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Relationships among Achievement Emotions, Mathematical Problem-Solving Beliefs, and Metacognition in Indonesian High School Students

Rafiq Zulkarnaen[1*], Gida Kadarisma[2]

[1] Universitas Singaperbangsa Karawang, Jawa Barat , Indonesia
[2] IKIP Siliwangi, Jawa Barat, Indonesia

[*] Correspondence: rafiq.zulkarnaen@fkip.unsika.ac.id

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Abstract

Mathematics learning is influenced not only by cognitive factors but also by affective components such as emotions, beliefs, and metacognition. However, limited research has explored how achievement emotions interact with mathematical problem-solving beliefs and metacognition, particularly among Indonesian students. This study examine the relationships between achievement emotions, mathematical problem-solving beliefs, and metacognition in 750 Indonesian high school students from 10th and 11th grades. The Participants completed questionnaires measuring achievement emotions (in classroom and test contexts), mathematical problem-solving beliefs, and metacognitive components awareness, cognitive strategies, planning, and self-checking. The findings demonstrated substantial associations among these elements: positive emotions, particularly enjoyment and pride, reinforced both problem-solving beliefs and metacognition, while negative emotions like anxiety and anger impaired them during mathematical problem-solving tasks. The outcomes emphasize the critical role of developing positive emotions such as enjoyment and pride while diminishing negative emotions, particularly anxiety, in enhancing students' metacognitive skills and mathematical problem-solving performance. In addition, this study supports the Control-Value Theory of Achievement Emotions by empirically validating that mathematical problem-solving beliefs act as intermediaries between emotions and metacognitive processes. This contribution offers new theoretical insight into how affective factors shape higher-order cognitive regulation, providing a novel understanding of the emotional foundations of mathematics learning in the Indonesian context. These findings emphasize the importance of emotions in shaping students' engagement with mathematics and highlight the need for teaching strategies that promote emotional well-being alongside cognitive development.

Keywords: Achievement Motivation; Cognitive Appraisals; Emotional Regulation; Problem-Solving Strategies; Self-Efficacy in Mathematics

Introduction

In mathematics learning, it is essential for educators to consider not only students' cognitive aspects but also their affective factors (Zulkarnaen, 2018). Affective factors broadly encompass attitudes toward mathematics, mathematical problem-solving beliefs, as well as emotions related to mathematics. Specifically, emotions such as anxiety, satisfaction, enjoyment, and surprise may arise when students encounter particular mathematical tasks (Gomez-chacon, 2000). These emotions including enjoyment, pride, anxiety, and boredom are common experiences for students. Emotions can be experienced in three academic contexts: within the classroom, during self-study, and when confronted with exams or tests (Lichtenfeld et al., 2012; Pekrun et al., 2002).

Emotions are typically categorized into positive and negative emotions. Positive emotions are believed to influence students' performance indirectly, mainly through the mediating roles of cognitive processes, metacognition, and self-regulatory behaviors (Pekrun, 2006; Goetz et al., 2006). The effect of emotions on performance operates through three distinct mechanisms: memory contingent upon mood states, strategies of cognitive and metacognitive learning, and the deployment of available cognitive resources (Pekrun & Stephens, 2010). Achievement emotions constitute the affective states associated with educational activities and academic performance outcomes (Pekrun & Stephens, 2010; Pekrun et al., 2002; Pekrun et al., 2014; Schukajlow et al., 2023). For example, affective states experienced during mathematical problem-solving engagement constitute achievement-related activities, whereas emotions pertaining to achievement outcomes encompass the dichotomy of success or failure in problem resolution. Pride in successfully solving a mathematical problem exemplifies an emotion tied to past achievements, while fear of failure in a math exam is an emotion related to future achievement outcomes (Schukajlow, et al., 2023).

Mathematical problem-solving is a vital component of mathematics learning, enabling students to apply their knowledge and prior experiences to various problem contexts (Zulkarnaen & Ruli, 2023). When students tackle mathematical problems, their performance is influenced by a combination of interconnected factors. These include how they feel about their achievements, what they believe about their ability to solve math problems, and the ways they reflect on and regulate their own thinking. Enjoyment and pride enhance students' ability to plan and engage effectively in the problem-solving process, which strengthens their confidence and persistence, whereas negative emotions often reduce cognitive engagement and hinder problem-solving performance (Pekrun et al., 2017). These emotional experiences are closely related to students' beliefs about their capability to solve mathematical problems and the strategies they adopt. Furthermore, Kossahdasabitah & Zulkarnaen (2025) found a strong positive correlation between metacognition and achievement emotions, suggesting that emotional factors play a crucial role in regulating metacognitive processes during mathematical problem solving.

