Thinking Skills and Creativity 52 (2024) 101497

Contents lists available at ScienceDirect

Thinking Skills and Creativity

journal homepage: www.elsevier.com/locate/tsc

The role of learning anxiety and mathematical reasoning as predictor of promoting learning motivation: The mediating role of mathematical problem solving

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ARTICLE INFO

Keywords:
Learning motivation
Learning anxiety
Mathematical problem solving
Mathematical reasoning

ABSTRACT

Mathematical problem solving stands as a fundamental aspect of 21st-century skills. Extensive educational studies have substantiated the cultivation of this competency, illustrating that exploring specific predictors and related variables can offer valuable insights for its enhancement. The study investigated how solving mathematical problems acts as a mediator between motivation for learning, anxiety about learning, and mathematical reasoning. A total of 345 primary school students participated in this study, responding to online questionnaires. Structural equation modelling was applied for data analysis, revealing satisfactory construct validity and instrument reliability. The findings highlighted a positive relationship between learning anxiety and mathematical reasoning, indicating their predictive role in improving learning motivation. In addition, the research identified mathematical problem solving as a mediator, playing a crucial role in reducing learning anxiety and fostering increased learning motivation. These outcomes have significant implications, underscoring the need to understand the intricate interaction between learning anxiety, mathematical reasoning, and motivation. This understanding could facilitate the development of targeted interventions and support systems, fostering a conducive learning environment that enhances student participation and academic achievement.

Introduction

Mathematics has long been considered a challenging subject for many students, often leading to feelings of anxiety and disengagement. The prevalence of learning anxiety can hinder students' ability to grasp mathematical concepts (Brady & Bowd, 2005), impacting their overall academic achievement (Eshet et al., 2021). However, understanding the motivational factors that drive students to excel in mathematics can help to enhance their learning experience and performance (Cho & Heron, 2015; Kim et al., 2014). Exploring the interplay between mathematics motivation, learning anxiety, and mathematical reasoning at different grade levels can shed light on effective educational strategies that address these challenges.

Mathematical reasoning plays a pivotal role, relying on an individual's prior knowledge to draw meaningful conclusions and establish cause-and-effect relationships (Dong et al., 2020). The ability to determine the validity or falsity of a mathematical law through reasoning is a significant aspect (Dreher, 2020). This educational goal underscores the importance for students to employ their

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https://doi.org/10.1016/j.tsc.2024.101497
Received 19 December 2023; Received in revised form 13 February 2024; Accepted 10 March 2024
Available online 11 March 2024
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reasoning skills in mathematical problem solving. The intricate skill of reasoning, crucial in the problem-solving process, harmonises the formulation of ideas and hypotheses necessary to unravel mathematical complexities (Kurnaz, 2018). The trajectory of student problem solving is influenced by various factors, including math learning anxiety (Evans & Mulvey, 2012; Karasel et al., 2010; Özcan & Eren Gümüş, 2019; Zhou et al., 2020), mathematical reasoning (Hansen, 2022a; Herbert & Williams, 2023a; Porru et al., 2019; Yu et al., 2022), and learning motivation (Al-Kiyumi & Albeloushi, 2021; Chen & Lin, 2020).

Regarding maths learning anxiety (Evans & Mulvey, 2012), research emphasises that the complexity of maths problems can trigger apprehension, leading to errors in problem solving. However, it is important to note that this study sample consisted of elementary- and secondary-level mathematics teachers, and its implications for students remain unexplored. Similarly, Karasel et al. (2010) identified a marginal but significant difference between student anxiety and problem-solving capabilities, focussing on elementary school students. According to the Self-determination theory (SDT) proposed by Ryan & Deci (2022), the focal point is on autonomy, competence, and relatedness as integral factors that influence motivation and overall well-being. By delving into variables relevant to primary school students, there is an opportunity to explore how environments that support autonomy, the development of competence, and the cultivation of positive relationships contribute to the enhancement of intrinsic motivation and psychological well-being. This suggests the need to investigate this correlation among primary-level students.

Previous studies have highlighted the negative impact of learning anxiety on student motivation to learn. P. Jiang et al. (2023) emphasised the importance of addressing learning anxiety to promote a positive learning environment and enhance students' overall motivation. This suggests that a better understanding of how learning anxiety interacts with other cognitive processes, such as mathematical reasoning and problem solving, could provide valuable insights into its effects on learning motivation. Similarly, there is a significant and positive correlation between fostering anxiety and intrinsic and extrinsic motivation, as well as amotivation (Luo et al., 2020). These findings offer theoretical support for the potential utilisation of anxiety to improve motivation in foreign language learning contexts. Furthermore, research has shown that strong mathematical reasoning skills are conducive to improved problem-solving abilities. In a study by Liang & She (2023), students with higher levels of mathematical reasoning demonstrated enhanced mathematical problem solving performance. This implies that the relationship between mathematical reasoning and problem solving could play a pivotal role in shaping students' learning motivation. Furthermore, Román-González et al. (2017) noted a positive association between reasoning and problem-solving abilities in primary and secondary school education. In addition, the connection between mathematical problem solving and motivation has been highlighted in previous research. Schukajlow et al. (2022a) discussed the reciprocal relationship between problem solving and motivation, suggesting that successful problem solving experiences can positively impact students' motivation to engage in further mathematical challenges. In other words, the mathematical problem solving was explained by motivation. In simpler terms, motivation was identified as a factor that influences mathematical problem-solving (Özcan, 2016). Furthermore, zcan & Eren Gümüş (2019) elucidated that maths anxiety indirectly affects mathematical problem solving by impacting self-efficacy, but did not exply on how mathematical problem solving functions as a mediating variable. A study by Zhou et al. (2020) demonstrated that the teacher-student relationship influences students' mathematical problem solving abilities through self-efficacy and maths anxiety. However, the impact of self-efficacy on maths anxiety is relatively small, and the study did not elucidate the direct relationship between anxiety and student problem solving, excluding the participation of teacher subjects.

