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Creative Thinking in Solving Non-Routine Mathematical Problems Through the Creative Problem Solving-Treffinger Model

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Abstract

This study analyzes students' creative thinking processes in solving non-routine mathematical problems using Treffinger's Creative Problem Solving (CPS) stages. The subjects included students with high, medium, and low mathematical abilities. Data were collected through worksheet analysis, visual representations, mathematical work, and semi-structured interviews, then analyzed using data condensation, display, and conclusion drawing. Researchers use time triangulation to validate the data. The findings show that creative thinking develops in stages and differs by ability level. High-ability students complete all CPS stages optimally, demonstrating deep understanding, flexible and original strategies, and reflective evaluation, with all creativity indicators (fluency, flexibility, originality, and elaboration) consistently emerging. Medium-ability students show a developing but unstable process; they can understand problems and generate ideas, but remain limited in strategy variation and evaluation. Low-ability students exhibit procedural thinking, marked by misconceptions, incomplete representations, minimal idea exploration, and a lack of evaluation. Overall, the CPS-Treffinger model is effective in fostering creative thinking but requires adaptation to students' ability levels. Teachers should design non-routine problem-based learning that encourages idea exploration, multiple representations, and reflective thinking to support the development of mathematical creativity.

Keywords: creative problem solving; creative thinking; non-routine problems

INTRODUCTION

Creative thinking is a crucial 21st-century competency in education, including mathematics learning. According to the Partnership for 21st Century Learning (Valverde et al., 2020), creative thinking is the ability to generate novel and valuable ideas that can be applied in complex problem-solving contexts. In the context of mathematics, creative thinking is the foundation for developing deep conceptual understanding and for designing problem-solving strategies that do not rely on routine procedures (Yuli & Siswono, 2011). However, mathematics learning in schools often emphasizes solving routine, results-oriented problems rather than deep, reflective thinking (Hendriana et al., 2018). This condition leads students to think convergently, follow predetermined algorithmic steps, and lack the Flexibility and originality needed to develop mathematical thinking.

The creative thinking process is a series of mental activities that enable individuals to generate novel and useful ideas or solutions in solving specific problems. Guilford, n.d. (1950) was one of the pioneers in psychological research on creativity, distinguishing between divergent and convergent thinking. According to him, creative thinking is identical to divergent thinking, namely the ability to generate many alternative answers, broaden perspectives, and find unexpected relationships between concepts. Torrance (2009) later deepened this concept by developing the Torrance Tests of Creative Thinking (TTCT), which measures four leading indicators of creative thinking: Fluency, Flexibility, originality, and elaboration. These four aspects reflect a person's ability to expand, modify, and combine ideas in solving complex problems.

The creative thinking process is not spontaneous but rather follows systematic stages, as Sadler-smith & Sadler-smith (2016) explained in their four-stage model of creativity: preparation, incubation, illumination, and verification. In the preparation stage, individuals gather information and understand the problem; the incubation stage is a period of unconscious idea maturation; illumination occurs when a new idea emerges as an "insight"; and verification involves evaluating and applying the idea. This model aligns with Amabile et al. (2007) componential theory, which posits that creativity arises from the interaction among domain skills, creative thinking skills, and intrinsic motivation. This means that the creative thinking process depends not only on cognitive intelligence but also on a supportive environment, curiosity, and an internal drive to experiment and innovate.

In addition to cognitive and affective aspects, Csikszentmihalyi (1996) theory of flow emphasizes the importance of optimal psychological conditions in the creative thinking process. When individuals are in a state of flow, they are fully immersed in thinking activities, with high focus and engagement, and can generate innovative ideas naturally. In the educational context, Csikszentmihalyi (1996) explains that creative thinking can be developed through a learning environment that provides freedom of expression, tolerance for mistakes, and appreciation for originality. Therefore, the development of creative thinking emphasizes not only the final result in the form of a new product, but also the process of exploring ideas, which involves the interaction among divergent thinking skills, motivation, and supportive learning experiences. Thus, creative thinking is a dynamic process that requires synergy between cognitive, affective, and social aspects to produce innovative and meaningful ideas. Mathematical creativity requires cognitive space, emotional stability, and the opportunity to explore alternative solutions or new ideas (Hasan & Juniati, 2025).

