^2/df	CFI	TLI	SRMR	RMSEA	p
First CFA	4332.702	296	14.637	.866	.853	.068	.054	.000*
Second CFA	2006.083	186	10.785	.925	.916	.049	.045	.000*

*p<.05

Following the confirmatory factor analysis (CFA) to assess the adequacy of the measurement model, a Pearson correlation analysis was conducted to examine the relationships among the study variables. The results of this analysis are presented in Table 2, showing the correlations among the constructs and their indicators, providing a clearer understanding of the interdependence within the data.

Table 2. Means, standard deviations, and correlation coefficients for key variables

	Mean	Sd	FMC	SE	ANX
1. SFMC	3.32	1.14	1		
2. SE	2.52	.77	.456**	1	
3. ANX	2.52	.78	-.308**	-.413**	1
4. MA	352.41		.347**	.317**	-.251**

**p < .01; Sd = Standard Deviation; SFMC = Subjective familiarity with mathematical concepts; SE = Mathematics self-efficacy; ANX = Mathematics anxiety; MA = Mathematics achievement

The correlation table includes four primary variables: mathematics achievement, mathematics anxiety, mathematics self-efficacy in formal and applied mathematics, and subjective familiarity with mathematical concepts. The results revealed a positive correlation ($r = .456$) between subjective familiarity with mathematical concepts and mathematics self-efficacy in formal and applied mathematics, indicating that higher levels of familiarity with mathematical concepts are associated with greater self-efficacy in mathematics. Subjective familiarity with mathematical concepts was also positively correlated with mathematics achievement ($r = .347$). In contrast, subjective familiarity with mathematical concepts was negatively correlated with mathematics anxiety ($r = −.308$), indicating that greater familiarity with mathematics is associated with lower levels of anxiety. Mathematics self-efficacy in formal and applied mathematics showed a positive relationship ($r = .317$) with mathematics achievement, implying that students with higher self-efficacy tend to perform better academically. At the same time, mathematics self-efficacy was negatively correlated with mathematics anxiety ($r = −.413$). suggesting that higher confidence in mathematical ability is associated with reduced anxiety. Furthermore, mathematics anxiety was negatively correlated with mathematics achievement ($r = −.251$), indicating that students experiencing higher levels of anxiety tend to demonstrate lower academic performance.

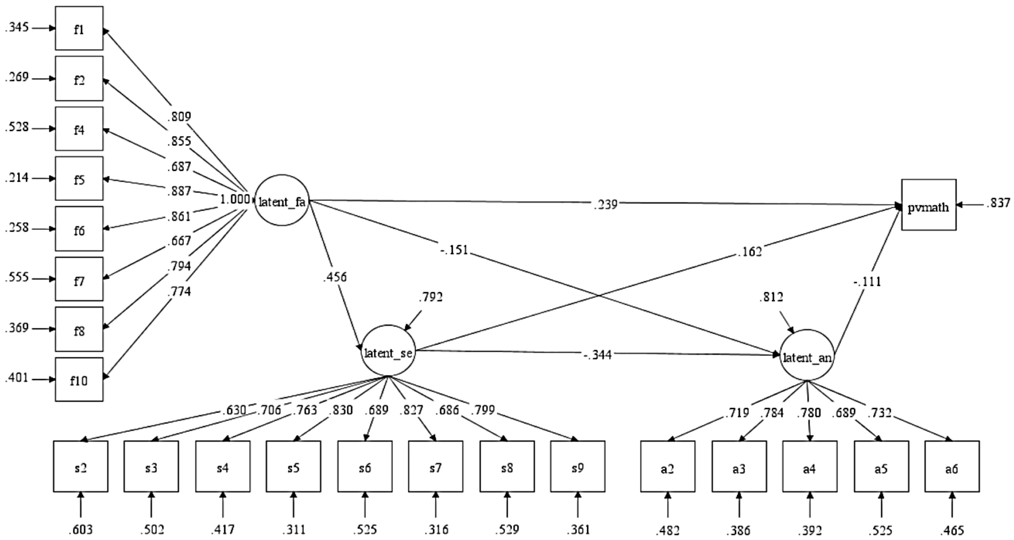
Hypothesis testing further clarified the relationships among subjective familiarity with mathematical concepts, mathematics self-efficacy in formal and applied mathematics, mathematics anxiety, and mathematics achievement within the PISA. Table 3 presents the standardized estimates, confidence intervals (lower and upper bounds), and p-values for each hypothesis.