In addition to these factors, students' problem-solving abilities can also be influenced by their learning motivation (Al-Kiyumi & Albeloushi, 2021; Chen & Lin, 2020). Learning motivation is essentially an internal drive that propels individuals toward specific goals (Filgona et al., 2020). Various elements can shape students' motivation to learn, including their aspirations, willingness to learn, physical and mental well-being, classroom environment, dynamic learning components, and the efforts of teachers in delivering lessons (Komariah et al., 2022). Numerous studies have explored the connections between learning anxiety, mathematical reasoning, mathematical problem solving, and student learning motivation. However, there is a gap in research regarding how the enhancement

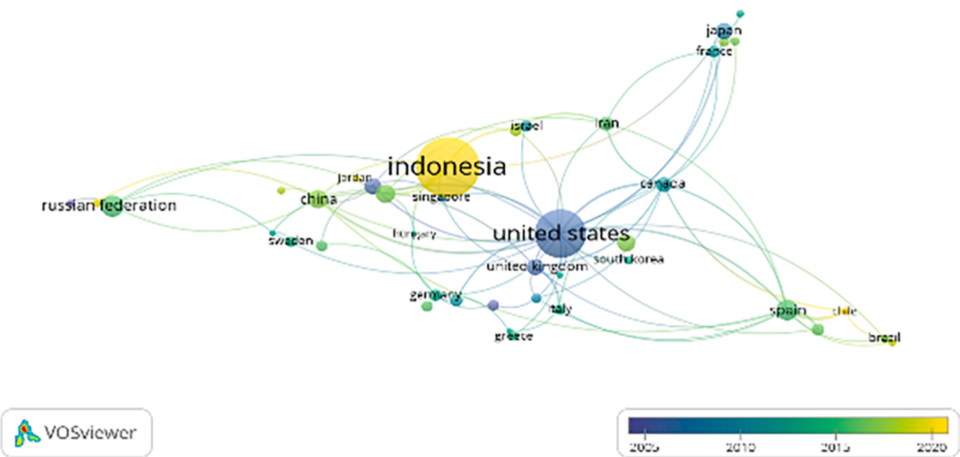

Fig. 1. VOSviewer output based on country analysis unit.

of mathematical reasoning influences other mathematical abilities, such as mathematical problem solving (Demir et al., 2023; Demir & Zengin, 2023; Geteregechi, 2023; Smit et al., 2022).

Although these individual factors have been explored, a comprehensive investigation of how learning anxiety, mathematical reasoning, and mathematical problem solving collectively contribute to the prediction of student learning motivation is lacking. Therefore, this research aims to bridge this gap by shedding light on the intricate dynamics between these variables and their implications for fostering a motivated learning environment in mathematics education.

Literature review

A comprehensive search was conducted, was conducted, for articles involving the four specified variables in the Scopus database to see recent topics, generating a total of 1,508 relevant documents. Subsequent VOSviewer analysis, which used country analysis units, generated the results depicted in Fig. 1, as illustrated below.

Examination of the analysis in Fig. 1 reveals that Indonesia is the leading country in terms of authors who contribute to articles that incorporate the combination of the four specified variables, closely followed by the United States. Shifting the analysis unit to research topics characterised by keywords yields the findings illustrated in Fig. 2, as presented below.

The analysis of Fig. 2 shows that the most frequent keywords in articles with titles using the combination of the four variables are, in order, "test", "paper", and "solution." Based on these documents, some studies include anxiety toward motivation (dos Santos Gonçalves et al., 2017; Marticion, 2021; Pollack et al., 2021) and mathematical problem solving (Dinç et al., 2022; Güner & Erbay, 2021; Hidayatullah & Csíkos, 2022; Zhou et al., 2020). Other studies focus on mathematical reasoning for problem solving (Hansen, 2022b), high-order thinking abilities (Marsitin et al., 2022), learning motivation (Suryaningrat et al., 2021; Tee et al., 2018), and mathematical problem solving for learning motivation (Kurniawati & Juniati, 2022; Schukajlow et al., 2022b). Based on the research description above, the aim of this article is to analyse the relationship between learning anxiety, mathematical reasoning in problem solving, and its impact on student motivation.

Theoretical framework

Learning anxiety and mathematical problem solving

The relationship between learning anxiety and the solution of mathematical problems has been the focus of several studies. Learning anxiety is a feeling of apprehension or fear that arises when students face learning challenges (Amiri & Ghonsooly, 2015), which can negatively impact their performance. Moreover, solving mathematical problems involves the ability to apply mathematical knowledge to real-life situations, which is an essential skill for students to succeed academically and professionally. Problem solving in mathematics is important in teaching mathematics to support 21st century skills (Nunokawa, 2005). In this line, an emphasis on problem-solving is essential, as it aligns with the core nature of mathematical principles (Roberts et al., 2022), going beyond mere

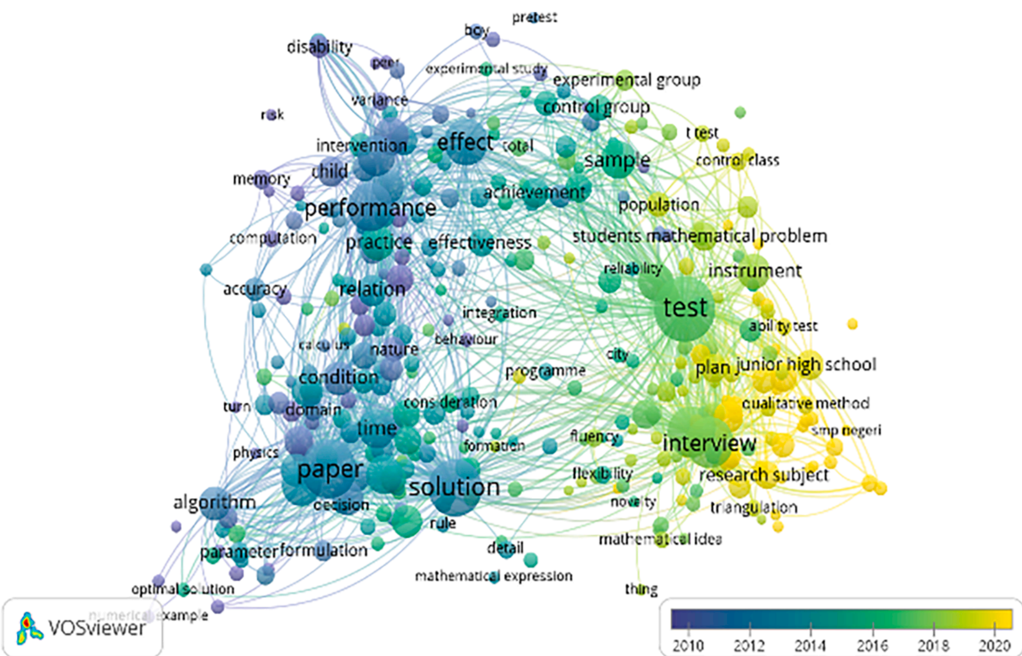

Fig. 2. VOSviewer output based on the unit of research keywords.

memorisation to promote a deep understanding and practical application (Buenrostro & Ehrenfeld, 2023). This approach nurtures critical thinking skills, encouraging students to analyse and reason through challenges, fostering cognitive development. Additionally, it instils perseverance and resilience, valuable life skills that can be applied beyond the classroom. In the context of our complex and modern world, prioritising problem solving in mathematics education equips students with the crucial ability to navigate and solve intricate problems, preparing them for diverse challenges in their future careers (Syamsul et al., 2020).

