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Exploring Students' Creative Thinking in Mathematical Problem Solving: A Descriptive Qualitative Study

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Abstract

This study explores students' creative thinking skills in mathematics through a descriptive qualitative approach. The purpose of the research is to examine how students construct and express original ideas when solving open-ended mathematical problems. Participants were selected purposively based on their prior experience with similar tasks, and data were obtained from students' written responses to problem-solving activities designed to promote divergent thinking. These tasks emphasized multiple solution strategies, reasoning justification, and reflection on originality. The data were analyzed thematically using NVivo 14, focusing on creativity indicators such as fluency, flexibility, originality, and elaboration. The findings indicate that some students were able to demonstrate creative approaches in generating diverse and original solutions, while others experienced difficulties due to limited conceptual understanding and time constraints. These results underscore the need for instructional practices that strengthen prerequisite knowledge, offer varied task designs, and allocate sufficient time to enhance students' mathematical creativity. Overall, the study contributes to the development of pedagogical strategies that foster creative problem-solving in mathematics classrooms.

INTRODUCTION

Mathematical creative thinking is one of the essential skills that students must possess in learning mathematics (Susilawati et al., 2020). This ability encompasses the capacity to generate new ideas, solve problems innovatively, and develop alternative solutions. In the context of 21st-century mathematics education, such skills are crucial, given the increasingly complex challenges students face that demand adaptive and creative problem-solving. Several scholars have identified four fundamental components of mathematical creative thinking: fluency, flexibility, originality, and elaboration (Pratiwi et al., 2021). These aspects empower students to solve problems using conventional methods and approach mathematical tasks from multiple perspectives, constructing unique, context-relevant solutions.

However, empirical evidence suggests that students' understanding of mathematical creative thinking often does not align with established theoretical definitions. Despite being introduced to creative thinking concepts in mathematics classrooms, many students struggle to apply them effectively in open-ended problem contexts. Observations indicate that when faced with problems with multiple possible solutions, students frequently display rigid thinking patterns and rely on familiar strategies, rarely exploring alternative or innovative approaches (Švecová et al., 2014;

Mourtos, 2010). This situation reflects a persistent gap between students' conceptual understanding and their practical application of creative thinking in mathematics (Suherman & Vidákovich, 2022; Iskandar & Juandi, 2022). Several studies attribute this gap to factors such as limited exposure to real-world mathematical problems that necessitate creative thinking, inadequate emphasis on higher-order thinking skills in instructional practices, and the absence of structured opportunities for students to practice creative exploration in mathematics (Aziz & Kharis, 2021; Fülöp, 2015; Luria et al., 2017). Addressing this issue requires more than conceptual instruction; pedagogical strategies that challenge fixed mindsets and foster flexibility, originality, and elaboration in student problem-solving.

Furthermore, recent studies have highlighted that students often encounter cognitive and emotional barriers when working on tasks requiring creative mathematical thinking. Mathematics anxiety and low confidence levels are commonly reported, especially when students are confronted with problems that do not have a single, definitive answer (Karasel et al., 2010; Bullard & Bahar, 2023). Consequently, students tend to rely on procedural methods and avoid exploring novel ideas, thereby limiting their creative capacities (Bayarcal et al., 2023; Supandi et al., 2021). Such tendencies are evident even in inquiry-based approaches such as problem-based learning, where students face challenges activating creative thinking processes (Purba et al., 2017; Sitorus et al., 2019). These difficulties underscore the importance of providing structured support to help students build the cognitive flexibility and divergent thinking skills essential for mathematical creativity (Treffinger, 1995; Herman, 2018). Thus, conducting in-depth analyses of students' responses is crucial for revealing their underlying thought processes and identifying specific areas that require pedagogical intervention.

In this context, qualitative research methods offer valuable tools for exploring how students think and interact with complex mathematical tasks. NVivo, a qualitative data analysis software, has proven particularly effective in examining students' responses within the framework of mathematical creative thinking. It enables researchers to systematically organize data from interviews, observations, and other sources, perform coding, identify recurring patterns, and extract meaningful themes. Within mathematics education research, NVivo facilitates a deeper understanding of students' cognitive processes and how they apply creative thinking when solving mathematical problems (Yulianto & Wijaya, 2022). Therefore, this study aims to analyze students' responses to open-ended mathematical problems, to investigate the manifestation of creative thinking components, and to identify pedagogical implications for enhancing mathematical creativity in classroom practice.