Table 3. Direct and indirect effects from the structural equation model

H	Hypothesis Test	Std. Estimate	Lower (5%)	Upper (5%)	P-value
H1a	SFMC → MA	.239	.209	.269	.000*
H1b	SE → MA	.162	.128	.196	.000*
H1c	ANX → MA	-.111	-.141	-.081	.000*
H2a	SFMC → SE	.456	.432	.480	.000*
H2b	SFMC → ANX	-.151	-.182	-.119	.000*
H3	SE → ANX	-.344	-.375	-.314	.000*
H4a	SFMC → SE → MA	.074	.058	.022	.000*
H4b	SFMC → ANX → MA	.017	.011	.022	.000*
H5	SFMC → SE → ANX → MA	.017	.012	.022	.000*

*p<.05; SFMC= Subjective familiarity with mathematical concepts; SE= Mathematics self-efficacy; ANX= Mathematics anxiety; MA= Mathematics achievement

The results of the hypothesis testing on subjective familiarity with mathematical concepts (see Figure 2) reveal significant relationships among familiarity with mathematical concepts, mathematics self-efficacy, mathematics anxiety, and mathematics achievement. Familiarity with mathematical concepts has a direct positive effect on mathematics achievement ($\beta = .239$, $p < .05$), indicating that students who perceive themselves as more familiar with mathematical concepts tend to achieve higher scores, thereby supporting H1a. Mathematics self-efficacy also has a positive and significant effect on student achievement ($\beta = .162$, $p < .05$), supporting the theoretical assumption that confidence in one's mathematical abilities enhances performance; thus, H1b is confirmed. Conversely, mathematics anxiety has a significant negative effect on mathematics achievement ($\beta = −.111$, $p < .05$), suggesting that students with higher levels of anxiety are associated with lower performance in mathematics. This finding validates H1c. Furthermore, familiarity with mathematical concepts has a strong positive effect on mathematics self-efficacy ($\beta = .456$, $p < .05$), indicating that greater knowledge of mathematical concepts enhances students' confidence in their mathematical abilities. This result also supports H2a. In addition, familiarity with mathematical concepts has a negative effect on mathematics anxiety ($\beta = −.151$, $p < .05$), suggesting that increased familiarity with mathematical concepts reduces students' anxiety toward mathematics, thereby confirming H2b. Mathematics self-efficacy also has a negative effect on mathematics anxiety (β = −.344, p < .05), indicating that students with higher self-confidence experience lower levels of mathematics anxiety. This result corroborates H3. On the other hand, familiarity with mathematical concepts influences mathematics achievement through the mediation of mathematics self-efficacy (β = .074, p < .05), demonstrating that self-efficacy serves as an important mechanism through which familiarity with mathematical concepts enhances performance. This finding supports H4a. Moreover, familiarity with mathematical concepts also affects mathematics achievement through the mediation of mathematics anxiety (β = −.017, p < .05), indicating that anxiety represents an additional, albeit weaker, pathway in this relationship. This result supports H4b. Furthermore, familiarity with mathematical concepts influences mathematics achievement through the sequential mediation of mathematics self-efficacy and mathematics anxiety (β = .017, p < .05), suggesting that greater familiarity increases self-efficacy, which in turn reduces anxiety and ultimately improves mathematics achievement. This finding confirms H5. All hypotheses are supported with p-value = .000, indicating that the observed effects are statistically significant.



latent_fa = Subjective familiarity with mathematical concepts; latent_se = Mathematics self-efficacy; latent_an = Mathematics anxiety; PVMATH = Mathematics achievement

Figure 2. Structural Equation Model Depicting the Serial Mediation

Discussion

Researchers frequently examine multiple factors that influence students' academic success when analyzing their performance in mathematics. In this context, subjective familiarity with mathematics, formal and applied, mathematics self-efficacy (both formal and applied), and mathematics anxiety have been identified as key psychological variables that play an important role in shaping student performance.

