Students' Creative Thinking Process in Solving Open-Ended Problems on Flat Shapes

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ABSTRACT

Creative thinking is crucial in mathematics education, particularly when students are required to solve open-ended geometry problems that allow multiple solution strategies. However, few studies have examined how students' creative thinking processes occur when solving open-ended problems on flat shapes, especially based on Wallas' four-stage model. This study aims to describe students' creative thinking processes in solving open-ended tasks on flat shapes through the stages of preparation, incubation, illumination, and verification. A descriptive qualitative approach was employed. From 32 junior high school students, three were selected purposively to represent high, moderate, and low levels of creativity. Data were collected through creative-thinking tasks and interviews, and analyzed using the Miles and Huberman model. The findings show clear differences in thinking patterns: highly creative students successfully performed all four stages and generated accurate and varied solutions; moderately creative students experienced difficulties during illumination, particularly in selecting correct formulas and understanding composite shapes; while low-creative students struggled from the preparation stage, indicating difficulty comprehending the problem and applying concepts. This study contributes to understanding how creative thinking develops across different ability levels and highlights the importance of learning strategies that support each stage of the creative thinking process. The results imply that open-ended tasks in geometry can be optimized to foster creative mathematical thinking when accompanied by appropriate guidance.

Keywords: creative thinking; flat Shape; geometry; thinking process; wallas

INTRODUCTION

Creative thinking is recognized as an essential 21st-century skill necessary for success in education, career, and life. In mathematics education, creative thinking is considered a key competency that enables students to generate multiple ideas and solutions in problem-solving contexts (Yenti et al, 2023; Cai et al, 2025). Mathematics learning plays an important role in fostering logical, analytical, and creative thinking, particularly through problem-solving activities that encourage exploration of diverse strategies rather than reliance on single procedural answers.

Open-ended problems are widely recommended in mathematics instruction because they allow students to construct various problem-solving strategies and solutions, thereby stimulating creativity and divergent thinking (Pratiwi et al, 2023; Erprabowo & Caswita, 2023). Recent studies also emphasize that open-ended tasks in geometry significantly support learners' fluency and flexibility in generating solutions (Istikomah et al, 2024; Simamora & Kamara, 2024). Creative thinking is characterized by the ability to produce original ideas and innovative products (Kurniawati, 2018) and is commonly assessed using indicators such as fluency, flexibility, originality, and elaboration (Torrance, 1974).

Geometry is a mathematical domain closely associated with creative thinking because it requires spatial reasoning and the ability to visualize and analyze geometric relationships (Gravemeijer et al, 2016; Putri et al, 2023). Flat-shape materials support students in understanding relationships among length, area, and angles and applying them in real-life contexts. Research shows that students with higher creativity levels perform better when solving non-routine and open-ended geometry problems (Schoevers et al, 2022). Furthermore, studies indicate that open-ended approaches in learning geometry, particularly when integrated with digital tools and problem-based learning, significantly enhance students' creative mathematical thinking (Cai et al., 2025; Erprabowo & Caswita, 2023).

Creative thinking involves a dynamic cognitive process. Wallas' (1926) four-stage model preparation, incubation, illumination, and verification describes how individuals generate and refine ideas through conscious and subconscious processes. Understanding these stages in students' problem-solving behavior provides deeper insight into how creativity develops during mathematics learning (Simamora & Kamara, 2024).

Despite its importance, Indonesian students' creative thinking ability remains relatively low. The latest PISA report shows that Indonesia continues to struggle in mathematics literacy and creative problem solving (OECD, 2023). Similarly, TIMSS results show that Indonesian students perform below the international average, reflecting weaknesses in higher-order thinking, including creativity (Mullis, Martin, & et al., 2020). One contributing factor is that learning practices still emphasize single-answer procedural tasks rather than exploration of ideas (Diana et al., 2025).

Previous studies have examined students' creative thinking in solving geometry problems; however, these studies primarily focus on the final outcomes of students' work rather than analyzing their creative thinking processes in detail (Vitara et al, 2022; Istikomah et al., 2024). Therefore, it is necessary to investigate how students demonstrate the stages of creative thinking during the process of solving open-ended problems, particularly in flat-shape geometry.

Thus, this study aims to describe students' creative thinking processes in solving open-ended problems on flat shapes based on Wallas' theory. Specifically, the research problem is formulated as follows: How do students demonstrate the stages of preparation, incubation, illumination, and verification when solving open-ended flat-shape problems? The findings are expected to provide insights for designing more effective instructional strategies to improve students' creative thinking in mathematics.