Solving non-routine mathematical problems is closely related to creative thinking processes because both require the ability to generate new ideas, Flexibility of thinking, and the ability to find unconventional strategies. According to Date & Type (1997), non-routine problems require students to understand situations that do not have a direct solution procedure and encourage the use of heuristic strategies such as trial and error, making analogies, or drawing representations. This process aligns with Treffi (2007) concept of divergent thinking, namely, the ability to generate multiple alternative solutions initially. Torrance (2009) emphasized that creative thinking involves Fluency, Flexibility, originality, and elaboration, all four of which emerge when students solve non-routine problems. Lithner (2008) added that solving non-routine problems encourages the emergence of creative mathematical reasoning, namely the process of building new relationships and strategies that differ from routine procedures. Thus, solving non-routine mathematical problems is an effective means of cultivating and measuring creative thinking skills because it meaningfully integrates the exploration of ideas with logical reasoning.

The Creative Problem Solving (CPS) model developed by Treffinger is a systematic approach to developing creative thinking skills for solving complex, non-routine problems. Treffinger (1995) defines CPS as a structured process that combines two main components: divergent thinking (generating many ideas) and convergent thinking (selecting the best idea), enabling students not only to think freely but also to evaluate and implement solutions effectively. The CPS process generally includes six stages: understanding the challenge, generating ideas, preparing for action, and reflective supporting steps in each phase (Treffi, 2007). Through this model, students are guided to understand the problem in depth, find various alternative solutions, and then assess the practicality and effectiveness of the ideas generated. In an educational context, CPS has been proven effective in developing creative thinking skills because it encourages students to use imagination, Flexibility, and originality in finding solutions (Treffinger & Isaksen, 2005).

The relationship between CPS and creative thinking can be explained through the divergent-convergent thinking framework, which is also central to Guilford, n.d (1950) theories of creativity. CPS provides a learning environment that facilitates Torrance's four indicators of creative thinking: Fluency, Flexibility, originality, and elaboration. In the idea generation stage, for example, students are encouraged to generate as many ideas as possible without fear of error, which fosters Fluency and originality. Furthermore, in the idea evaluation stage, students use convergent thinking skills to select and develop the most logical and practical solutions. Several studies have shown that implementing CPS in mathematics learning can significantly improve students' creative thinking skills. This is because CPS emphasizes a balance between the freedom to explore ideas and the discipline of logical thinking, two important aspects of scientific and mathematical creativity.

In the context of non-routine mathematical problem-solving, the CPS plays a crucial role because its stages help students navigate situations that lack straightforward solution procedures. According to Chang (2010), mathematical problem-solving requires the ability to understand the problem, devise a strategy, and reflect on the solution steps that align with the CPS structure. Research by Hershkowitz et al., (2017) and Lithner (2008) shows that creative thinking skills contribute significantly to successful non-routine problem-solving, as students need to generate novel strategies when standard procedures are inadequate. Therefore, implementing the CPS model in mathematics instruction can enhance the quality of creative thinking processes and strengthen students' ability to solve non-routine problems by purposefully integrating divergent and convergent thinking. This model bridges the gap between creativity and mathematical reasoning, making the learning process more meaningful and adaptive to complex problem-solving challenges.

The Creative Problem Solving (CPS) ability of students in secondary schools is still in the moderate to low category, characterized by the tendency of students to only be able to solve routine, procedure-based problems, but experience difficulties when faced with open-ended, contextual, and non-algorithmic problems. This is evident from the low indicators of fluency (fluency of ideas), flexibility (diversity of strategies), originality (uniqueness of solutions), and elaboration (development of solutions). This condition is in line with the finding that Indonesian students tend to only be able to solve routine problems and experience difficulties with high-level reasoning-based problems ((Agustina et al., 2024). The low CPS is also influenced by the dominance of routine problems in the classroom, which limits the development of fluency, flexibility, and originality, as explained, routine problems only encourage fixed procedures, while non-routine problems require creative, analytical, and evaluative thinking. The implementation of non-routine mathematics problems can be done through the following stages: (1) providing contextual problems that do not have a standard procedure, (2) facilitating the exploration of various solution strategies, (3) group discussions to compare solutions, and (4) reflection on the thinking processes used by students. Teachers act as facilitators who encourage scaffolding and open-ended questions so that students build understanding independently (Agustina et al., 2024). This approach has been proven effective in improving CPS because it encourages divergent and metacognitive thinking. In learning practice, the use of non-routine mathematical problems can be carried out through stages based on Polya's problem-solving theory, namely understanding the problem, planning a strategy, implementing the plan, and reflecting (Ratnasari, 2022). In addition, providing open-ended and contextual problems has been shown to increase mathematical creativity through the development of various solution strategies and discussions of alternative answers (Kirisci et al., 2020), as well as encouraging creativity indicators such as fluency, flexibility, and originality through multi-solution exploration in mathematics classes. Thus, the systematic integration of non-routine problems in learning is a key strategy for continuously improving students' CPS.