At multiple educational levels, many students maintain beliefs about solving mathematical problems that can detrimentally influence their ability or inclination to engage productively in problem-solving tasks (Stylianides & Stylianides, 2014). Higher levels of mathematical problem-solving self-belief correlate with improved mathematical performance and competency, factors that may play a role in students' career planning processes (Kwon et al., 2021). Conversely, high school students tend to be more affected in their career planning by beliefs that stem from unsuccessful mathematics performance (Franz-Odendaal et al., 2016). Students with strong metacognitive are more adept at planning, monitoring, and adjusting their problem-solving strategies, which leads to better outcomes in solving complex problems. These concepts form the basis for the current study, which seeks to examine the relationships between achievement emotions, mathematical problem-solving beliefs, and metacognitive. Within the Indonesian educational context, research in mathematics learning has largely emphasized cognitive aspects, whereas affective components particularly achievement emotions have received comparatively limited scholarly attention. This gap is noteworthy, as Control-Value Theory (CVT) posits that students' perceptions of control and value play a crucial role in shaping achievement emotions, which subsequently influence cognitive engagement, motivation, and academic performance (Zulkarnaen & Nur, 2024). Proficient emotional self-regulation correlates with increased enjoyment and pride, which subsequently enhance student motivation and facilitate superior learning outcomes (Kossahdasabitah & Zulkarnaen, 2025). Accordingly, an examination of the interrelations among achievement emotions, beliefs pertaining to mathematical problem-solving, and metacognitive processes is imperative for constructing a more integrated understanding of contributory factors to students' mathematical problem-solving proficiency.

Metacognitive experiences, such as reflecting on one's thinking process, can influence how students make decisions about their learning and evaluate their abilities, which, in turn, affects their achievement-related emotions (Efklides et al., 2011). Based on these self-assessments, students may experience emotions such as anxiety, pride, or joy after a successful outcome, or shame, anger, and boredom following failure (Leiss et al., 2010; Pekrun, 2006; Pekrun & Stephens, 2010). Students evaluate their abilities to solve mathematical problems and assess whether they can achieve the desired outcome. This evaluation is influenced by previous learning experiences, as well as the challenges or successes they encounter during problem-solving. Emotions are recognized as an integral part of the problem-solving process, influencing attention, cognitive processing, and self-regulation all of which are crucial for successful problem solving (Hannula, 2015). During problem-solving, students may experience emotions that are activated (e.g., high arousal) or deactivated (e.g., low arousal), such as enjoyment, anger, or boredom (Efklides et al., 2011). Students who evaluate their ability to solve problems with confidence are more likely to persist through difficulties and ultimately succeed in solving the problem correctly (Zulkarnaen & Ruli, 2023).

The main aim of this research is to explore, utilizing a SEM framework, the connections between achievement emotions, beliefs about mathematical problem-solving, and metacognitive processes. The study proposes that: (1) achievement emotions significantly influence mathematical problem-solving beliefs; (2) mathematical problem-solving beliefs are positively associated with students' metacognition; and (3) enjoyment and pride positively influence metacognition, while negative anxiety, anger, and boredom negatively impact metacognition in the context of mathematical problem-solving.

Methods

To address the research objectives, data were collected from a state high school in Karawang, West Java, Indonesia, to accomplish the research objectives. The study included 750 participants from the 10th and 11th grades. Random sampling techniques were applied to ensure equitable inclusion opportunities for all students. The measurement process was conducted about two months into the school year, extending from September's beginning to October's end in 2024.

The original Achievement Emotions Questionnaire for Mathematics (AEQ-M), developed by Bieleke et al. (2023), assesses achievement emotions across seven scales: enjoyment, pride, anger, anxiety, shame, boredom, and hopelessness, all related to mathematics in three settings: class, self-studying, and test. The scales demonstrated good to very good reliability, with Cronbach's alpha values ranging from 0.84 to 0.91. For the purpose of this research, five items were included for each of the following emotions: enjoyment (e.g., "I enjoy my class so much that I am strongly motivated to participate"), pride (e.g., "After having done my math homework, I am proud of myself"), anxiety (e.g., "Math scares me so much that I would rather not attend school"), boredom (e.g., "I think the mathematics class is boring"), and anger (e.g., "I am annoyed during my math class"). All items were scored on a 5-point Likert scale (1 = not true at all, 2 = hardly true, 3 = neutral, 4 = largely true, 5= exactly true).