METHODS

This study employed a descriptive qualitative approach to investigate students' creative thinking skills in mathematics. A qualitative design enables researchers to explore individuals' experiences and meanings in depth, emphasizing context-specific insights over numerical generalization (Creswell & Poth, 2018). This approach was appropriate for the study's goal of understanding how students construct and express creative ideas in mathematical problem-solving situations. The participants were selected using purposive sampling, a non-probability technique that allows researchers to intentionally select individuals based on specific characteristics relevant to the study (Miles, Huberman, & Saldaña, 2014). Students who had previously completed mathematics tasks involving open-ended problems were chosen in this case. This ensured the participants had sufficient experience with the reasoning and creativity under investigation. Data were collected through students' written responses to open-ended mathematical tasks, designed to elicit divergent thinking and novel solution strategies. These tasks required students to explore multiple pathways, justify their reasoning, and reflect on the originality of their answers. The data collection process followed ethical procedures, including obtaining informed consent from participants and ensuring confidentiality.

The research was conducted in three stages: (1) preparation of the open-ended tasks aligned with indicators of creative mathematical thinking, (2) administration of the tasks in a classroom setting under teacher supervision, and (3) collection and transcription of students' written responses. The tasks were adapted from prior research on creative thinking in mathematics (Silver, 1997; Leikin & Lev, 2007). This study utilized NVivo 14, a software that supports coding, organizing, and visualizing large volumes of qualitative data. Thematic analysis was applied to identify recurring patterns, strategies, and indicators of creativity, including fluency, flexibility, originality, and elaboration (Guilford, 1967; Krathwohl, 2002). Initial codes were generated based on theoretical constructs and refined inductively during the coding process. Data triangulation was employed throughout the analysis by comparing patterns across student responses and cross-validating interpretations with a second coder. This increased the credibility and trustworthiness of the findings (Lincoln & Guba, 1985). This study aimed to provide rich, contextual insights into students' creative mathematical thinking and inform pedagogical strategies that support creativity in mathematics education by employing a qualitative design with robust analytical procedures.

RESULT AND DISCUSSION

This section presents the study's findings and discusses the implications in light of relevant literature. It is divided into two main sub-chapters: the presentation of research results and the subsequent discussion.

Result

The following section presents the results of this study based on data collected through observation and student responses. The analysis focuses on students' problem-solving behaviors in learning probability material, structured around Polya's problem-solving theory. Each sub-section includes a detailed explanation supported by NVivo visualizations to identify common patterns and behaviors among the participants. After the data collection process, the observations were analyzed to identify behavioral segments related to students' problem-solving abilities. These segments include identifying the problem, analyzing the task, implementing strategies, and evaluating the solution. The coding process used open coding techniques, where each behavioral segment was labeled based on the meaning of the students' actions. For instance, students who demonstrated effective problem identification and proposed alternative solutions were coded as "able to identify," while those who failed to understand the task and showed no initiative were labeled as "unable to identify."

Based on the coding results, four major themes were identified according to Polya's problem-solving steps:

1. Understanding the Problem
2. Devising a Plan
3. Carrying Out the Plan
4. Looking Back

Each theme is described below.

1. Understanding the Problem

This theme captures students' ability to recognize and understand the core of a given problem. It includes identifying key elements, contextual understanding, and achieving the objective. Students who excelled in this area could clearly explain what the question was asking and relate it to prior knowledge. This understanding is critical to ensure that subsequent steps are carried out accurately. From the NVivo node "Understanding the Problem," three sub-nodes emerged:

- Able to understand the problem well
- Understands the problem but lacks depth
- Unable to understand the problem