The results of the present study indicate that subjective familiarity with mathematical concepts has a positive and significant effect on mathematics achievement. When students perceive themselves as familiar with mathematical concepts, they are more likely to understand the subject matter and demonstrate a greater willingness to engage in learning activities (Breetzke et al., 2024). This perceived familiarity is associated with reduced stress and increased engagement (Yuan et al., 2023), as well as heightened motivation to explore and solve new problems (Voica et al., 2020). Moreover, familiarity with mathematical concepts enables students to employ more effective learning strategies, such as problem-solving and seeking assistance when difficulties arise (Tambunan, 2019). Strong prior knowledge, often reflected in high levels of subjective familiarity, facilitates the comprehension of new concepts and supports the solution of complex problems (Rach & Ufer, 2020). These mechanisms, including enhanced confidence, reduced cognitive load, increased motivation, and activation of prior knowledge, help explain why students with higher subjective familiarity achieve better outcomes in mathematics. Noble (1963), addressing the relationship between meaningful learning and familiarity, emphasized the influence of prior learning experiences on academic achievement. Subsequent research has similarly demonstrated a relationship between perceived familiarity and learning outcomes, showing that familiarity supports clearer self-expression and more sophisticated explanations of subject matter (Clifton, 1997; Schönwetter et al., 2002). This suggests that the similarity between the findings of the current study and those reported in the literature is not surprising. Students who are familiar with mathematical concepts tend to experience lower cognitive load (Mapson & Major, 2021) and demonstrate greater self-control (e.g., the use of effective learning strategies and reduced dependence on teacher support) during the learning process compared to less familiar students (Murray, 1991; Scott & Dienes, 2010). Familiarity also appears to attract and sustain students' attention, thereby enhancing achievement. Studies by Soppe et al. (2005) and Sockalingam and Schmidt (2013) found that students show greater interest in familiar contexts, which is positively associated with academic success. These findings suggest that the influence of familiarity on student achievement may stem from reduced learning time, stronger integration of new and prior knowledge, facilitated learning and transfer, and increased interest in content and context.

On the other hand, research consistently demonstrates that self-efficacy plays a central role in students' mathematics achievement, often exerting a stronger influence than many other affective variables (Yang et al., 2024). High levels of self-efficacy enhance students' motivation and persistence, enabling them to persevere in the face of challenging tasks and to manage difficulties more effectively (Koh et al., 2022; Schunk & Mullen, 2012). In addition, self-efficacy supports metacognitive and self-regulatory processes. Students with greater confidence tend to set clearer goals, monitor their progress more effectively, and employ more effective learning strategies, such as engaging in challenging tasks that require critical thinking and the application of new ideas (Usher, 2012; Syaiful et al., 2022; Varveris et al., 2023). Through these interconnected mechanisms, including increased motivation and improved self-regulation, self-efficacy makes a substantial contribution to enhanced mathematical performance, explaining its strong and sustained effect on student achievement (Doménech-Betoret et al., 2017). In contrast, mathematics anxiety has a well-documented negative impact on mathematics performance, consistent with extensive evidence showing that anxiety impairs academic achievement (Devine et al., 2012; Foley et al., 2017; Süren & Kandemir, 2020; Zhang et al., 2019). High levels of mathematics anxiety reduce students' ability to concentrate and to retain key information during problem solving (Ramirez et al., 2013). Anxiety also undermines students' confidence in their abilities, leading to increased insecurity and diminished self-belief (Xie et al., 2019). This loss of confidence, in turn, reduces motivation to engage in mathematical tasks and hinders learning progress. Furthermore, fear of making mistakes, which is a common component of mathematics anxiety (Demedts et al., 2022), causes students to adopt overly cautious or avoidant approaches, limiting their opportunities for learning through exploration and experience.

The study findings reveal a strong positive relationship between subjective familiarity with mathematical concepts and mathematics self-efficacy, indicating that students who perceive themselves as more familiar with mathematical concepts also feel more capable of handling mathematical tasks. This result is consistent with existing literature, which highlights the important role of familiarity with mathematical concepts in building self-confidence and fostering greater academic engagement (Jin et al., 2022; Street et al., 2022). Familiarity facilitates learning by allowing students to process related concepts more efficiently, thereby enhancing their sense of confidence. This sense of confidence, in turn, strengthens perceptions of self-efficacy (De Vries et al., 2010). Furthermore, subjective familiarity with mathematical concepts is found to have a small but statistically significant negative effect on mathematics anxiety. Prior research indicates that familiarity can reduce anxiety levels to some extent (Calvo & Eysenck, 2008). Although the effect is modest, this finding suggests that higher perceived knowledge may alleviate feelings of fear and uncertainty related to mathematics, making students more willing to engage with learning tasks. By increasing students' sense of competence, familiarity with mathematical concepts not only enhances self-confidence but also contributes to a reduction in learning-related anxiety, which is known to impede motivation and slow the learning process.

Another key finding of this study is the strong negative effect of mathematics self-efficacy on mathematics anxiety. The results indicate that higher perceptions of mathematics self-efficacy are effective in reducing levels of mathematics anxiety. This finding is consistent with a substantial body of research demonstrating a similar relationship (Hoffman, 2010; Jain & Dowson, 2009; Lee, 2009; Ma & Xu, 2004; Taheri-Kharameh, 2017; Živković et al., 2023). High self-efficacy enables students to better manage stress and academic pressure by encouraging the use of effective coping strategies, such as planning, consistent preparation, and proactive engagement with learning tasks (Freire et al., 2020; Kristensen et al., 2023). Belief in one's own competence allows students to remain calm and focused even in challenging academic situations, thereby mitigating the disruptive effects of anxiety (Muharani & Sucipto, 2023). Moreover, high levels of self-efficacy are associated with more positive attitudes toward learning and a greater willingness to engage actively in academic activities, which ultimately contributes to improved academic performance (Klassen & Usher, 2010). In contrast, students with lower self-efficacy tend to experience higher levels of anxiety, particularly in evaluative contexts, which can hinder their academic performance (Barrows et al., 2013).