RESEARCH METHODS

This study employed a descriptive qualitative design to investigate students' creative thinking process in solving open-ended problems on flat shapes. The research was conducted at SMP Negeri 1 Puri with a population of 32 students from class IX. Data were collected from three students selected through purposive sampling to represent different levels of creativity: very creative, quite creative, and less creative. The categorization was based on the students' performance in the creative thinking test.

1. Very creative: students who met all indicators of creative thinking.
2. Quite creative: students who met one or two indicators.
3. Less creative: students who did not meet any indicators.

Data were collected using a creative thinking test and follow-up interviews. The creative thinking test required students to:

Draw a variety of flat shapes (as many as possible) that have a perimeter equal to the perimeter of the flat shape drawn on the sheet!
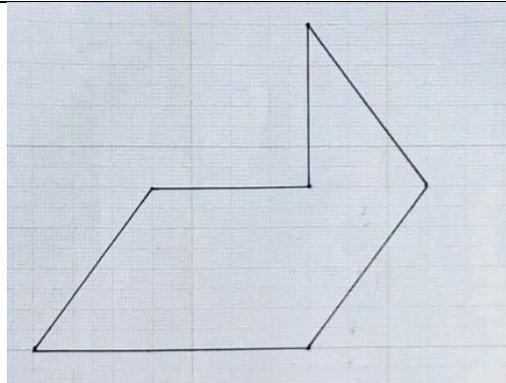

Figure 1. Creative Thinking Test

Interviews were conducted to explore the students' thought processes while solving the problems. The instruments were reviewed by mathematics educators to ensure clarity and suitability for measuring creative thinking.

1. Administer the creative thinking test to the selected participants.
2. Conduct individual interviews to obtain detailed explanations of the students' problem-solving strategies.
3. Record and transcribe all responses for analysis.

Data analysis followed a three-step process: data reduction, data display, and conclusion drawing/verification. Data reduction involved selecting and summarizing relevant information from the test results and interview transcripts. Data display was done by organizing the information in tables and narratives to identify patterns and differences in students' creative thinking processes. The final stage involved drawing conclusions and verifying findings to ensure accuracy and credibility. All analyses were conducted manually without the use of software.

Permission was obtained from the school, and informed consent was secured from all participants. Participants were assured of confidentiality and the right to withdraw at any time. The study was conducted in the classroom and during interviews at SMP Negeri 1 Puri. Data collection took place over a period of two weeks.

RESULTS AND DISCUSSION

Based on the findings of the study, three students representing each creative thinking category were selected to describe their creative thinking processes in solving open-ended problems on flat shapes. The following section presents the results and discussion for the highly creative student.

Creative Thinking Process of Highly Creative Students

The results of research on highly creative students on creative thinking questions can be seen in Figure 2. Student's Solution Illustrating the Creative Thinking Process in Determining the Perimeter of a Composite Flat Shape.
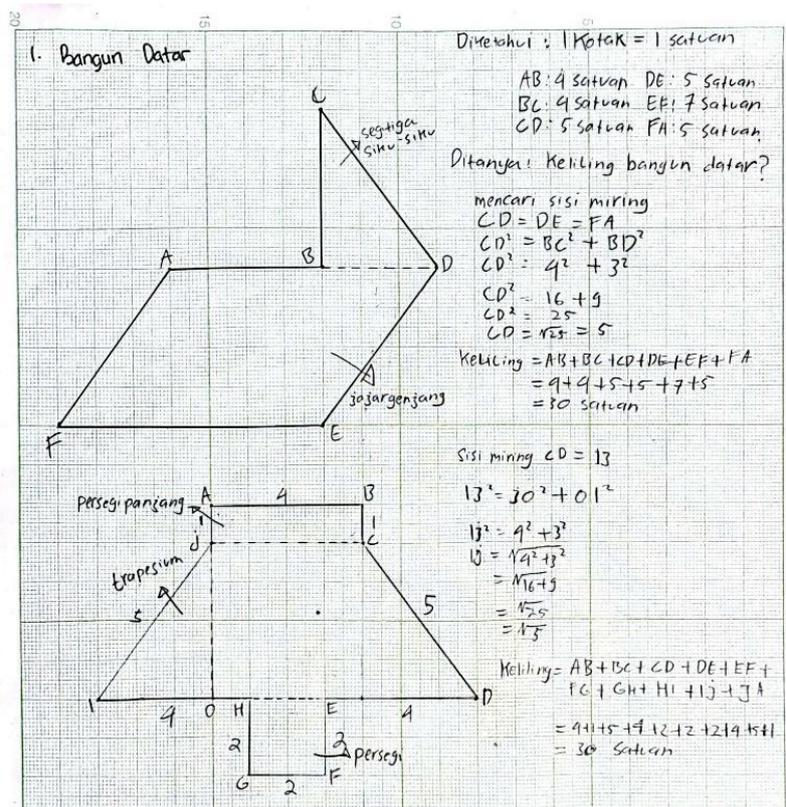
Figure 2. Student's Solution Illustrating the Creative Thinking Process in Determining the Perimeter of a Composite Flat Shape