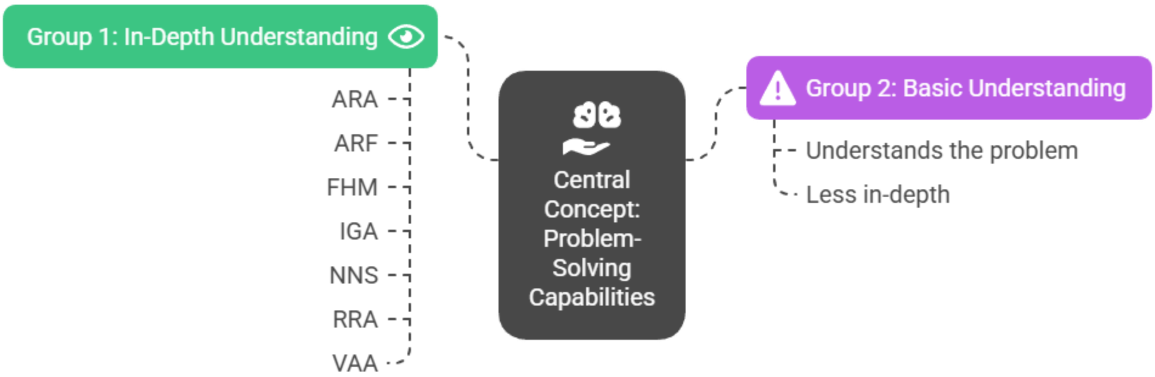

Figure 1. Understanding the Problem

Figure 1 illustrates the coding results related to students' ability to identify and understand the given problem. Out of a total of 26 students, only seven were categorized as "able to understand the problem well." These students successfully identified the core issue and provided responses that demonstrated logical connections to the task's context. Their ability reflects not only accurate recognition of the problem but also the capacity to articulate their reasoning coherently. In contrast, the majority, 19 students, fell into the category of "understanding the problem but less in-depth." This group generally recognized the existence of a problem but failed to articulate their understanding comprehensively. Their responses tended to be superficial, lacking sufficient elaboration, critical reasoning, or detailed justification. Such outcomes suggest that while surface-level comprehension exists, deeper cognitive engagement with the problem remains limited. The imbalance between the two categories indicates that overall problem comprehension within the group is relatively low. This raises important pedagogical implications: students may require additional scaffolding in problem-solving tasks, more explicit guidance in identifying key issues, and structured opportunities to practice critical thinking. To better understand the underlying causes of these difficulties, further qualitative exploration through interviews is recommended. Such follow-up investigations could reveal whether the challenges stem from instructional strategies, students' prior learning experiences, or limited exposure to open-ended problem-solving contexts.

2. Devising a Plan

This theme focuses on students' ability to develop a structured and logical approach to problem-solving. Students must exhibit creativity, consider multiple strategies, and select the most efficient method. Effective planners could formulate a precise sequence of steps and account for various possibilities.

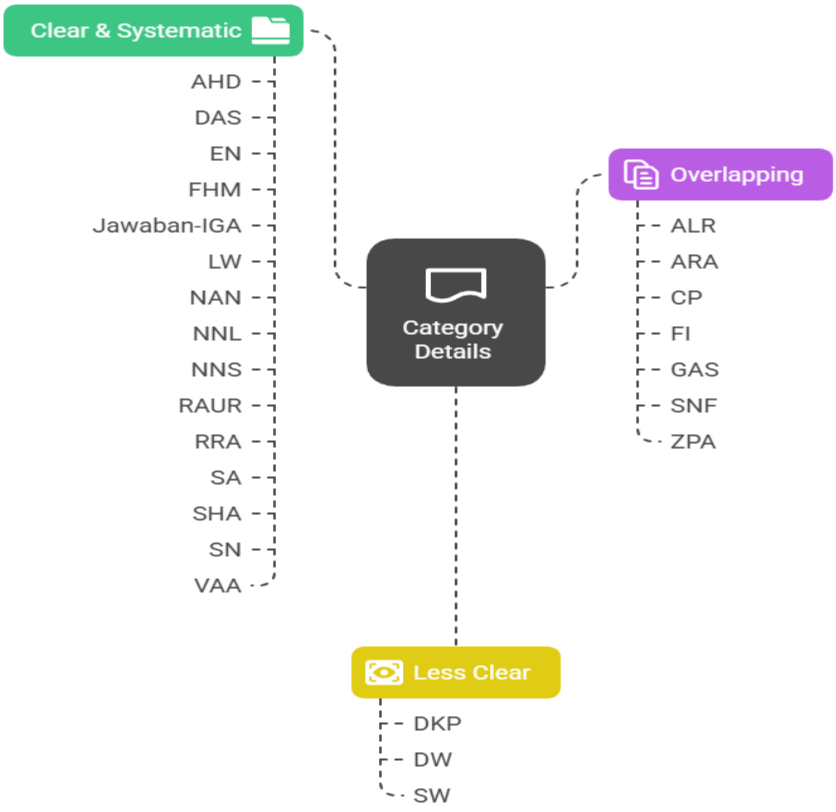

Figure 2. Devising a Plan

As shown in Figure 2, most students were able to devise clear plans for some of the tasks. However, consistency across all tasks was lacking. Some students succeeded in creating a plan for one task but failed to do so for another, and a few could not devise any plan at all. Further in-depth interviews are necessary to fully understand these difficulties, particularly in probability-related problems.