The Mathematical Problem-Solving Beliefs Questionnaire (MPSBQ), adapted from Sintema & Mosimege, (2023) consists of six subscales: I can solve time-consuming mathematics problems (e.g., “I feel I can do math problems that take a long time to complete”), There are word problems that cannot be solved with simple, step-by-step procedures (e.g., “Memorizing steps is not that useful for learning to solve word problems”), Understanding concepts is important in mathematics (e.g., “In addition to getting a right answer in mathematics, it is important to understand why the answer is correct”), Word problems are important in mathematics (e.g., “A person who can’t solve word problems really can’t do math”), Effort can increase mathematical ability (e.g., “Working can improve one’s ability in mathematics”), and Mathematics is useful in daily life (e.g., “I study mathematics because I know how useful it is”). The survey consisted of 36 items on a 4-point Likert scale (1 = strongly disagree, 2 =disagree, 3 = neutral, 4 = agree, and 5 = strongly agree).

The adaptation process involved several stages: (1) the original instrument was translated into Indonesian; (2) contextual adjustments were made to align the items with the school environment and educational context in Indonesia; (3) a pilot test was conducted after translation and contextual modification; and (4) the results indicated excellent validity with a score of 0,90 and high reliability with a score of 0,85. The Metacognition Questionnaire (MQ) adopted form O’Neil & Abedi (1996) with four sub-scale: awarennes (e.g., “I was aware of my own thinking”), cognitive strategy (e.g., “I attempted to discover the main ideas in the test questions”), planning (e.g., “I tried to determine what the test required”), and self-checking (e.g., “I corrected my errors”). The survey consit 20 item on a 4-point Likert scale (1 = Not at all, 2 = Some-what, 3 = neutral, 4 = Moderately so, 5 = Very much so).

The preliminary analysis included correlations between the observed variables. Following this, multivariate normality tests were conducted using the PRELIS-2 program to evaluate the underlying statistical assumptions for confirmatory factor analysis and structural equation modeling estimation methods. Confirmatory factor analysis (CFA) was conducted to validate the measurement models of the Achievement Emotions Questionnaire for Mathematics (AEQ-M), the Mathematical Problem-Solving Beliefs Questionnaire (MPSBQ), and the Metacognition Questionnaire (MQ). The use of CFA was appropriate because this study aimed to confirm the theoretical structure of each construct based on previously established models and to ensure that each latent variable was accurately represented by its observed indicators with acceptable levels of validity and reliability. To evaluate model fit, various goodness-of-fit indices were considered. Confidence intervals (95%) for the path coefficients were also estimated in the final model. The comparative fit index (CFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA) are common criteria for evaluating model fit in structural equation modeling. A good model fit is indicated by CFI and TLI values greater than 0.95, whereas RMSEA values should be below 0.08 for an adequate fit and below 0.06 for an excellent fit.

Following the CFA, Structural Equation Modeling (SEM) was applied to examine the hypothesized relationships among achievement emotions, mathematical problem-solving beliefs, and metacognition within a single comprehensive model. The use of SEM was justified because it allows simultaneous estimation of multiple dependent relationships and provides robust analyses of both direct and indirect effects among latent variables. This analytical approach enabled the researchers to test the predictive and mediating pathways among affective and cognitive constructs while accounting for measurement errors. Therefore, combining CFA and SEM offered a rigorous and comprehensive framework to validate the measurement models and to evaluate the theoretical relationships proposed in this study.

Results and Discussion

The evaluated variables demonstrated complete data integrity with no missing values observed; consequently, imputation methodologies were not implemented. Table 1 delineates the descriptive properties of each variable under investigation, whilst Table 2 elucidates the bivariate correlations among these constructs.