Non-routine mathematical problems are an effective way to stimulate students' creative thinking. (Chang, 2010) emphasized that solving non-routine problems requires applying heuristic strategies such as experimentation, planning, and generalization, which cannot always be solved using standard steps. (Lithner, 2008) added that when faced with non-routine problems, students tend to develop creative mathematical reasoning, namely the ability to construct new strategies and arguments based on conceptual understanding, rather than simply copying previously learned procedures. This process aligns with (Holyoak, 2005) theory of creative thinking, which encompasses Fluency, Flexibility, originality, and elaboration. However, previous research has shown that students often experience difficulties in the exploration and elaboration stages of ideas when faced with non-routine problems (Yuli & Siswono, 2011); (Sriraman, 2004). This highlights the need for a learning model that systematically guides students through the stages of creative thinking, rather than simply emphasizing the outcome.

One relevant learning model for developing creative thinking in the context of non-routine problem-solving is Creative Problem Solving (CPS), developed by Treffinger (1995). The CPS-Treffinger model emphasizes the creative thinking process in three main stages: Understanding the Challenge, Generating Ideas, and Planning for Action. In the first stage, students are guided to understand the problem in depth through exploration and clarification; the second stage emphasizes developing as many ideas as possible without limiting creativity; while the third stage focuses on evaluating and implementing the most effective solutions (Treffinger & Isaksen, 2005). Treffinger's research shows that the CPS approach helps students develop Flexibility and originality of thinking because it provides space for them to put forward alternative ideas. In the context of mathematics education, applying the CPS model can facilitate students' engagement in a structured creative thinking process when tackling non-routine problems that require high-level reasoning.

Although various studies have addressed the development of creative thinking in mathematics learning, most research focuses on the products of creative thinking, such as increased creativity scores or creative thinking ability test results, and has not yet examined students' creative thinking processes in depth in the context of non-routine problem solving. Research by Yuli & Siswono (2011) emphasizes the importance of understanding the stages of students' creative thinking by analyzing their thought processes during mathematical problem solving. This aligns with Leung & Silver (1997) view, which asserts that mathematical creativity is not only evident in the final product but also in the thought process involving exploration of strategies, representations, and justification of solutions. Furthermore, Shabani (2010), through social constructivism theory, it emphasizes that creative thinking develops through social interaction and scaffolding, making process analysis crucial in understanding how mathematical ideas are formed.

In developing the state of the art, a number of recent studies have begun to focus on analyzing creative thinking processes. For example, a study by Sriraman (2004), which examined mathematical creativity through a cognitive approach and emphasized the importance of investigating students' mental processes in generating new ideas. Research by Plucker & Makel (1970) also shows that creativity cannot be understood solely from the product but must be analyzed through the interaction between the process, the individual, and the context. Meanwhile, the OECD (2023) report on the PISA study emphasized the importance of creative problem-solving skills, which require students to explore, integrate, and reflect on various strategies in non-routine situations. Another study by Bruder & Jurado (1969) also highlighted that non-routine tasks can foster creative thinking through thinking classroom activities, where students actively construct and test their ideas.

However, research explicitly linking the CPS-Treffinger model to the creative thinking process in solving non-routine mathematical problems is still limited, especially in the Indonesian educational context. The CPS model developed by Treffi (2007) emphasizes the stages of problem clarification, idea generation, and solution development, which are theoretically highly relevant for examining students' creative thinking processes in depth. This gap indicates the need for qualitative research that comprehensively examines how students construct, develop, and evaluate their mathematical ideas as they progress through each stage of the CPS model, so that it can provide new contributions to the development of creativity-based mathematics learning theory and practice.