3. Carrying Out the Plan

This theme focuses on how well students implemented their planned steps. It reflects discipline, precision, and adaptability. A student who can carry out a plan demonstrates attention to detail and understanding of how and why their chosen method leads to a solution.

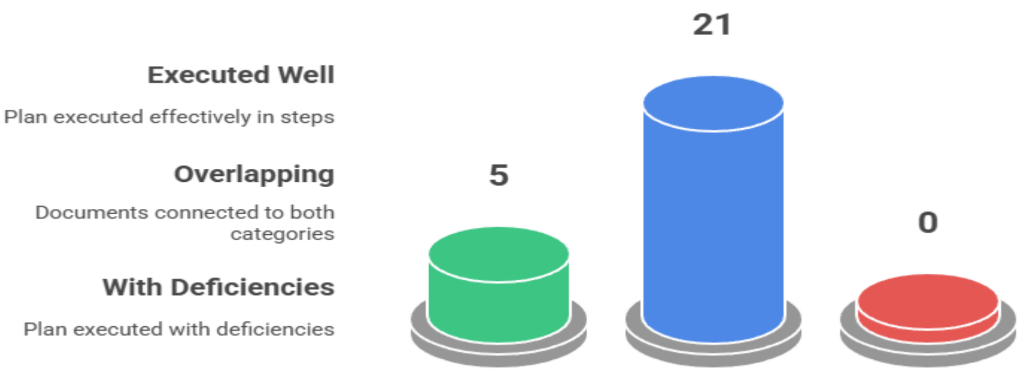

Figure 3. Carrying Out the Plan

Figure 3 indicates that even students who struggled to create a plan could sometimes implement steps effectively. This suggests that planning and execution are not always dependent. Some students might find it easier to act on intuition during execution, even without a structured plan.

4. Looking Back

The final theme involves students' ability to evaluate their solutions. This includes reviewing steps and outcomes to detect and correct errors. Strong evaluators can confirm that their answer is correct and aligned with the problem's goals. This reflective process enhances accuracy and reinforces conceptual understanding.

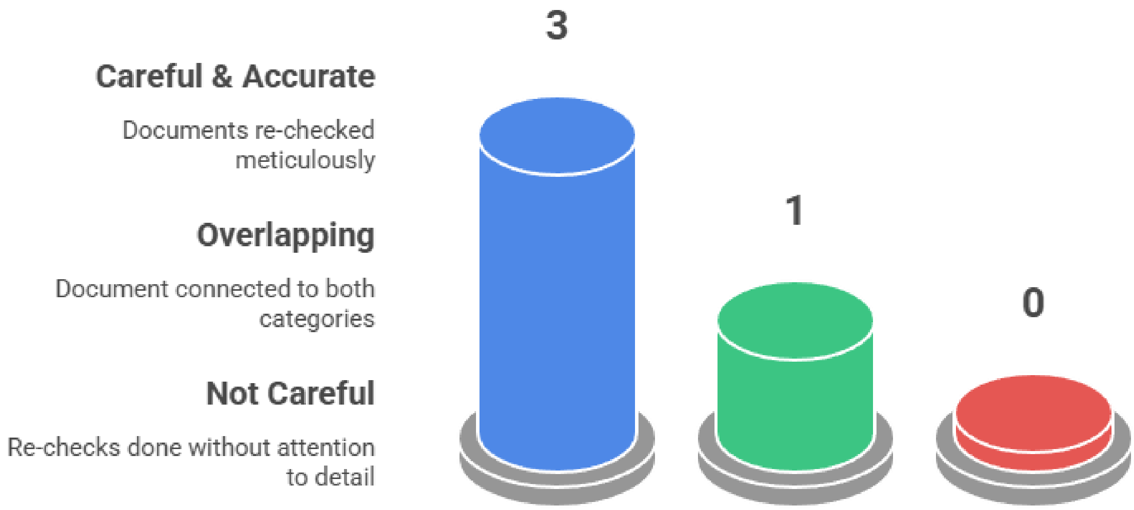

Figure 4. Looking Back

Figure 4 shows that only four out of 26 students reviewed their answers. Of these, three checked accurately, while one did so with partial accuracy. This reveals a significant issue in mathematical instruction: Students often overlook the importance of re-evaluating their work.