Table 1. Properties of All Study Variables

Variable	No. Items	M	SD	α	Range	Skewness	Kurtosis
Achievement Emotions Questionnaire for Mathematics (AEQ-M)							
Enjoyment	5	3.29	0.56	0.65	1-5	0.09	-0.08
Pride	5	3.37	0.57	0.59	1-5	-0.26	0.10

Anger	5	3.65	0.52	0.71	1-5	-0.20	-0.13
Bored	5	3.34	0.49	0.52	1-5	-0.18	0.22
Anxiety	5	3.41	0.62	0.77	1-5	-0.25	-0.42
Mathematical Problem-Solving Beliefs Questionnaire (MPSBQ)							
I Can Solve Time-consuming Mathematics Problems (TCMP)	6	3.55	0.61	0.84	1-5	-0.50	0.15
There are word problems that cannot be solved with simple, step-by-step procedures (SbsP)	6	3.36	0.68	0.86	1-5	-0.28	-0.04
Understanding concepts is important in mathematics (UciM)	6	3.34	0.75	0.87	1-5	-0.33	-0.28
Word problems are important in mathematics (WPiM)	6	2.48	0.90	0.91	1-5	0.48	-0.47
Effort can increase mathematical ability (EfiMa)	6	2.68	0.75	0.87	1-5	0.33	-0.26
Mathematics Is Useful in Daily Life (Muidl)	6	2.23	0.77	0.89	1-5	0.84	0.43
Metacognitive Questionnaire (MQ)							
Awareness	5	3.65	0.55	0.71	1-5	-0.19	0.20
Cognitive Strategy	5	3.81	1.29	0.72	1-5	-0.16	-0.82
Planing	5	3.65	1.11	0.68	1-5	-0.09	-0.60
Self-checking	5	3.40	0.62	0.75	1-5	-0.55	0.43

Cronbach's alpha coefficient was calculated to determine the internal reliability of each questionnaire. In general, the values showed high internal consistency within the three instruments measuring achievement emotions, mathematical problem-solving beliefs, and metacognition. The PRELIS program was used to assess normality through Mardia's measure of relative multivariate kurtosis (MK); the values were MK = 1.12 for the AEQ-M CFA, MK = 1.19 for the MPSBQ CFA, and MK = 1.13 for the MQ. All MK values were nonsignificant.

Table 2. Correlations matrix for all study variable

Latent Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Joy	-														
2. Pride	.35	-													
3. Anger	-.25	-.32	-												
4. Bored	-.57	-.38	.35	-											
5. Anxiety	-.51	-.45	.48	.53	-										
6. TCMP	.37	.31	-.24	-.33	-.34	-									
7. SbsP	.31	.20	-.24	-.23	-.22	.52	-								
8. UCiM	.47	.32	-.27	-.39	-.36	.74	.40	-							
9.WPiM	.41	.25	-.27	-.30	-.28	.66	.74	.53	-						
10.EfiMa	.42	.37	-.30	-.34	-.36	.42	.44	.34	.23	-					
11. Muidl	.38	.26	-.09	-.26	-.15	.33	.66	.42	.35	.38	-				
12. Aw	.12	.14	-.08	-.13	-.16	.39	.42	.34	.41	.31	.32	-			
13. CS	.28	.23	-.13	-.19	-.12	.42	.34	.21	.22	.42	.34	.35	-		
14. Plan	.20	.36	-.15	-.16	-.15	.35	.32	.42	.21	.35	.26	.45	.51	-	
15. SC	.21	.36	-.02	-.17	-.21	.62	.25	.33	.38	.21	.37	.37	.46	.57	-

Note: all correlation at p < 0,001. Joy: enjoyment; TCMP: I Can Solve Time-consuming Mathematics Problems; SbsP: There are word problems that cannot be solved with simple, step-by-step procedures; UciM: Understanding concepts is important in mathematics; WPiM: Word problems are important in mathematics; EfiMa: Effort can increase mathematical ability; Muidl: Mathematics Is Useful in Daily Life (Muidl); Aw: awareness, CS: cognitive strategy; SC: self-checking.

Confirmatory factor analysis (CFA) was conducted to assess the factor structure of the AEQ-M, MPSBQ, and MQ instruments.The CFA of Achievement Emotions Questionnaire for Mathematics (AEQ-M) included 30 observed variables and six latent variables: enjoyment, pride, anger, bored, and anxiety. All factor loading of AEQ-M were significant at the 0.001 level and the average factor loading was 0.84. The CFA of Mathematical Problem-Solving Beliefs Questionnaire (MPSBQ) included 36 observed variables and six latent variable: TCMP, SbSp, UciM, WpiM, EfiMa, Mudl. All factor loading of MPSBQ were significant at the 0.001 level and the average factor loading was 0.68. The CFA of Metacognitive Questionnaire (MQ) included 20 observed variables and four latent variable: awareness, cognitive strategy, planing, and self-checking. All factor loading of MPSBQ were significant at the 0.001 level and the average factor loading was 0.77.