Learning anxiety, also known as study anxiety, can have a significant impact on student academic performance. Research has shown that anxiety, particularly in the context of language learning, can lead to negative feelings, decreased confidence, and excessive worry, all of which can interfere with learning and performance. For example, a study on students' speaking anxiety found that lower levels of anxiety were associated with better speaking performance. Similarly, research has indicated that anxiety can disrupt complex learning and effective thinking, which in turn can affect academic performance (Zheng & Cheng, 2018). Therefore, it is important for educators to be aware of the potential impact of learning anxiety and to provide support and strategies to help students manage and overcome it.

Additionally, previous research has shown that learning anxiety can have a negative impact on mathematical problem solving performance. For example, a study by Jiang et al. (2021) found that learning anxiety negatively affected students' performance (i.e., mathematical problem-solving skills). Similarly, in a study by Ramirez et al. 2016), students with higher levels of maths anxiety tended to have lower maths scores compared to their peers with lower levels of maths anxiety. This finding highlights the detrimental effect of maths anxiety on children's maths performance during their early years of schooling. Furthermore, research has also found that learning anxiety can affect the problem solving process itself. For example, a study by Novak & Tassell (2017), the results of the study indicated that preservice teachers with higher levels of maths anxiety exhibited lower performance in geometry, word problem solving, and nonword problem solving tasks. The findings suggest that maths anxiety can have a detrimental impact on preservice teachers' overall maths performance across different problem solving contexts. Furthermore, the study examined the relationship between maths anxiety and mathematics performance in pre-service teachers while considering other relevant factors such as self-efficacy and maths experience. The results revealed that math anxiety was a significant predictor of mathematics performance, even when controlling for self-efficacy and prior math experiences. In conclusion, previous research has shown that learning anxiety has a negative impact on mathematical problem solving performance and the problem solving process. Therefore, it is important for educators to understand the relationship between learning anxiety and mathematical problem solving and to develop effective strategies to help students overcome their anxiety and improve their mathematical problem solving skills.

H1: learning anxiety predicts the solution of mathematical problems in a positive and meaningful way.

Learning anxiety and learning motivation

The relationship between learning anxiety and learning motivation has been a topic of interest in educational psychology. Learning anxiety can negatively affect a student's motivation to learn and can lead to a decrease in academic performance (Hashempour & Mehrad, 2014; Oflaz, 2019). However, high motivation can help students overcome learning anxiety (Schukajlow et al., 2023) and achieve better academic results (Affuso et al., 2023).

Several studies have found a negative relationship between learning anxiety and learning motivation. For example, a study by Tan & Pang (2023) discusses the integration of research traditions on test anxiety and achievement motivation. The authors highlight the lack of attention paid to the motivational component of test anxiety and describe how the two traditions could be integrated by examining the relationships between the two constructs. The study provides a theoretical and research-based framework for understanding test anxiety and its relationship with achievement motivation. The authors argue that the integration of these two research traditions can lead to a more comprehensive understanding of test anxiety and its impact on academic performance. Simultaneously, Rochmawati et al. (2023) highlighted a positive correlation between learning anxiety and motivation, indicating that students who exhibit proficiency in managing learning anxiety tend to demonstrate improved performance in their learning motivation. This suggests that effectively handling learning anxiety can positively influence students' motivation levels and consequently, their overall learning outcomes. Another study by Xu et al. (2022) indicated that online learners may feel less motivated and more anxious due to the lack of intermediate feedback, requiring them to be more self-regulated. In general, previous research has consistently shown that there is a relationship between learning anxiety and learning motivation, with higher levels of learning anxiety leading to lower motivation and vice versa. Thus, addressing and managing learning anxiety is crucial to fostering students' learning motivation and academic success.

H2: Learning anxiety is expected to be positively associated with learning motivation.

Mathematical reasoning and mathematical problem solving

Mathematical reasoning and mathematical problem solving are two important aspects of mathematics learning. Mathematical reasoning is a critical skill in mathematics, where individuals analyse given hypotheses, statements, and problems to determine their truth values or solutions (Making, 2009). It involves drawing logical conclusions based on evidence or stated assumptions. Another case, such as inductive, deductive, and abductive (Jeannotte & Kieran, 2017). Although mathematical problem solving involves utilising mathematical concepts, including skills, strategies, and the application of concepts like recognising repeating patterns, to tackle and solve a specific problem (Klang et al., 2021; Li & Disney, 2023).

Research indicates the importance of mathematical reasoning and problem-solving skills. Previous studies have demonstrated a robust correlation between mathematical reasoning and the process of mathematical problem solving. Research conducted by Amalina

& Vidákovich (2023) highlighted the influence of cognitive factors, specifically mathematical reasoning, on mathematical problem-solving abilities. Additionally, a positive correlation has been observed between reasoning and problem-solving skills in primary and secondary school education (Román-González et al., 2017). Although these studies were conducted within a Western context, the same connection could potentially exist in non-Western contexts. Affirming that capacity reasoning (i.e., mathematical reasoning) serves as a predictor of future mathematical performance in children and adolescents (Green et al., 2017). In conclusion, mathematical reasoning and mathematical problem solving are closely related, and both are crucial for success in mathematics fields. Several studies have shown that mathematical reasoning ability significantly predicts mathematical problem solving performance, highlighting the importance of developing students' mathematical reasoning skills.

H3: Mathematical reasoning is expected to be positively associated with mathematical problem solving.

Mediating role of mathematical problem solving

As previously discussed, mathematical problem solving encompasses students' confidence in their capacity to employ mathematical concepts and strategies to address specific problems (DiNapoli & Miller, 2022; Klang et al., 2021). It is not merely an action, but rather a self-assessment of one's ability to reason, motivation, and manage anxiety in creating solutions. Enhanced mathematical problem solving skills are strongly linked to higher levels of learning anxiety, as people who exhibit these skills tend to invest more effort and focus on producing novel ideas (Leavy & Hourigan, 2022). On the contrary, reduced learning anxiety might diminish the drive to generate inventive solutions. In essence, a student's proficiency in managing learning anxiety significantly impacts their capacity for mathematical problem-solving.