Figure 5. Word Cloud of Interview Results

The word cloud analysis provides valuable insights into students' perceptions of their learning experiences. The most salient word, "aku" (I), suggests that students interpret and articulate their academic struggles through a highly individual perspective. This self-centered reflection implies that learners are more focused on their personal challenges rather than engaging with learning as a collective process. The strong presence of "soal" (problem/question) highlights that academic tasks and problem-solving activities are the primary sources of difficulty for students. This finding aligns with previous research indicating that task complexity often becomes a barrier to more profound understanding when students lack adequate scaffolding. Negative descriptors such as "nggak" (not), "kadang" (sometimes), "kesulitan" (difficulty), and "bingung" (confused) reinforce this pattern, suggesting that students frequently encounter uncertainty, struggle with comprehension, and lack consistent strategies to deal with academic demands.

Interestingly, the appearance of "temen" (friend/peer) and "guru" (teacher), although less dominant, indicates that the social dimension of learning is present but not fully emphasized in students' reflections. Peers are perceived as a reference point, while teachers are acknowledged as sources of support. However, the relatively more minor prominence of these words suggests that students do not perceive collaborative learning or teacher support as central mechanisms for overcoming their difficulties. Another noteworthy aspect is the limited presence of positive words such as "bener" (correct/right) and "banget" (very). Although they appear, they are overshadowed by the dominance of negative terms. This imbalance demonstrates that students' discourse is primarily shaped by challenges and confusion, reflecting a learning environment where frustration may outweigh positive reinforcement.

Taken together, these findings imply three key issues. First, students' problem-solving difficulties must be addressed through more explicit guidance, particularly in strategies for approaching complex tasks. Second, peer-assisted learning should be promoted more systematically, given that peers are recognized but underutilized as a learning resource. Third, teachers need to strengthen their role not only as facilitators of knowledge but also as motivators who provide constructive feedback to balance the negative perceptions of learning.

Based on the analysis, several pedagogical implications can be drawn. Educators should:

1. Provide scaffolding in problem-solving – offering step-by-step guidance to help students move beyond surface-level engagement.
2. Encourage collaborative learning – designing tasks that foster peer interaction and cooperative problem-solving.
3. Enhance motivational support – ensuring feedback highlights progress and achievement, thereby shifting student discourse toward more positive learning experiences.
4. Integrate reflective practices – encouraging students to articulate not only their struggles but also their strategies for overcoming them, building metacognitive awareness.

By addressing these areas, teaching and learning practices can better respond to students' needs, transforming their experiences from predominantly difficulty-centered to growth-oriented and empowering.

Discussion

Variations in students' ability to solve trigonometric ratio problems indicate uneven development in mathematical thinking, particularly in the stages of understanding and planning problem-solving strategies. Observations and interviews revealed that the majority of students struggled to comprehend the context of the problems, especially problem-based questions that require interpretative and analytical thinking skills. These findings suggest that current instructional practices have not fully strengthened conceptual understanding, which is fundamental to mathematical problem-solving (Cetin, 2015; Dewi & Waluya, 2021). Theoretically, understanding the problem is a prerequisite in the problem-solving process. Polya and Schoenfeld (1987) emphasized that failure to understand the problem can directly lead to failure in designing and executing solution strategies. Similarly, Tambychik and Meerah (2010) noted that students' difficulties often stem from the initial stage of problem comprehension, rather than procedural aspects. The lack of pedagogical approaches that promote deep mathematical thinking exacerbates this issue (Harel & Sowder, 2013).

In the context of trigonometry, the subject's abstract and visual nature requires pedagogical strategies that foster both conceptual understanding and a productive disposition toward mathematics (Dewi & Waluya, 2021). However, the implementation of problem-based learning is often hindered by time constraints, teachers' preparedness, and students' cognitive capacities (Westwood, 2011). Research in China has shown that successful problem solving depends heavily on systematic and explicit instruction in strategy development (Cai & Nie, 2007). A notable finding of this study is the mismatch between students' planning and execution abilities. Some students who did not produce written plans were able to solve the problems correctly, while others who prepared plans failed during implementation. This phenomenon can be explained through Cognitive Load Theory, which posits that excessive cognitive load during planning may hinder execution, especially for students with limited working memory capacity (Sweller, 1994; Phan et al., 2017; David, 2012).