The correlation matrix revealed that positive emotions such as joy and pride were moderately related (r = .35), while joy showed strong negative correlations with boredom (r = –.57) and anxiety (r = –.51), indicating an inverse relationship between positive and negative emotions. Among problem-solving beliefs, UCiM exhibited the strongest associations with TCMP and WPiM (r = .74), highlighting the role of conceptual understanding in problem-solving confidence. Within metacognitive components, Planning (r = .51) and Self-Checking (r = .57) were most strongly related, suggesting that these aspects are central to students' metacognitive regulation, whereas Awareness showed relatively weaker associations.

Table 3. Result of CFA of AEQ-M, MPSB, and MQ

Questionnaire	χ^2	df	TLI	CFI	$RMSEA$	$90\%\ CI$
AEQ-M	997.23	109	0.94	0.96	0.042	[0.041, 0.043]
MPSBQ	500.35	59	0.88	0.97	0.061	[0.061, 0.063]
MQ	1034.05	146	0.97	0.97	0.038	[0.036, 0.039]

The measurement and structural models demonstrated acceptable fit to the data, CFI > 0.90, RMSE < 0.08, and TLI > 0.90 indicating that the proposed model adequately represents the observed relationships among the variables. Structural equation modeling (SEM) to verify our hypotheses that achievement emotions (enjoyment, pride, anxiety, bored, and anger) influence mathematical problem-solving beliefs, and the mathematical problem-solving beliefs influence metacognition. In turn, achievement emotions and mathematical problem-solving beliefs affect metacognition. Results of the SEM are shown in Figure 1 after removing insignificant paths. All the standardized coefficients were significant at the .001 level.

As expected, enjoyment affected all aspect of mathematical problem-solving beliefs (TCMP, β = 0.65; SbsP, β = 0.45 UciM, β = 0.28; WPiM, β = 0.34; EfiMA, β = 0.18; Muidl, β = 0.24); enjoyment affected cognitive strategy and self-checking (β = 0.32, β = 0.65 respectively); pride affected TCMP (β = 0.23), pride affected planing and self-checking checking (β = 0.61, β = 0.32 respectively); anxiety affected TCMP, SbSP, and EfiMA (β = -0.27, β = -0.31, β = -0.21 respectively); anxiety affected planing and self-checking checking (β = -0.35, β = -0.27 respectively); and, SbSP, UCiM, EfiMa effected Cognitif Strategy (β = 0.27, β = 0.31, β = 0.21 respectively).