Based on the description, this study has a high urgency because it seeks to bridge the gap between theory and practice of creative mathematics learning. This study not only assesses students' creative thinking results but also examines how the creative thinking process occurs at each stage of non-routine problem solving using the CPS-Treffinger model. The formulation of this research problem examines how the characteristics of students' creative thinking processes differ based on their level of mathematical ability (high, medium, and low) when solving non-routine mathematical problems using the CPS-Treffinger model, how do indicators of mathematical creativity, including fluency, flexibility, originality, and elaboration, emerge and develop at each stage of the CPS in each category of student ability? Specifically, the purpose of this study is to describe students' creative thinking processes in solving non-routine mathematical problems using the stages of the CPS-Treffinger model, thereby identifying the characteristics of creative thinking that emerge at each problem-solving phase. Thus, this study is expected to provide theoretical contributions by enriching studies on the relationship between creativity and mathematical problem solving, as well as practical contributions in the form of learning models that teachers can apply to foster students' mathematical creativity.

METHOD

This study uses a qualitative, descriptive-exploratory research design because it aims to explore and describe in depth the creative thinking process of students in solving non-routine mathematical problems through the stages of the Treffinger Creative Problem-Solving model. This approach focuses on students' dynamic, contextual, and in-depth thinking processes. The study was conducted in the even semester of the 2025/2026 academic year at one of the Senior High Schools in Pasuruan City that has implemented problem-based learning.

The purpose of this study is to describe in depth the characteristics and stages of students' creative thinking in solving non-routine mathematical problems across the phases of the CPS-Treffinger model: Understanding the Challenge, Generating Ideas, and Planning for Action (Treffinger, 1995). The research subjects consisted of three eleventh-grade high school students selected based on their high, medium, and low levels of mathematical ability. The ability categories were determined based on the results of a mathematical ability test administered to all eleventh-grade students. Based on these results, the researcher used a purposive sampling technique, which intentionally selects subjects who can provide in-depth information relevant to the research focus. One student with high, one with medium, and one with low ability was selected as the main subject, allowing the researcher to compare variations in creative thinking processes across levels of mathematical ability.

The research procedure involved four operational stages. First, the preparation stage, in which the researcher developed the research instrument, including non-routine problem-solving questions based on mathematical contexts designed to stimulate creative thinking processes, according to Torrance (1973) indicators. Second, the implementation stage, in which students were asked to solve the problems using the CPS-Treffinger model approach. During the process, the researcher conducted a think-aloud protocol to record students' thinking patterns verbally, as well as observing and recording their thinking behavior. Third, an in-depth interview was conducted after students completed the assignment to explore further the reasons and thinking strategies they used. Fourth, the documentation and triangulation stage, in which the researcher collected all student work, recordings, and field notes for comprehensive analysis.

The research instruments used in this study produced complementary data types to reveal students' creative thinking processes in depth. First, the researcher, as the primary instrument, obtained data in the form of field notes, interpretations of learning situations, and reflections on student behavior and responses during the activities. The primary instrument served as both a contextual data collector and interpreter in qualitative research, and this data was analyzed through iterative data condensation, data display, and conclusion drawing or verification (Miles, 2014). Second, a non-routine mathematics problem-solving test generated data in the form of students' written answers reflecting strategies, representations, and solution quality. This instrument served to identify indicators of creative thinking (fluency, flexibility, originality, elaboration), and was analyzed using content analysis techniques by classifying answers based on creativity indicators and Treffinger's CPS stages. Third, a semi-structured interview guide generated verbal data in the form of students' explanations, reasons, and thought processes when solving problems; this instrument served to explore cognitive processes not apparent in written answers and was analyzed through thematic coding techniques to identify patterns of creative thinking at each stage of the CPS. Fourth, the observation sheet generated data in the form of actual student behavior during the problem-solving process, such as idea exploration, interactions, and ways of evaluating solutions; its role was as supporting data to validate the findings from the tests and interviews (triangulation), and was analyzed by matching behavioral indicators with aspects of creativity according to Torrance (2009). Overall, data from the four instruments were analyzed in an integrated manner using source and method triangulation techniques, so that a comprehensive picture of students' creative thinking processes in solving non-routine mathematical problems was obtained.