The highly creative student demonstrated the ability to solve the given open-ended geometry problem accurately and flexibly. Figure 2 shows that the student identified the known and unknown information in the problem, correctly interpreted the composite flat shape as a combination of several basic figures such as rectangles, squares, parallelograms, and triangles and applied appropriate mathematical reasoning to determine the perimeter.

At the preparation stage, the student carefully analyzed the problem, showing a full understanding of the given data. This was evident from the identification of sides and the recognition that the figure consisted of multiple basic geometric shapes. Such understanding aligns with the *fluency* and *elaboration* dimensions of creative thinking described by Torrance (1974).

During the incubation stage, the student took approximately three minutes to reflect and select a suitable strategy. This "thinking pause" indicates metacognitive awareness in problem solving, as observed in the mathematical creative process of students solving open-ended geometry problems (Simamora & Kamara, 2024; Aziz et al., 2025). During this phase, students deliberately monitor and regulate their thinking before proceeding to solution construction, demonstrating self-regulation and engagement in creative problem solving (Pratiwi et al., 2023; Erprabowo & Caswita, 2023). Such pauses allow students to explore alternative strategies and enhance originality and flexibility in their solutions, which are key indicators of creative thinking in mathematics (Istikomah et al., 2024; Nanang Diana et al., 2025). The incubation phase also provides an opportunity for students to integrate their prior knowledge and newly acquired insights, promoting deeper understanding and application of geometric concepts (Cai et al., 2025; OECD, 2023). Overall, this stage reflects the critical

role of reflective thinking in fostering mathematical creativity and higher-order thinking skills in classroom learning.

At the illumination stage, the student generated an organized and logical plan for solving the problem. By labeling points A, B, C, D, and so on, and using the Pythagorean Theorem to calculate the slanted sides, the student demonstrated flexibility in applying known mathematical concepts in a new context. The student then summed the side lengths to find the perimeter of 30 units. This result was verified for accuracy at the verification stage, indicating a reflective and evaluative approach to solution checking.
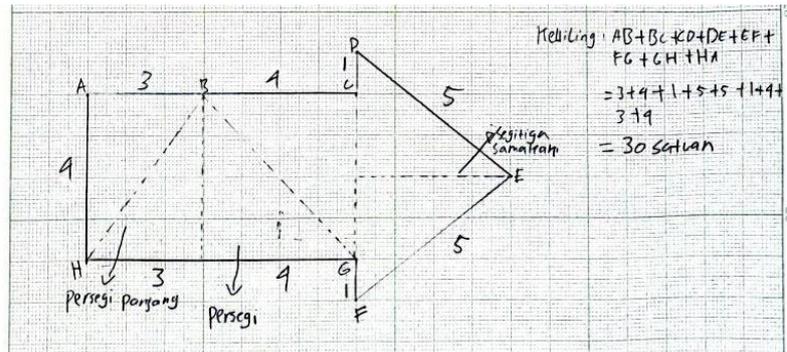

Figure 3. Student's Alternative Solution Combining a Rectangle, Trapezoid, and Square.

When constructing the first alternative figure, the student combined several basic flat shape rectangles, trapezoids, and squares resulting in a figure with the same perimeter of 30 units. The student's ability to modify the structure of the figure while maintaining the same total perimeter demonstrates strong flexibility and originality, which are key indicators of high creative thinking as outlined by Guilford (1967). In the context of mathematics education, this aligns with the perspective of Torrance (1974) and Cai & Leikin (2025), who emphasize that creative thinking involves not only generating multiple solutions but also applying mathematical concepts in novel and flexible ways. Such behaviors indicate that the student is engaging in divergent thinking, effectively transferring conceptual understanding to different problem contexts and reflecting a high level of mathematical creativity.