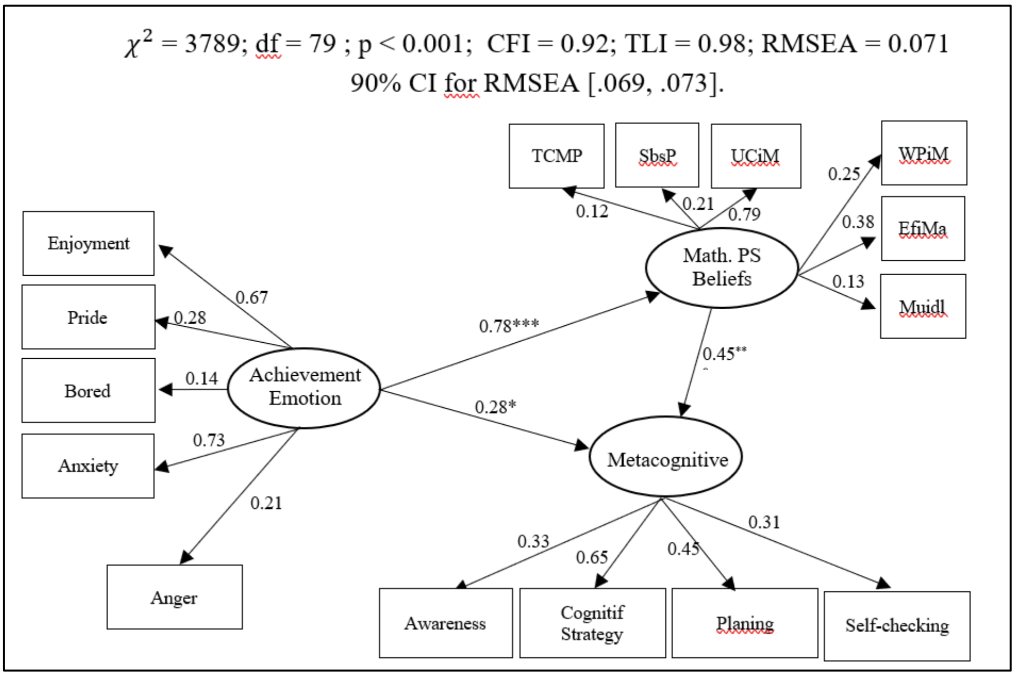

Figure 1. Path diagram of the mediation model. Figures represent standardised regression coefficients. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The present study examines the relationships among achievement emotions (e.g., enjoyment, pride, anxiety, anger, and boredom), mathematical problem-solving beliefs, and metacognition in high school students while solving mathematical problems. The study's key contributions are threefold. First, consistent with the hypotheses, the results indicate that emotions such as enjoyment, pride, and anxiety significantly influence mathematical problem-solving beliefs. Second, mathematical problem-solving beliefs are positively associated with students' metacognition. Third, enjoyment and pride positively influence metacognition, while anxiety, anger have a negative impact on metacognition in the context of mathematical problem-solving. This relationship is partially mediated by mathematical problem-solving beliefs.

The current results confirm that achievement emotions are pivotal in determining mathematical problem-solving beliefs. Previous studies have revealed that positive emotions, particularly enjoyment, are significantly related to strengthened beliefs in mathematical competence (Goetz et al., 2010; Peixoto et al., 2016). This suggests that when students experience enjoyment and pride, they are more likely to believe in their abilities, which, in turn, strengthens their motivation and persistence in solving challenging problems. In contrast, negative emotions such as anxiety are detrimental to competence beliefs (Goetz et al., 2010; Li et al., 2021; Peixoto et al., 2016), highlighting the critical importance of emotions in mathematics learning and problem-solving activities (Avry et al., 2020).

Although students may hold relatively stable beliefs about mathematics, their emotions during problem-solving are generally more intense and fluctuate more significantly (Leder & Grootenboer, 2005). Achievement emotions during mathematical problem-solving interact with and influence the heuristics or strategies students use. Emotions like anxiety, pride, and enjoyment can affect the selection and application of problem-solving strategies. This dynamic process, where emotions and heuristics continuously influence one another, is supported by Debellis & Goldin (2006) concept of affective pathways, which describes the interaction between emotional states and problem-solving heuristics.

Creating a positive learning environment that fosters enjoyment and active engagement with mathematics is crucial. This can be achieved through the integration of enjoyable, hands-on activities, promoting collaborative problem-solving, and applying mathematical concepts to real-world situations to make the subject more engaging and relatable for students (Van der Beek et al., 2024). Theoretically, this study extends Pekrun's Control-Value Theory (CVT) by demonstrating that mathematical problem-solving beliefs mediate the relationship between achievement emotions and metacognition. This finding deepens the understanding of how affective and cognitive processes interact in mathematical learning. Compared with previous studies, such as Zulkarnaen and Nur (2024) which emphasized the direct impact of achievement emotions on mathematics learning outcomes, the present research highlights an indirect pathway through belief systems. Thus, the results contribute to a more comprehensive model of emotional regulation in mathematics education, explaining how achievement emotions shape higher-order cognitive processes through students' problem-solving beliefs.

Flavell (as cited in Buratti & Allwood, 2015) defines metacognition as "an individual's knowledge about their own cognitive processes or anything related to them." Similarly, Brown (as cited Tarricone, 2011) describes it as an individual's awareness and control over their cognitive system. Thus, metacognition can be understood as "thinking about thinking." In the context of mathematical problem-solving, students' mathematical problem-solving beliefs refer to their perceptions of their ability to solve mathematical problems. Stronger problem-solving beliefs are linked to greater self-confidence, which, in turn, improves the accuracy of students' predictions regarding problem difficulty. When students believe in their ability to solve a problem, they are more likely to accurately assess its difficulty and allocate their efforts more effectively.