RESULTS

Research shows that students with high mathematical abilities can solve non-routine mathematical problems using structured, creative thinking processes, following the stages of the CPS-Treffinger model. Student worksheets demonstrate problem-solving activities that include understanding the situation, exploring possible triangular shapes, using visual representations, performing geometric calculations, and reflecting on alternative solutions.

The research results show significant differences in students' creative thinking processes at each stage of Treffinger's Creative Problem Solving (CPS) based on their mathematical ability level. Students with high ability demonstrate a mature and structured thinking process, starting with the ability to deeply understand problems by identifying important information and transforming geometric representations into coordinate form. In the idea generation stage, students are able to generate a variety of alternative solutions, use flexible strategies, and demonstrate originality in their approaches, such as combining geometric and coordinate concepts. In the action planning stage, students are able to systematically evaluate solutions, conduct mathematical verification, and provide logical and reflective arguments. This indicates that all indicators of creative thinking fluency, flexibility, originality, and elaboration are developing optimally and supporting each other.

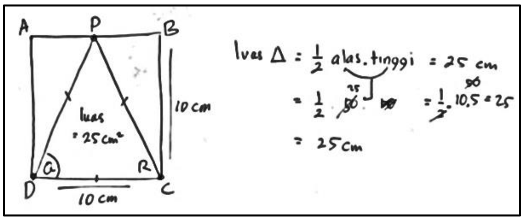
Conversely, students with moderate ability demonstrate a developing but unstable creative thinking process. They can understand problems and generate several alternative solutions, but are still limited to simple variations and have not yet explored more complex strategies. The evaluation process is also suboptimal due to a lack of in-depth mathematical verification. Meanwhile, students with low abilities exhibited procedural and fragmented thinking patterns, characterized by misconceptions of basic concepts, incomplete representations, and minimal exploration of ideas and evaluation of solutions. Overall, these findings confirm that the quality of conceptual understanding, representational skills, and divergent and evaluative thinking skills significantly influence student success at each stage of the CPS. Therefore, differentiated pedagogical support is needed to enable each student to optimally develop their creative thinking skills.

Subjects With High Mathematical Ability

Subjects with high mathematical abilities demonstrate characteristics of mature, systematic, and reflective thinking in solving non-routine mathematical problems. Subjects can understand problems in depth by identifying important information, transforming representations into more meaningful forms (e.g., from geometry to coordinates), and developing diverse solution strategies that are not fixated on routine procedures. In addition, subjects demonstrate the ability to explore various alternative solutions, use flexible approaches, and evaluate results argumentatively and logically. This indicates that creative thinking indicators such as fluency, flexibility, originality, and elaboration develop optimally, thus supporting the formation of an effective and high-quality problem-solving process.

Understanding the Challenge

At the beginning of the answer, students identify important information from the question, namely: Area of a square = 100 cm² → side of a square = 10 cm, Area of a triangle = 25 cm², then the relationship between the positions of points P, Q, R, and connecting the question to the coordinate system. The results of the students' answers can be seen in Figure 1.



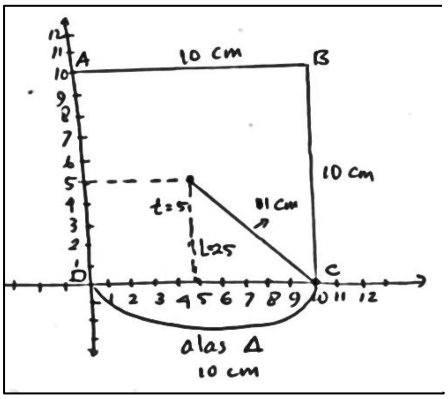
Area of triangle
= ½ × base × height = 25 cm²
½ × 50
½ × 10 × 5 = 25
= 25 cm²

Figure 1. Results of the Work of Subjects with High Mathematical Ability in Identifying Important Information from Questions

The findings show that students clarify problems by reinterpreting numerical information and drawing it as sketches. Students convert geometric relationships to coordinates (P(5,5), Q(5,0), R(10,0)), demonstrating the ability to transform representations, one of the indicators of elaboration and Flexibility according to Torrance.

Generating Ideas

In the idea exploration stage, students with high mathematical abilities draw several possible triangle shapes, calculate the hypotenuse using the Pythagorean Theorem, test alternative triangle shapes (e.g., equilateral, right-angled), and state that more than one shape is possible according to the problem conditions. The results of the students' answers can be seen in Figure 2.