The SDT suggests that satisfying psychological needs, including competence, autonomy, and relatedness, plays a fundamental role in human motivation (Ryan & Deci, 2022). Although the search results offer valuable information on the application of SDT in the context of mathematics anxiety and motivation, they do not directly address the specific research question regarding the mediating role of mathematical problem solving. According to the social cognitive theory, learning motivation is influenced by the social structures in which one lives. In the context of the cognitive environment, mathematical problem solving can be shaped by several factors, such as learning anxiety (Kramarski et al., 2010) and mathematical reasoning (Hasanah et al., 2019). The articles and papers discuss the cognitive processes associated with mathematical problem solving in dynamic mathematics environments, the relationship between mathematical reasoning and problem solving abilities (T. T.-Y. Wong, 2018), the influence of cognitive skills on mathematical problem-solving performance (Desoete & Roeyers, 2005), and the mediating role of cognitive flexibility in students' problem-solving in school level of mathematics learning. Consequently, the presence of competence and social interactions could potentially foster mathematical problem-solving abilities, subsequently enhancing learning motivation.

H4: Mathematical problem solving positively mediates the association between mathematical reasoning, learning anxiety, and learning motivation.

Methods

Participants

The study involved 345 elementary school students in Lampung Province, Indonesia, selected by stratified random sampling (Nguyen et al., 2021). Among the participants in the cross-sectional study, 193 were men and 152 were women, representing public and private schools. These students were drawn from various districts and villages, which included various ethnic backgrounds such as

Table 1
Characteristics of the Demographics of the Research Sample.

	Demografi	Frequency	Percentage (%)
Gender	Male	193	55.9
	Female	152	44.1
Age	10 years old	191	55.4
	11 years old	154	44.6
Class	5^{th}	232	67.2
	6^{th}	113	32.8
Type school	Public	101	29.3
	Private	244	70.7
Place	City	173	45.1
	Subbursts	211	54.9
Ethnics	Javanese	154	44.6
	Lampung	98	28.4
	Sundanese	10	2.9
	Batak	21	6.1
	Others	24	7.0
	Padang	14	4.1
	Bugis	24	7.0

Note: $n = 345$; mean age = 10.45; SD = .49; S.E = .03.

Javanese, Lampung, Sundanese, Padang, and others. The research obtained approval from the Institutional Review Board of the Universitas Islam Negeri Raden Intan Lampung, Indonesia, which adhered to the institution's ethical standards. Additionally, all participants gave their informed consent before participating in the study. Table 1 presents detailed demographic characteristics of the participants.

Instrument

This study aims to initiate the relationship between learning anxiety and mathematical reasoning, examining how they interrelate with learning motivation and mathematical problem solving. The survey initially collected personal details from participants, which included class, sex, ethnicity, age, and type of educational institution.

Learning anxiety. The instrument was adapted from Caviola et al. (2017). The Abbreviated Maths Anxiety Scale (AMAS) is a frequently used questionnaire to assess anxiety levels. Comprising three elements, respondents rate their anxiety using a 6-point Likert scale, varying from 1 (indicating minimal anxiety) to 6 (representing high anxiety). The selected items include inquiries such as 'Starting a new topic in mathematics' and 'Watching the teacher break down a complex problem on the blackboard.' The initial items exhibited strong reliability, boasting a Cronbach's alpha of .93. In the context of this investigation, an in-depth evaluation was conducted to assess both the validity and reliability of the measurement scale utilised.

Mathematical reasoning. The concept of mathematical reasoning pertains to an individual understanding of the skill of mathematical concepts (Smit et al., 2017). It involves not only an understanding of mathematical ideas but also the ability to analyse, synthesise, and use this knowledge in various contexts. Three items were adapted from Öztürk & Sarikaya (2021), translated into Indonesian, and assessed using a 6-point Likert scale (ranging from 1 = never to 6 = always). The items evaluate behaviours such as "providing counterexamples when needed" and "establishing cause-and-effect relationships." In its original version, the scale exhibited high reliability, indicated by a Cronbach alpha coefficient of .92. In addition, we examine both validity and reliability for measurement instruments.

Learning motivation. SDT distinguishes between different types of motivation and their respective outcomes, acknowledging the interconnection of intrinsic and extrinsic motivations (Ryan & Deci, 2022). Intrinsic motivation refers to initiating an activity because it is interesting and satisfying in itself, while extrinsic motivation involves performing activities for external rewards or pressures (Chan et al., 2023; Ryan & Deci, 2022). In other words, learning motivation refers to the enthusiasm and drive that students display when they engage in learning activities. The learning motivation scale was adapted from Shurygin et al. (2023) in three items, such as 'I prefer my classroom work to be challenging so that I can learn new things', 'I like what I am learning in this class', and 'I think what I am learning in this class is good for me.' The students used a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree) to respond to the questionnaire. The original scale was reliable and valid to measure student learning motivation. In this study, we performed the validity and reliability of the scale.

Mathematical Problem Solving. As previously described in the literature, mathematical problem solving encompasses the use of mathematical skills, strategies, and the application of concepts, such as identifying recurring patterns, to address and resolve particular mathematical challenges (Klang et al., 2021; Li & Disney, 2023). In this study, we adapt the scale from Saadati et al. (2023), which are three items. An example of the items is "I can solve most math problems if I make an effort", "I can usually find several solutions to solve math problem", and "It is important for me to develop my problem-solving skills". In our study, we rated these instruments on a 6-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = somewhat agree, 5 = agree and 6 = strongly agree). In this study, we also tested the validity and reliability of these scales.

Data analysis

In this study, an initial examination of the data was carried out that included descriptive statistics and correlations between variables using SPSS version 29. Our aim was to investigate the associations between learning anxiety, mathematical reasoning, mathematical problem solving, and learning motivation through structural equation modelling (SEM). However, prior to performing SEM, it was recommended to assess the construct validity and reliability of our measurement tools. To accomplish this, we opt for confirmatory factor analysis (CFA) to scrutinise the questionnaire's construct validity. In the evaluation of SEM using SmartPLS version 4, several model fit indices are commonly used to assess the goodness of fit. These indices include Comparative Fit Indices (CFI), Tucker-Lewis Indices (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardised Root Mean Square Residual (SRMR). According to recent studies, the suggested thresholds for evaluating fit indices are CFI > 0.90, TLI > 0.90, SRMR ranged 0 to 0.1, and RMSEA < 0.5 (Hu & Bentler, 1999). In addition, R software was used to create visual representations depicting the relationships between variables within the scale, showcasing students' performance.

Results

Internal reliability and convergence validity

The evaluation of the validity of the instrument construct in this study involved the use of confirmatory factor analysis. Table 2 provides insight into the strength of the relationships between indicators and their respective latent constructs, as well as the reliability and convergent validity of the measurement model used in the study. The loading factors of the items ranged between .59 to .89. These values indicate the extent to which each indicator measures the underlying construct (K. K.-K. Wong, 2013). Higher outer loading values (closer to 1) suggest a stronger relationship between the indicator and the latent variable.