The second alternative consisted of a combination of rectangles, squares, and isosceles triangles, again resulting in the same perimeter. Finally, in the third alternative, the student created a composite shape composed of a rectangle, a square, and two right triangles, still maintaining a consistent perimeter of 30 units.
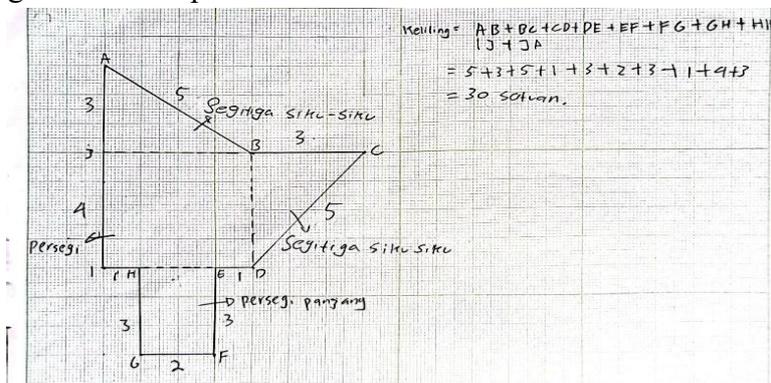

Figure 4. Student's Third Alternative Solution Combining Two Right Triangles and a Rectangle

This consistency across multiple designs demonstrates the student's ability to transfer conceptual understanding across various contexts, an indicator of *flexibility* and *fluency* in mathematical creativity (Siswono, 2018; Nisaa et al., 2024). Furthermore, The student's verbal responses during the interview indicate that idea generation occurred through iterative reasoning and mental visualization, consistent with the 'estimation' or 'trial-and-error' stage in the creative thinking process, which facilitates the development of unique and creative solutions (Gunawan, Ferdianto, Mulyatna, & Untarti, 2025)

The student stated that the first idea required more time to conceptualize, while subsequent alternatives were generated more quickly. This aligns with cognitive models of creativity, where initial problem representation often demands more cognitive effort (Amabile, 1996; Lestari et al., 2024). Moreover, the student's use of geometric decomposition breaking complex shapes into simpler components reflects a higher-order problem-solving strategy.

The findings suggest that highly creative students exhibit all four stages of the creative thinking process: preparation, incubation, illumination, and verification in a coherent manner. The ability to generate multiple correct alternatives with consistent results demonstrates not only mathematical accuracy but also originality and elaboration in problem solving.

This supports previous studies (Huda et al., 2025; Siswono, 2018) emphasizing that open-ended geometry problems encourage creative flexibility and promote deeper understanding of geometric relationships. However, the present findings extend prior research by showing that even within similar perimeters, students can express creativity through visual composition, not just numerical reasoning.

These results imply that teachers should design learning activities that encourage students to explore multiple representations and alternative solutions in geometry. Providing open-ended tasks can stimulate students' divergent thinking and foster creative reasoning.

Nevertheless, this study involved only three participants; thus, generalizations should be made cautiously. Future research should include a larger and more diverse sample to validate the patterns of creative thinking observed in this study.

Creative Thinking Process of Fairly Creative Students

The results of research on fairly creative students on creative thinking questions can be seen in Figure 5.
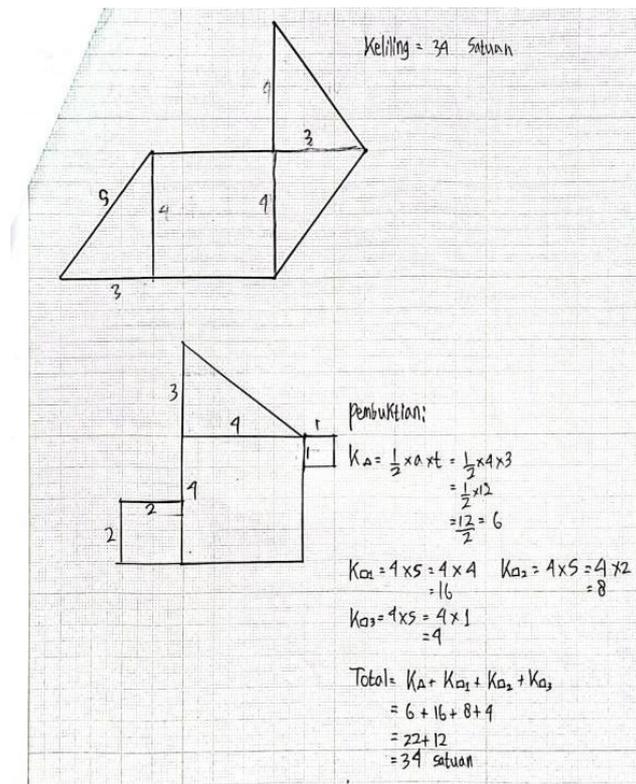
Figure 5. Students' Answers are Fairly Creative