10 cm (top side of the square)
10 cm (right side of the square)
Coordinate axes labeled with numbers along the x-axis and y-axis
Point "O" at the origin (0,0)

Points labeled "A" (top-left), "B" (top-right), and "C" (bottom-right)
Inside the square:
Point "P"
A vertical segment labeled "5 cm"
A slanted segment labeled "11 cm"
Bottom side labeled "side = A" (likely referring to side length A)

Figure 2. Results of the Work of Subjects with High Mathematical Ability: Converting Geometric Relationships in Coordinates

Researchers : *Describe the ideas that came to you when you tried to solve this problem.*
Subject : *I have an idea to use the concepts of calculating triangles and squares, and the mathematical concept of coordinate points.*

Sketches and notes show students generating multiple possible solutions and considering multiple configurations. This is strong evidence of Flexibility and originality in creative thinking.

Planning for Action

Students select the solution they consider most appropriate by systematically recalculating the side lengths, comparing alternative triangle shapes with the area requirements, confirming their agreement with the problem information, and deciding that the most likely triangle is a right triangle that approximates an equilateral triangle. In the written reflection section, students explain their choice of solution, demonstrating strong mathematical evaluation and argumentation skills.

Table 1. Relationship Between CPS Stages and Creative Thinking Aspects of Students with High Mathematical Ability

CPS – Treffinger Stages	Student Behavior Findings	Aspects of Creative Thinking
Understanding the Challenge	1. Identifying important information (area of square, length of side, area of triangle) 2. Analyze the position conditions of points P, Q, and R. 3. Converts the representation of a geometric shape to a coordinate system (e.g., P(5,5), Q(5,0), R(10,0)). 4. Make a clear and structured sketch.	Elaboration (high), Flexibility (high), Fluency (good).
Generating Ideas	1. Generates several possible triangle shapes (equilateral, right-angled, nearly equilateral) 2. Using the Pythagorean Theorem to test the length of the sides. 3. Testing multiple point configurations in a square. - Produces more than one valid alternative solution.	Flexibility (very high), Originality (high), Fluency (high), Elaboration (good).

CPS – Treffinger Stages	Student Behavior Findings	Aspects of Creative Thinking
Planning for Action	1. Choose the best solution based on examining the side length and area. 2. Perform systematic calculations and value verification. 3. Compare alternatives and evaluate their suitability to the problem conditions. 4. Provide reflective and argumentative reasons for the final decision.	Elaboration (very high) Originality (good) Flexibility (good in evaluation)

The data in Table 1 shows that students with high mathematical abilities can optimally complete each stage of Treffinger's Creative Problem Solving (CPS). At the Understanding the Challenge stage, students not only identify information but also analyze relationships between concepts and transform representations into coordinates, demonstrating high elaboration, flexibility, and good fluency. At the Generating Ideas stage, students generate various alternative solutions and use a variety of strategies, demonstrating high flexibility and originality, supported by good fluency and elaboration. Furthermore, at the Planning for Action stage, students are able to select the best solution through systematic evaluation and verification, demonstrating very high elaboration and reflective thinking skills. Overall, all indicators of creative thinking develop strongly and are integrated at each stage of the CPS.

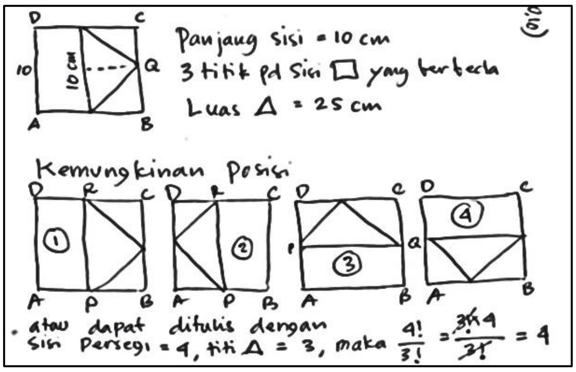
Based on the data on indicators of mathematical creative thinking ability, students demonstrated strong performance across all aspects. On the fluency indicator, students were able to write down important information in full, calculate several relevant parameters, and produce numerous initial sketches. This demonstrates the ability to generate many ideas in a relatively short time, in line with Guilford, n.d (1950) view that Fluency reflects the abundance of ideas in problem-solving. In the flexibility indicator, students tried several triangle shapes and changed approaches to the coordinate system. This shift in strategy demonstrates the ability to shift from one framework of thought to another, in line with Torrance (1973) theory of mental flexibility, which emphasizes the use of multiple perspectives in finding solutions.