The table also includes reliability measures such as Cronbach's alpha, composite reliability, and extracted average variance (AVE). These values indicate the internal consistency and reliability of the measurement model. Cronbach's alpha assesses the interrelatedness between items within each construct, which ranged between .70 and .91, with values closer to 1 indicating higher reliability. Composite reliability is another measure of internal consistency, with values greater than 0.7 generally considered acceptable. AVE demonstrates the amount of variance captured by latent variables compared to measurement error, with higher values (above 0.5) indicating better convergent validity. In this study, the AVEs were between .61 and .84.

Discriminant validity

A discriminant validity test was conducted to examine whether latent factors exhibit empirical differences from each other (Hair Jr. et al., 2021). The HTMT (Heterotrait-Monotrait ratio) was used to assess discriminant validity, as suggested by Henseler et al. (2015). A summary of the findings is presented in Table 3.

The results displayed a range of values from .09 to .94. As a result, discriminant validity has been confirmed for all values below 0.95 (Hair et al., 2010; Henseler et al., 2015).

Descriptive statistics

Table 4 shows the statistical summary of the variables under study. Most of the students revealed a tendency to learn anxiety, as evidenced by the mean score (M = 4.52, SD = .85) on the 6-point Likert scale. The participants' scores in mathematical reasoning averaged at M = 4.51, SD = .88. Furthermore, mathematical problem solving and learning motivation were indicated by mean scores of (M = 4.92, SD = .59) and (M = 4.56, SD = .75), respectively. In terms of data normality, Kline (2015) suggested that skewness values should not exceed |3|, and kurtosis should remain below |10|. For this study, the skewness values ranged from -.55 to -.15, while kurtosis was observed between -.37 and .99. The correlation between the elements of each variable is also provided in Table 5.

SEM measurement

Structural equation modelling analysis was conducted to scrutinise the hypotheses posited in this study (Fig. 3). The fit indices for the structural relationship among these variables were as follows: Chi-square = 265.474, df = 48, $p < .001$, CFI = 0.96, TLI = 0.91, RMSEA = 0.12, and SRMR = 0.06. As discussed earlier, the accepted thresholds for CFI and TLI are > 0.90, while for RMSEA and SRMR, they should be below 0.8 (Hu & Bentler, 1999; Kwong-Kay Wong, 2013; Meyers et al., 2016). The results reveal that the fit of the model, as assessed by CFI, TLI, RMSEA, and SRMR, falls within the suggested criteria, affirming a positive fit for the model.

The determination of the coefficient revealed that learning motivation was accounted for by solving mathematical problems, mathematical reasoning, and learning anxiety at 54.6% ($R^2 = .546$). Similarly, learning anxiety was explained by mathematical reasoning in the amount 17.4% ($R^2 = .174$). Furthermore, the solving of mathematical problems was explained by learning anxiety and mathematical reasoning, which is approximately 22.2% ($R^2 = .222$).

With regard to the path coefficients, the analysis revealed significant associations among the variables. Learning anxiety demonstrated a direct association with learning motivation ($\beta = .682, p < 0.001$). Learning anxiety has also been found to be positively associated with mathematical problem-solving ($\beta = .067, p < 0.001$). Additionally, mathematical reasoning was positively associated with learning anxiety ($\beta = .417, p < 0.001$). Furthermore, mathematical reasoning was also found to be positively associated with learning motivation and mathematical problem-solving, ($\beta = .108, p < 0.001$) and ($\beta = .682, p < 0.437$), respectively.

Table 2
Loading Factors and Convergence Validity among Variables.

Laten Variables	Outer loads	Cronbach's alpha	Composite Reliability	AVE
Learning anxiety		0.83	0.94	0.84
	LA1	0.59		
	LA2	0.85		
	LA3	0.89		
Learning Motivation		0.78	0.82	0.61
	LM1	0.87		
	LM2	0.59		
	LM3	0.63		
Mathematical Problem Solving		0.91	0.92	0.78
	MP1	0.68		
	MP2	0.50		
	MP3	0.81		
Mathematical Reasoning		0.70	0.84	0.63
	MR1	0.73		
	MR2	0.70		
	MR3	0.72		

Note: Learning anxiety = LA; learning motivation = LM; mathematical problem solving = MP; mathematical reasoning = MR.

Table 3
Discriminant validity – Heterotrait Monotrait Ratio (HTMT).

	LA	LM	MP	MR
LA	-			
LM	0.94	-		
MP	0.15	0.09	-	
MR	0.52	0.49	0.09	-

Table 4
Statistical descriptive of the data and normality data.

Variables	M	SD	Skewness	Kurtosis
Learning anxiety	4.52	.85	-.15	-.37
Mathematical Reasoning	4.51	.88	-.55	.99
Mathematical Problem Solving	4.94	.59	-.28	.16
Learning Motivation	4.56	.75	-.42	.03

Specific indirect effects are presented in Table 6, which illustrates the total direct and indirect effects. To evaluate the mediating role of mathematical problem solving in the relationship between learning motivation, learning anxiety, and mathematical reasoning, bootstrapping was used with an itinerary of 5000.

The indirect effect of mediating mathematical problem solving was positively associated with the relationship between mathematical reasoning and motivation for learning, but not significant ($\beta = .008$, $p > .05$). Similarly, the mediation role of mathematical problem solving was positively associated with learning anxiety and learning motivation ($\beta = .001$, $p > .05$), but not significant.

Student performance

The violin plot in Fig. 4 illustrates the performance of the students in mathematical reasoning, mathematical problem solving, learning anxiety, and learning motivation. A violin plot serves as a variant of a box plot designed to compare a wide range of data points within a data set. It depicts essential statistical characteristics, including the symmetry of the distribution, the central tendency, and the dispersion of data points. This type of plot allows for an enhanced understanding of the distribution of data values, providing additional insights into the dataset beyond what a traditional box plot offers (Potter et al., 2006). The summary of the performance of the students can also be found in Table 7.

Looking at gender, both male and female students show similar scores in all four categories. However, in terms of age, 11-year-old students tend to score higher in mathematical reasoning compared to 10-year-olds. Regarding grade, fifth-grade students have higher scores on mathematical reasoning and learning anxiety compared to sixth-grade students. In terms of school type, students in public schools generally have higher scores in all categories compared to those in private schools. Students in urban areas generally score higher compared to students in suburban areas in all categories. When considering ethnicity, there are some differences in scores between different ethnic groups. For example, students of Bugis ethnicity tend to score higher in all categories compared to others, while Batak and Sundanese students exhibit slightly lower scores in various areas.