Figure 5 presents the answer of a fairly creative student (CK) when solving the open-ended problem about flat shapes. The student correctly understood the problem statement and identified that the figure consisted of a combination of three right triangles and one square. At the preparation stage, the student demonstrated comprehension of the task by restating the problem and applying formulas learned in class. However, at the incubation stage, the student paused and spent approximately five minutes attempting to determine how to calculate the perimeter.

During the illumination stage, CK tried to apply the perimeter formula but mistakenly used the area formula for triangles and included the inner sides of the composite figure in the total perimeter calculation. These errors indicate that the student's conceptual understanding of the perimeter of composite figures was incomplete. Nevertheless, the student displayed persistence by constructing an alternative figure composed of a triangle and three squares of different sizes. Despite this attempt, the same misunderstanding about perimeter calculation persisted.

At the verification stage, the student visually rechecked the figure but did not verify the numerical calculation, resulting in uncorrected errors. This pattern suggests that fairly creative students tend to show fluency and some degree of flexibility, yet still face limitations in accuracy and conceptual understanding, particularly when translating ideas into correct mathematical representations.

Interview excerpts confirm this observation. When asked about the process, CK explained:

"I found the perimeter to be about the same, but it took me about seven minutes to draw the different flat shapes."

The student also noted, *"I just stay quiet while thinking, other than that, I play*

with pencils and doodles," showing signs of incubation and mental rest before illumination. However, the tendency to check only visually (*"Yes, I went back to look at the drawing I made"*) reflects a limited verification phase.

This finding supports previous research by Siswono (2018) and Huda et al., (2025), which emphasizes that fairly creative students can generate alternative solutions but often struggle with the precision of mathematical concepts. CK's process reflects partial realization of the creative thinking stages proposed by Torrance (1974): preparation and illumination were evident, but incubation was less productive and verification incomplete. This indicates that while such students possess idea generation ability, their conceptual consistency is still developing.

Teachers should provide guided reflection or peer review activities to strengthen the verification process and help students distinguish between area and perimeter concepts. Open-ended geometry tasks should be accompanied by scaffolding to encourage students not only to generate ideas but also to evaluate their accuracy critically.

Creative Thinking Process of Non-Creative Students

The results of research on uncreative students on creative thinking questions can be seen in Figure 6.
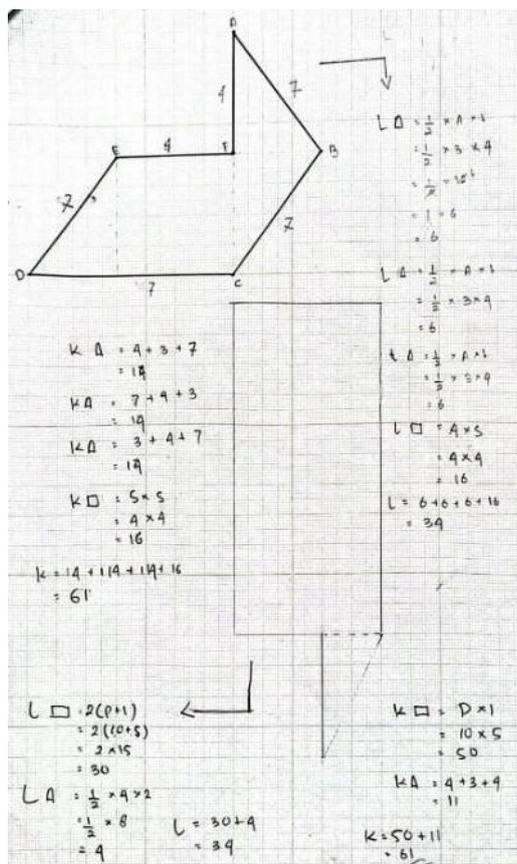

Figure 6. Students' Answers Not Creative

Figure 6 shows the work of the student in the non-creative category (TK) when solving open-ended problems about flat shapes. At the preparation stage, TK experienced confusion

in interpreting the problem. The student struggled to distinguish between *perimeter* and *area* and mistakenly attempted to calculate both simultaneously. Although TK recognized that the figure was composed of three right triangles and one square, this conceptual understanding was not applied accurately.