Indicators of originality also emerged strongly when students independently converted geometry problems to coordinates without any problem guidance. This strategy demonstrated the novelty of ideas and the ability to generate unconventional solutions, in line with the definition of originality as a unique, distinct solution from those commonly used by the majority of students. In the elaboration aspect, students provided very detailed calculation steps, attached supporting formulas, and explained the process verbally in depth. These findings support Torrance's theory that elaboration is the ability to enrich ideas with meaningful details, thereby improving the quality of solutions.

Overall, these findings indicate that students ranked high to very high on all indicators of mathematical creativity. This finding supports claims in the literature that students with strong representational skills and conceptual understanding tend to demonstrate more mature creative performance in problem-solving (Leung & Silver, 1997).

Subjects With Moderate Mathematical Ability

Based on the analysis of students' answer sheets with moderate mathematical abilities, it was found that students demonstrated creative thinking processes at an intermediate level, characterized by the emergence of aspects of Fluency and elaboration that were quite good, but Flexibility and originality remained limited. Students were able to redraw the square, marking points P, Q, and R on different sides, and creating several alternative triangle positions. In their answers, students identified four possible point positions that form a triangle with a given area in the square, both in drawings and in simple combinatorial calculations. The results of the students' answers can be seen in Figure 3.



Side length = 10 cm
3 points (P, Q, R) are on different sides
Area of the triangle = 25 cm²

Possible positions
(1), (2), (3), (4), different diagram variations
Square sides = 4
Points of the triangle = 3
So, 4! / 3!
= (4 × 3 × 2 × 1) / (3 × 2 × 1) = 4 possibilities

Figure 3. Results of The Work of Subjects With Moderate Mathematical Abilities In Creating Possible Positions Of Points P, Q, and R.

In the second part, students write down the steps to solve the problem based on the text, including observing the problem's direction, noting important information, redrawing the geometric shape, and analyzing it through visual representation. Students also demonstrate an understanding that the possible triangle shapes are right triangles or isosceles triangles, provided that the three points are on different sides of the square.

In general, students attempted to construct mathematical arguments by referring to side lengths and point position requirements, but did not yet perform in-depth area calculations. Nevertheless, the work demonstrated exploratory efforts through alternative drawings and verbal justifications oriented toward understanding geometry.

Understanding the Challenge

At this stage, the student demonstrates the ability to understand the basic information in the problem. He notes the side length of the square (10 cm), the area of the triangle (25 cm^2), and the main requirement that points P, Q, and R must be on different sides of the square. The student also redraws a diagram of the square and its points.

The main finding at this stage was that Fluency was evident in the ability to identify important information directly. Elaboration was quite good, as evidenced by the inclusion of side lengths, point labels, and line directions. However, Flexibility was still limited; students had not yet broadly evaluated the possible relationships between sides before drawing alternative shapes. Overall, students understood the problem but had not yet fully explored the possible triangle configurations.

Generating Ideas

This stage is the core of creativity, generating as many ideas/alternative solutions as possible. The student demonstrated an understanding that points can be placed on the sides of a square in different ways, and then sketched four possible triangle positions. He also used combinatorial notation to explain that there are $4!/(3! \cdot 2!) = 4$ possible positions of points on a square.

Analysis of creativity indicators at the generating ideas stage: Fluency: Students produced four alternative visual representations of triangles in a square. This demonstrates Fluency in expressing ideas, although these alternatives tended to be variations in position rather than variations in more complex mathematical forms. Flexibility: Students were moderate. They were able to switch representations from images to combinatorial calculations, but had not yet displayed different geometric approaches (e.g., using symmetry, variable side lengths, or triangle rotation). Originality was still low. All alternative images created were general variations of point positions commonly found in fundamental geometry problems. There was no apparent attempt to create more complex or unique triangle shapes. Elaboration was quite apparent, for example, in writing the steps, detailing the requirements for point positions, and redrawing the square. However, exploration of calculating the area of a triangle had not yet emerged in depth. The Generating Ideas stage in students with moderate abilities shows a tendency towards basic creative thinking, with idea output that remains linear but shows a direction of development.