Based on these findings, it is essential to examine how mathematics self-efficacy and mathematics anxiety interact to shape the relationship between subjective knowledge and academic achievement. Mathematics self-efficacy plays a crucial mediating role in the relationship between subjective familiarity with mathematics and academic achievement. When students feel comfortable with mathematical concepts and believe in their abilities, they are more likely to understand the material effectively and to develop a positive attitude toward mathematics, viewing it as an opportunity for learning and academic growth (Blotnicky et al., 2018; Živković et al., 2023). This combination of knowledge and self-confidence promotes the development of self-regulatory skills, such as planning, goal setting, and progress monitoring, which enable students to manage their learning more effectively and enhance their mathematical performance (Tian et al., 2018). In this way, subjective familiarity and self-efficacy work together to establish a stable foundation that supports motivation, self-regulation, and academic success. Thus, self-efficacy is not merely an affective belief but a catalyst that empowers students to transform passive knowledge into active and successful performance. In addition, mathematics anxiety serves as a mediating factor in the relationship between subjective familiarity with mathematics and mathematics achievement. Although subjective familiarity with mathematics exerts a strong direct positive effect on performance, it also contributes indirectly by reducing levels of mathematics anxiety. This pattern suggests that while subjective knowledge can alleviate some of the negative effects of anxiety, it may not fully eliminate them. Despite the significant detrimental influence of anxiety, the positive effect of subjective familiarity may function as a protective factor, enabling students to sustain a certain level of performance despite emotional challenges. A strong sense of familiarity with mathematical content enhances self-confidence and reduces the uncertainty often associated with anxiety. Moreover, higher levels of subjective familiarity are linked to improved self-regulation skills, which help students manage stress and anxiety related to mathematics more effectively (Furner & Duffy, 2022). This capacity for self-regulation allows students to cope with challenging situations and maintain strong academic performance even in the presence of anxiety.

Finally, a multiple mediation process is observed in which subjective knowledge of mathematics influences students' mathematics achievement through the sequential effects of mathematics self-efficacy and mathematics anxiety. This finding underlines the importance of an integrated approach that simultaneously strengthens subjective knowledge and self-efficacy while addressing mathematics anxiety in order to achieve optimal academic performance. The combined influence of subjective knowledge and mathematics self-efficacy provides a strong foundation for mathematical success. When students are confident in their understanding of mathematical concepts and believe in their ability to solve mathematical problems, they exhibit higher levels of motivation and engagement in learning mathematics (Durksen et al., 2017). This dual confidence enhances performance and helps mitigate the negative effects of mathematics anxiety. The effects of both subjective knowledge of mathematics and mathematics self-efficacy are evident in shaping students' academic outcomes. Supporting students in developing effective strategies to manage anxiety can further enhance their performance. Students who feel confident in their abilities are better equipped to apply anxiety-management techniques and to confront mathematical challenges more effectively (Zhu et al., 2024). Moreover, when students perceive themselves as knowledgeable and competent, they are more likely to engage actively in their studies and remain motivated to tackle challenging tasks (Acosta-Gonzaga, 2023). This increased engagement and motivation, in turn, contribute to improved performance and help students overcome the obstacles associated with mathematics anxiety.

Conclusion

In conclusion, this study elucidates the dynamic psychological mechanisms underlying mathematics achievement, demonstrating that subjective familiarity and mathematics self-efficacy form a synergistic relationship that operates through both motivational and self-regulatory pathways to directly enhance performance and indirectly mitigate the detrimental effects of mathematics anxiety. From a theoretical perspective, these findings contribute a robust multiple mediation model to the existing literature by clarifying the distinct yet sequential roles of these constructs and extending beyond simple direct-effect explanations. From a practical standpoint, the results underline the need for multifaceted educational interventions that integrate pedagogical strategies aimed at strengthening conceptual familiarity with psychological approaches designed to cultivate resilient self-beliefs and effective anxiety-management skills. Future research should employ longitudinal studies to examine how these relationships evolve over time, as well as experimental approaches to evaluate the effectiveness of integrated intervention programs that simultaneously target these key psychological determinants of academic success.

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