Discussion

The study was to evaluate the role of mathematical problem solving as a mediator in the relationship between learning motivation, learning anxiety, and mathematical reasoning. The significant direct association between learning anxiety and learning motivation highlights a compelling interrelationship between student behaviour and emotional responses that affect their academic involvement. This strong positive correlation suggests that as learning anxiety increases, learning motivation tends to increase simultaneously. This finding implies that students who experience higher levels of anxiety in their learning process may also demonstrate greater motivation. The study also supports previous studies (Affuso et al., 2023; Rochmawati et al., 2023; Schukajlow et al., 2023; Xu et al., 2022) which implies that student learning anxiety has a positive effect on learning motivation. This counterintuitive relationship could be interpreted in several ways. One perspective suggests that anxiety might serve as a motivating factor for some students, leading them to push harder in their studies to overcome or cope with their anxieties. On the contrary, another viewpoint could indicate that anxious students could channel their distress into increased motivation, striving to alleviate their anxiety by achieving academic success.

The finding of the current study found that learning anxiety was positively associated with solving mathematical problems. The positive association between learning motivation and mathematical problem solving aligns with previous research (R. Jiang et al., 2021; Novak & Tassell, 2017; Ramirez et al., 2016), adding weight to the relationship between these variables. This finding highlights the detrimental effect of maths anxiety on children's maths performance during their early years of schooling. Furthermore, studies have indicated that learning anxiety can significantly affect actual problem solving procedures. Consequently, educators must recognise the potential consequences of learning anxiety and offer assistance and tactics to help students cope and overcome this challenge.

Another finding obtained within the scope of the research that mathematical reasoning is an important predictor of learning

Table 5
Correlation matrix for all items.

	LA1	LA2	LA3	MR1	MR2	MR3	MP1	MP2	MP3	LM1	LM2	LM3	LA	MR	LM	MP
LA1	1															
LA2	.499**	1														
LA3	.543**	.762**	1													
MR1	.311**	.427**	.387**	1												
MR2	.130*	.277**	.265**	.481**	1											
MR3	.214**	.245**	.264**	.495**	.549**	1										
MP1	.118*	.097	.061	-.011	.001	-.022	1									
MP2	.022	.073	.021	-.072	-.083	-.050	.345**	1								
MP3	.062	.086	.138*	-.079	.038	-.026	.560**	.409**	1							
LM1	.645**	.506**	.401**	.363**	.133*	.138*	.087	-.012	-.004	1						
LM2	.521**	.423**	.540**	.427**	.154**	.152**	.015	-.086	.046	.520**	1					
LM3	.496**	.518**	.515**	.415**	.178**	.231**	-.028	-.038	-.039	.549**	.380**	1				
LA	.790**	.881**	.900**	.438**	.262**	.281**	.107*	.045	.112*	.601**	.577**	.594**	1			
MR	.262**	.385**	.368**	.802**	.829**	.820**	-.017	-.093	-.032	.262**	.295**	.330**	.396**	1		
LM	.684**	.595**	.604**	.497**	.188**	.214**	.029	-.053	.005	.835**	.789**	.796**	.731**	.364**	1	
MP	.083	.107*	.092	-.070	-.021	-.042	.783**	.758**	.830**	.027	-.013	-.045	.110*	-.062	-.010	1

**. $p < .01$; *.$p < .05$; N = 345.

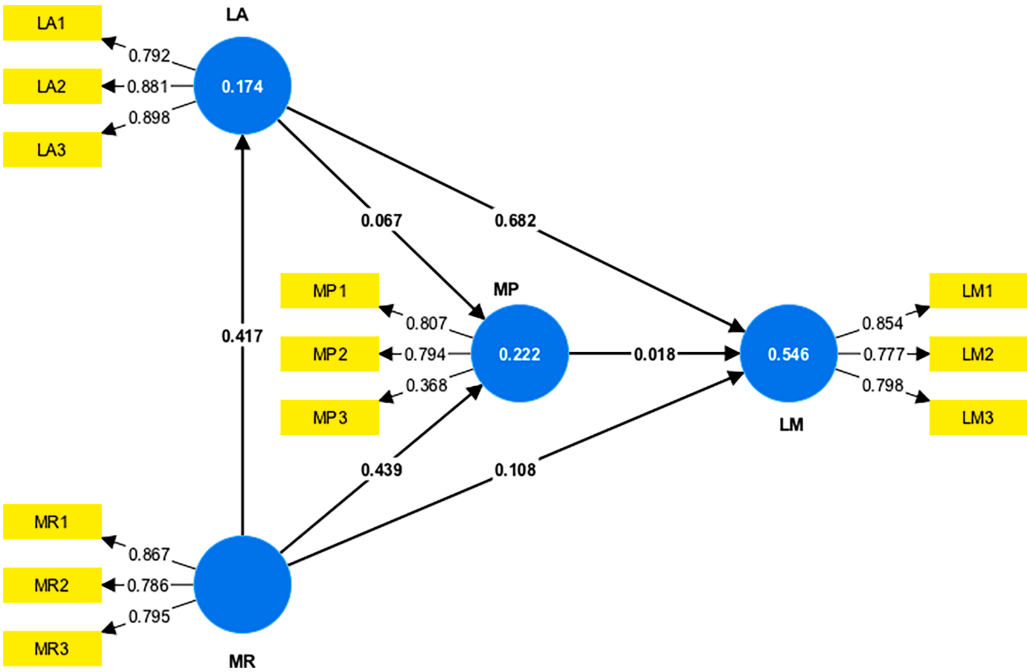

Fig. 3. Standardised association between learning anxiety = LA; learning motivation = LM; mathematical problem solving = MP; mathematical reasoning = MR.

Table 6
Total direct and indirect effect among variables.

Path	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	*p*
LA -> LM	.682	.684	.043	15.710	< .01
LA -> MP	.067	.067	.066	1.010	>.05
MP -> LM	.018	.017	.044	.402	>.05
MR -> LA	.417	.418	.045	9.161	< .01
MR -> LM	.108	.107	.046	2.331	< .05
MR -> MP	.439	.463	.074	5.962	< .01
MR -> LA -> LM	.284	.286	.036	7.937	<.01
MR -> LA -> MP	.028	.028	.028	.993	>.05
MR -> MP -> LM	.008	.007	.021	.365	>.05
LA -> MP -> LM	.001	.001	.004	.279	>.05
MR -> LA -> MP -> LM	.000	.000	.002	.275	>.05

Note: Learning anxiety = LA; learning motivation = LM; mathematical problem solving = MP; mathematical reasoning = MR.

anxiety. This supports our initial reason for the fact that mathematical reasoning is positively associated with learning anxiety. Our literature has also revealed that math reasoning has a positive influence on learning anxiety (Ching et al., 2020; Shimizu, 2022; Živković et al., 2023). When people engage in mathematical reasoning tasks, they often encounter complex cognitive challenges that can induce stress or anxiety (Suárez-Pellicioni et al., 2016). This cognitive strain, which arises from problem solving and logical analysis, can lead to feelings of frustration or inadequacy, particularly if people perceive their mathematical abilities as lacking. Consequently, struggling with mathematical reasoning could lead to a perceived lack of competence, contributing to anxiety during learning situations. Furthermore, fear of making mistakes or not solving problems correctly can exacerbate anxiety levels, preventing effective participation in mathematical tasks. This anxiety, if left unaddressed, can impact concentration, problem solving skills, and overall learning outcomes in mathematics. Recognising and addressing the emotional aspects related to mathematical reasoning can pave the way for targeted interventions and support strategies.