Prediction skills allow students to consider learning objectives, relevant characteristics of problems, and available time when approaching a task. This skill enables them to estimate the difficulty of a problem and regulate their engagement based on anticipated outcomes. The ability to select appropriate strategies and allocate resources is closely associated with prediction skills (Desoete, 2008). Monitoring, in turn, involves being aware of one's understanding and progress during the mathematical problem-solving process. It refers to an individual's real-time awareness of their comprehension and performance during the task. An example of monitoring is engaging in periodic self-testing throughout the learning process (Winne, 1997). After completing a task, students can evaluate their performance by comparing it to others or their previous attempts. This evaluation helps identify mistakes or areas for improvement in the problem-solving process (Desoete et al., 2001).

Metacognition plays a vital role in mathematical problem-solving as it involves regulating cognitive processes throughout the problem-solving journey. By actively predicting, monitoring, and evaluating their performance, students can adjust their strategies, identify difficulties, and improve their problem-solving approach. The integration of metacognitive skills in problem-solving promotes more effective and efficient learning, as students are better able to assess their progress, identify errors, and refine their strategies, ultimately enhancing their overall problem-solving performance.

The results of this study support the hypothesis proposed in the introduction: enjoyment and pride positively influence metacognition, while negative emotions such as anxiety, anger, and boredom negatively impact metacognition in the context of mathematical problem-solving. The presence of positive emotions, notably enjoyment, correlates with increased deployment of advanced metacognitive and cognitive processing strategies among students (Acosta-Gonzaga & Ramirez-Arellano, 2021). Positive emotions also predict academic motivation and the use of meaningful learning strategies (Trigueros et al., 2020) , while negative academic emotions are associated with lower levels of metacognitive engagement (Tugade & Fredrickson, 2004). Students who feel less boredom, anger, shame, and hopelessness but more engagement and pride tend to use more advanced metacognitive strategies (Butz et al., 2016). High metacognitive awareness facilitates the acquisition and understanding of mathematical concepts and ideas (Layco, 2020). This theoretical contribution highlights that emotions influence not only students' motivation and cognitive engagement but also their higher-order thinking through belief systems. Academically, the study integrates affective, cognitive, and metacognitive dimensions into a unified framework, offering a more comprehensive explanation of how emotional regulation supports self-regulated learning and adaptive problem-solving in mathematics. Moreover, research on achievement emotions in mathematics education particularly within the Indonesian context remains limited. Therefore, this study provides a valuable reference for understanding the essential role of emotions in mathematics education and for guiding future research in this area.

Enjoyment positively predicts the use of metacognitive strategies (Muis et al., 2015). After experiencing joy, students are more likely to engage in monitoring their progress than using other strategies during mathematical problem-solving (Di Leo et al., 2019). Educators ought to support students throughout their educational journey by conveying genuine enthusiasm and dedication to learning, thereby cultivating self-efficacy beliefs and perceptions of academic competence that serve as cornerstones for scholastic success (Trigueros et al., 2020). Students' perception of mathematics as useful and relevant increases their likelihood of experiencing positive emotions, maintaining motivation, and having fewer negative emotional experiences. Providing meaningful, real-world problems can increase student engagement, while connecting mathematical concepts to real-life applications can deepen students' appreciation of the subject's importance. When students face difficulties in their thinking, their emotions play a key role in maintaining their engagement in learning (Barnes, 2020).

Conclusion

This study's findings emphasize the substantial impact of achievement emotions in forming mathematical problem-solving beliefs and metacognitive processes in secondary school students. Positive emotions, such as enjoyment and pride, were found to enhance students' beliefs in their mathematical competence and were positively associated with better metacognitive regulation. In contrast, negative emotions like anxiety, anger, and boredom negatively impacted students' metacognitive processes, thereby hindering their ability to employ effective problem-solving strategies. Additionally, mathematical problem-solving beliefs were identified as an important mediator in the relationship between achievement emotions and metacognition, suggesting that how students perceive their ability to solve mathematical problems influences their emotional experiences and metacognitive strategies.

These results underscore the importance of fostering a positive emotional climate in mathematics learning. Teachers should create learning environments that encourage engagement, reduce anxiety, and promote positive emotions to enhance students' confidence and persistence in problem-solving. Integrating enjoyable activities, real-world problem-solving tasks, and collaborative learning can help reduce negative emotions and increase the likelihood of students engaging in effective metacognitive strategies. Future research should explore additional factors that influence the dynamic relationship between emotions, beliefs, and metacognition in mathematics problem-solving. Understanding how these elements interact can provide valuable insights for developing interventions aimed at improving students' emotional regulation and metacognitive skills, ultimately enhancing their performance in mathematics.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the research, authorship, and publication of this article.

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