At the incubation stage, TK spent approximately ten minutes trying to find an approach to the problem but showed difficulty in developing alternative ideas. The prolonged silence and doodling behavior indicate the presence of incubation but with limited productive reflection. During the illumination stage, TK began calculating but committed conceptual and procedural errors. The student misapplied the formula for perimeter and area, and also added inner sides of the composite figure, revealing a lack of understanding of geometric properties.

At the verification stage, TK did not recheck the results due to time constraints, as confirmed in the interview:

"No, because the time is up."

The overall process illustrates that non-creative students often demonstrate incomplete or fragmented engagement in Wallas' four stages of creativity. TK's effort to use both area and perimeter formulas suggests cognitive confusion rather than creative exploration.

This finding aligns with previous research by Kushendri & Zanthy (2019), which found that students who fail to interpret problem information correctly tend to perform inaccurate calculations and omit verification. The difficulties experienced by TK at both the preparation and illumination stages confirm that the lack of problem comprehension directly hinders the emergence of creative thinking. According to Wallas' (1926) theory, the inability to progress smoothly from preparation to illumination limits the generation of original or flexible ideas.

Furthermore, compared to highly creative and fairly creative students, TK's thinking process was characterized by low fluency, minimal flexibility, and absence of originality. This suggests that motivation and prior conceptual mastery significantly affect students' engagement with open-ended problems. These findings are consistent with Khasanah & Sugiarti (2019) and Diana et al. (2025), who emphasize that differences in creative thinking can be influenced by cognitive readiness, classroom environment, and students' emotional responses to learning challenges.

Teachers should provide step-by-step scaffolding that reinforces basic conceptual understanding before students engage with open-ended geometry problems. Encouraging reflection through guided questioning may help non-creative students develop better problem representation and transition more effectively between stages of the creative process.

This study contributes to the growing body of research on mathematical creativity by integrating Wallas' four stages of creative thinking with open-ended geometry problem solving in secondary education. Unlike previous studies that primarily focused on students' final answers or creativity scores, this research provides a detailed qualitative exploration of students' thought processes across each stage. It also introduces visual composition and geometric decomposition as observable indicators of mathematical creativity, expanding the scope of creativity research beyond symbolic reasoning to include visual-spatial flexibility.

Despite its meaningful insights, this study has several limitations. The small number of participants, three students representing different creativity levels limits the generalizability of the results. In addition, only one type of geometry problem was used, focusing on perimeter, which may not capture the full range of creative potential in other mathematical topics. Future research could expand to larger and more diverse populations, integrate digital drawing tools for real-time process tracing, or explore longitudinal changes in students' creative thinking development. Such directions would deepen our understanding of how instructional design and learning environments influence creativity in mathematics.

CONCLUSION

The findings of this study indicate that highly creative students are able to successfully complete all four stages of Wallas' creative thinking process and produce optimal solutions, while fairly creative students exhibit some difficulties, particularly during the illumination stage, such as applying incorrect formulas. Non-creative students face more substantial challenges, struggling to understand the problem comprehensively and to apply geometric concepts correctly. This study contributes to both theory and practice. From a theoretical perspective, it extends prior research by linking Wallas' four-stage model with detailed qualitative analysis of students' thought processes in solving open-ended geometry problems. It also highlights visual composition and geometric decomposition as additional observable indicators of mathematical creativity, broadening the scope of creativity research beyond symbolic reasoning. Furthermore, the results underscore the importance of metacognitive awareness and problem representation strategies in the development of creative thinking.

Practically, the study offers guidance for teachers in designing open-ended tasks that nurture creativity across different ability levels. The findings suggest the use of instructional strategies such as scaffolding, guided reflection, and peer review to support students' conceptual understanding and verification processes. Emphasizing multiple representations and alternative solutions in classroom activities can enhance students' fluency, flexibility, originality, and elaboration, which are key dimensions of mathematical creativity.

For future research, expanding the study to include different mathematical topics, larger and more diverse samples, and digital tools for real-time tracing of creative thinking processes would provide deeper insights and strengthen the generalizability of these findings. Overall, this study demonstrates how systematic observation of students' creative thinking stages can inform both theory and instructional practice in mathematics education.

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