Additionally, in this research, we found that the identification of a positive association between mathematical reasoning and learning motivation is a significant finding within this research context. In this sense, mathematical reasoning was positively associated with learning motivation. The research has also been supported by previous research (Agus et al., 2020; Cheung & Kwan, 2021; Tee et al., 2018). Mathematical reasoning involves the application of creative thinking (Suherman & Vidákovich, 2022), self-efficacy (Hidayatullah et al., 2023), and analytical skills to solve mathematical problems and scenarios (Herbert & Williams, 2023b). When individuals engage in such cognitive processes, they often experience a sense of accomplishment or intellectual stimulation, which fosters a positive attitude toward learning (Suherman & Vidákovich, 2023). As individuals navigate mathematical challenges and

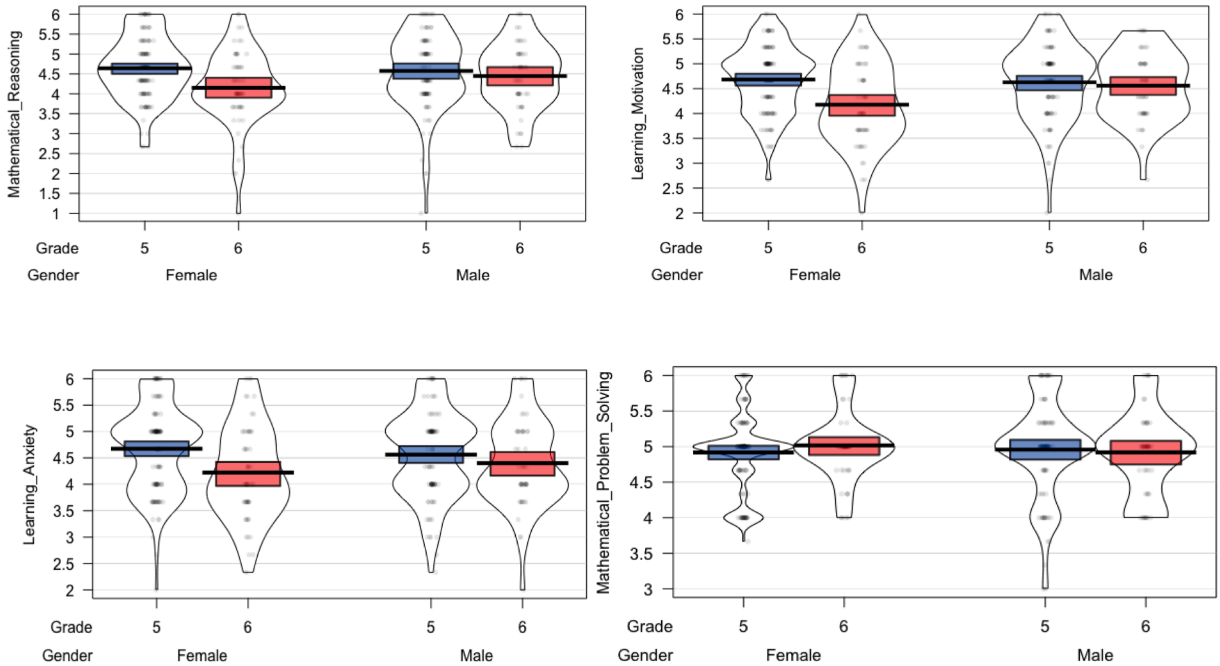

Fig. 4. Pirate plot of student performance among variables of different grade and gender.

Table 7
Summary of the student's learning motivation, learning anxiety, mathematical reasoning, and mathematical problem solving in various categories.

Category	MR		MP		LA		LM	
	M	SD	M	SD	M	SD	M	SD
Gender								
Female	4.49	.88	4.95	.55	4.53	.86	4.53	.77
Male	4.53	.91	4.95	.65	4.51	.84	4.60	.74
Age								
10 years old	4.40	.96	4.96	.58	4.55	.84	4.56	.75
11 years old	4.64	.77	4.93	.61	4.48	.86	4.56	.76
Grade								
5^{th}	4.61	.86	4.93	.62	4.63	.83	4.66	.73
6^{th}	4.29	.91	4.97	.54	4.31	.86	4.36	.78
Type school								
Public	4.79	.73	4.99	.56	4.67	.79	4.77	.64
Private	4.39	.92	4.93	.61	4.46	.87	4.48	.79
Place								
City	4.68	.89	4.99	.61	4.64	.91	4.65	.78
Subbursts	4.21	.79	4.87	.57	4.33	.69	4.40	.69
Ethnicity								
Javanese	4.53	.77	4.95	.59	4.48	.86	4.54	.79
Lampung	4.64	.88	4.87	.50	4.43	.81	4.50	.71
Sundanese	4.13	.98	5.07	.58	4.50	.68	4.20	.80
Batak	4.13	1.47	4.78	.63	4.62	.77	4.52	.63
Others	4.24	1.09	5.13	.65	4.49	.93	4.63	.65
Padang	4.38	.55	5.38	.45	4.83	.81	4.71	.73
Bugis	4.67	.67	4.93	.83	4.92	.91	4.96	.53

Note: Learning anxiety = LA; Learning motivation = LM; Mathematical problem solving = MP; Mathematical reasoning = MR; Mean score = M; Standard deviation = SD.

successfully solve problems, they may develop a higher sense of self-efficacy and confidence in their abilities. This growing confidence can fuel intrinsic motivation, as people become more invested in their learning process and derive satisfaction from mastering mathematical concepts or puzzles. Furthermore, the sense of accomplishment derived from successful mathematical reasoning tasks can act as a catalyst for continued participation and the desire to explore more challenging problems, further driving intrinsic motivation.