The effectiveness of problem-solving strategies is not solely determined by the sequence of stages but also by cognitive flexibility and self-regulation in managing the evolving demands of the task (García et al., 2019). Affective factors, such as anxiety or low self-confidence, can further impair the execution of plans even when they have been formulated (Furinghetti & Morselli, 2009). Additionally, the possibility that students engage in mental planning without written documentation should not be overlooked. Proulx (2019) noted that mental mathematics often involves verbal or visual representations, which, although undocumented, can be effective in specific contexts. Zhang et al. (2019) emphasized that successful execution depends on one's ability to adapt to changes in the problem context.

Collaborative problem-based learning can alleviate cognitive load by distributing tasks among students, thus enabling more structured planning and execution (Tarmizi & Bayat, 2012). However, without explicit training in strategic thinking, the disconnect between planning and execution persists as a significant challenge in mathematics instruction. Another critical finding is the limited ability of students to verify or reflect upon their answers. Out of 26 students, only four engaged in self-checking behavior. This reflects a low level of metacognitive awareness, despite the ability to monitor and evaluate one's thinking process being a key component of reflective learning (Efklides, 2001; Schmitz & Perels, 2011). The absence of this reflective phase means students often fail to recognize procedural or conceptual errors, reducing opportunities for correction.

Arum, Widjajanti, and Retnawati (2019) asserted that metacognitive awareness has a direct impact on problem-solving effectiveness, particularly in strategic decision-making. Students with low metacognitive skills often overlook the verification stage, despite its importance in ensuring solution accuracy. Pennequin et al. (2010) found that explicit metacognitive training significantly improves the performance of low-achieving students in solving mathematical word problems.

In science education, Akben (2020) demonstrated that the problem-posing approach can enhance metacognitive awareness by stimulating evaluative and reflective thinking. In mathematics, similar strategies could strengthen students' ability to reassess their solutions. Rushton (2018) also highlighted the pedagogical value of error analysis in cultivating error awareness and promoting conceptual improvement. In-depth interviews also revealed systemic challenges in the teaching and learning process, particularly concerning time constraints. Nearly all students reported difficulty understanding the material and solving problems, primarily due to the incomplete delivery of content resulting from limited instructional time. This highlights the importance of effective time management and reinforcing prerequisite knowledge to support competency attainment. Unlike previous studies that emphasized heuristic or scaffolding approaches to enhance students' problem-solving abilities, this study highlights external factors—minimal instructional time and insufficient content coverage—as key determinants of learning difficulties. Therefore, this study highlights the importance of strengthening both metacognitive development and instructional management in mathematics education, particularly for complex topics such as trigonometry.

CONCLUSIONS

This study set out to investigate the difficulties faced by students in solving trigonometric ratio problems, with a particular focus on their ability to understand, plan, execute, and reflect on problem-solving tasks. The findings indicate that a significant number of students struggle at the initial stage of understanding the problem, which consequently affects their ability to plan and carry out effective strategies. Furthermore, the study found a notable discrepancy between students' planning and execution abilities, as well as a general lack of metacognitive reflection, particularly in the form of verification and self-evaluation. Taken together, these results suggest that students' mathematical problem-solving performance is influenced not only by cognitive and metacognitive skills but also by external instructional factors such as limited teaching time and incomplete content delivery. The findings align with previous literature emphasizing the importance of conceptual understanding, strategic thinking, and metacognitive regulation in mathematics education. One of the main implications of this study is the need for pedagogical interventions that simultaneously strengthen students' conceptual knowledge and metacognitive awareness. Integrating problem-based learning with structured strategy instruction and reflective practices may prove effective in supporting students through all stages of problem-solving. Moreover, addressing systemic constraints such as time allocation and curriculum pacing is essential to ensure that instructional goals are adequately met. The current study is limited by its sample size and context, focusing on a single mathematical topic within a specific school setting. Future research could expand on these findings by exploring longitudinal impacts of metacognitive training or by applying similar methods across different mathematical domains and educational levels. In conclusion, fostering deeper mathematical understanding and metacognitive capacity, while ensuring adequate instructional support—remains critical to enhancing students' overall problem-solving proficiency.

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