The discovery of a positive association between mathematical reasoning and mathematical problem solving is a notable result of our research. These investigations also support the study in the literature that we have mentioned before (Amalina & Vidákovich, 2023; Green et al., 2017; Román-González et al., 2017). Mathematical reasoning involves the cognitive processes used to understand, analyse, and logically solve mathematical problems, often requiring critical thinking and analytical skills (Altun & Yildirim, 2023). When individuals possess strong mathematical reasoning abilities, they tend to approach problem solving tasks with a more structured and systematic mindset (Maries & Singh, 2023). This structured approach allows people to break down complex problems into manageable components, apply logical reasoning, and employ various problem solving strategies effectively. As a result, people with higher proficiency in mathematical reasoning often demonstrate improved capabilities to solve mathematical problems efficiently and accurately (Angraini et al., 2023). The correlation between mathematical reasoning and mathematical problem solving highlights the integral role of reasoning skills in effectively navigating mathematical challenges. Strengthening mathematical reasoning abilities can potentially lead to improved problem solving skills (Anggoro et al., 2023), allowing people to tackle a wide range of mathematical problems with confidence and accuracy (Ruiz et al., 2023). Understanding this positive association emphasises the importance of fostering mathematical reasoning skills in educational settings to cultivate proficient problem-solving skills among learners.

Lastly, the research revealed an intriguing discovery about the mediation role of mathematical problem solving in its association with both learning anxiety and learning motivation. This mediation effect signifies that mathematical problem solving plays a crucial role in influencing the relationship between these factors (Hasanah et al., 2019; Kramarski et al., 2010). Specifically, in terms of learning anxiety, the mediation analysis revealed a positive association between mathematical problem solving and reduced learning anxiety. This suggests that people with stronger problem-solving skills in mathematical contexts tend to exhibit lower levels of learning anxiety. Proficiency in problem solving might equip people with the confidence and tools needed to approach learning tasks more effectively, thus mitigating feelings of anxiety associated with learning (Van Vo & Csapó, 2023). On the contrary, in the context of learning motivation, the mediation analysis demonstrated a positive link between mathematical problem solving and increased learning motivation. Individuals who show stronger mathematical problem solving abilities are more likely to exhibit higher levels of motivation toward learning. Enhanced problem solving skills might foster a sense of achievement, participation, and interest in learning, thus positively influencing motivation levels. The identified mediation roles underscore the importance of mathematical problem solving in influencing both learning anxiety and motivation. Strengthening problem-solving skills could potentially serve as a pathway to alleviate learning anxiety while simultaneously fostering a more motivated approach to learning.

Limitations and future research

Although this study presents valuable information on the factors that influence the solving of mathematical problems among primary education students, there are several notable limitations. First, the use of a cross-sectional design implies that the relationship between variables is correlational rather than causal. Therefore, future investigations should aim to validate these findings through longitudinal studies. Second, reliance on self-reported data from students might limit the depth of understanding, suggesting the need to complement this approach with observational methods for a more comprehensive view of students' learning motivation. Consequently, future research should explore various methodologies to gain deeper insight into strategies to increase learning motivation. Third, the study exclusively focusses on mathematical problem solving variables in relation to mathematical reasoning, learning anxiety, and learning motivation. However, there exist additional factors, such as critical thinking, creative thinking, and knowledge of pedagogical content that could significantly impact the ability to solve mathematical problems among students. Further exploration of these factors in relation to mathematical problem solving could illuminate nuanced strategies to foster enhanced problem-solving abilities in educational settings. Lastly, we do not have any control variables (i.e., socioeconomic status, gender, creative thinking skills) in this study. Future research endeavours could consider incorporating these variables to provide a more comprehensive understanding of the factors that influence the observed results.

Conclusions

The study explored the role of mathematical problem solving as a mediator between learning motivation, learning anxiety, and mathematical reasoning. A key finding highlighted the strong direct association between learning anxiety and learning motivation, underscoring the intricate interplay between student behaviour and emotional responses that influence their academic participation. This unexpected positive correlation suggests that increased learning anxiety might coincide with increased motivation, which is consistent with previous research. Furthermore, the study indicated a positive link between learning anxiety and solving mathematical problems. This aligns with previous evidence suggesting that learning anxiety can alter actual problem solving processes and maths performance, which warrants attention from educators to help students cope with such challenges. Another significant finding was the identification of mathematical reasoning as a predictor of learning anxiety, supporting the initial hypothesis that stronger mathematical reasoning positively relates to learning anxiety. This aligns with the existing literature that indicates that participating in mathematical reasoning tasks can induce stress due to the complexity of problem solving, potentially affecting learning outcomes.

Furthermore, the study revealed a positive association between mathematical reasoning and motivation to learn. This finding corroborates previous research, suggesting that engaging in mathematical reasoning fosters a positive attitude toward learning, possibly due to the intellectual stimulation and sense of accomplishment derived from solving mathematical problems. In addition, the research highlighted a positive correlation between mathematical reasoning and mathematical problem solving. This aligns with previous studies, which indicate that people who are proficient in reasoning tend to excel in problem-solving tasks, underscoring the importance of strengthening reasoning skills to enhance problem-solving abilities. Lastly, the study revealed the mediation role of mathematical problem solving between learning anxiety, learning motivation, and other variables. Proficiency in problem solving emerged as a key factor in reducing learning anxiety and fostering greater motivation for learning. Strengthening problem-solving skills could serve as a strategy to alleviate learning anxiety while promoting a more motivated learning approach. In practical terms, educators have a powerful tool at their disposal to enhance student motivation: integrating reasoning activities into the curriculum. Simultaneously, interventions that focus on improving problem-solving skills can serve a dual purpose by alleviating learning anxiety and fostering greater motivation. Policymakers should take note of these practical applications and consider initiatives that prioritise the development of these skills, thus contributing to a more effective and positive learning environment. The theoretical implications of the study emphasise the intricate relationship among mathematical reasoning, problem solving proficiency, and learning motivation. These insights advocate for the development of educational frameworks that seamlessly integrate these elements, enriching the overall quality of the learning experience. Recognising the synergies between reasoning, problem solving, and motivation, educators and curriculum designers can design interventions that holistically nurture students' mathematical abilities. On a broader scale, incorporating these findings into educational reforms can lead to a more comprehensive and effective approach to mathematics education. Policymakers can play a crucial role in ensuring that these insights guide future initiatives, shaping an educational landscape that better equips students for success in mathematics and beyond.

CRediT authorship contribution statement

Nanang Supriadi: Supervision, Funding acquisition, Writing – review & editing. **Wan Jamaluddin Z:** Visualization, Writing – review & editing. **Suherman Suherman:** Conceptualization, Writing – original draft, Formal analysis, Methodology, Writing – review & editing, Visualization.

Declaration of competing interest

There are no conflicts of interest to declare.

Data availability

Data will be made available on request.

Acknowledgements

We are thankful to the Universitas Islam Negeri Raden Intan Lampung, Indonesia for their research funding support. We also thank the Doctoral School of Education, the University of Szeged, which provided suggestions and discussions for an idea in the research view. The study was supported by a grant from the University of Szeged Open Access, the Grant Number is 6833.

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