Planning for Action

At this stage, the student attempts to draw a tentative conclusion. He explains that triangle PQR can be either a right triangle or an isosceles triangle, as long as its vertices are on three different sides. However, the student does not perform mathematical verification to determine whether the alternative positions drawn actually yield an area of 25 cm².

Findings in the planning for action stage: Students were able to identify the relationship between the conditions and the triangle's shape, but had not yet tested the feasibility of the area. Numerical verification and analysis had not yet been conducted, so the Planning for Action stage was not fully completed. Creativity in the evaluation stage was still weak, as students relied on textual inferences rather than mathematical analysis.

Table 2. Relationship between CPS Stages and Creative Thinking Aspects of Students with Average Mathematical Ability

CPS – Treffinger Stages	Student Behavior Findings	Aspects of Creative Thinking
Understanding the Challenge	1. Identifying basic information (side length, area of triangle, point conditions). 2. Redrawing the square and labeling points P, Q, R. 3. Not evaluating the possibility space before creating alternatives.	Fluency (good), Elaboration (reasonably good), Flexibility (limited)
Generating Ideas	1. Produces four triangle sketches in a square, using the combinatorial calculation 4!/3! to explain the number of alternatives. 2. Variations of the idea focus on changing the position of the points, not variations of the geometric structure.	Fluency (moderate–good), Flexibility (moderate), Originality (low), Elaboration (reasonably good),
Planning for Action	1. Giving an argument that the triangle may be right-angled or isosceles, has not verified the area of 25 cm²; the conclusion is conceptual, not supported by calculations.	Elaboration (limited to verbal explanation), Originality (low), Flexibility (weak in evaluation)

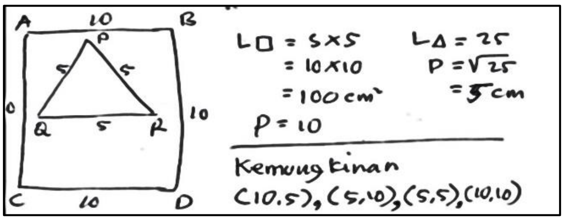
The data in the table 2. Shows that students with moderate mathematical abilities have a fairly well-developed creative thinking process, but it is not yet optimal at each stage of Treffinger's Creative Problem Solving (CPS). At the Understanding the Challenge stage, students are able to identify basic information and create visual representations, resulting in good fluency and elaboration. However, flexibility is still limited due to a lack of extensive exploration of various possibilities. At the Generating Ideas stage, students can generate several alternative solutions, such as sketching four triangles and using a combinatorics approach, indicating fairly good fluency and moderate flexibility. However, originality remains low because the ideas they generate tend to be conventional and structurally invariant. At the Planning for Action stage, students only provide conceptual conclusions without mathematical verification, resulting in low elaboration, flexibility, and originality in the evaluation stage. Overall, students' creative thinking abilities are at a moderate level, with a tendency for suboptimal exploration of ideas and solution evaluation.

Analysis of students' creative thinking skills at each stage of Creative Problem Solving (CPS) showed varying performance patterns across four indicators: Fluency, Flexibility, originality, and elaboration. At the Understanding the Challenge stage, students demonstrated good Fluency in writing basic information, but their Flexibility and originality were still low because they had not explored alternative solution strategies. Elaboration was in the moderate category, indicating that their ability to explain information was still limited. At the Generating Ideas stage, students again demonstrated good Fluency and generated several ideas, but their Flexibility was only moderate because the variety of ideas was not yet diverse. Originality remained low, as indicated by a lack of new or innovative ideas, while elaboration was moderate. At the Planning for Action stage, all indicators were in the low category. This indicates that students had not yet conducted in-depth verification, numerical reflection, or action planning. These findings indicate that although students were able to understand the problem and generate several ideas, their creative thinking skills were not yet fully developed, especially in Flexibility, originality, and action planning.

Students with Low Mathematical Ability

The students' work demonstrated a typical solution pattern for students with low mathematical abilities when faced with non-routine problems based on plane figures. On the answer sheets, students appeared to perform several initial steps, including redrawing visual information, calculating the area of a square, and finding the lengths of the sides of a triangle based on the available area values. However, these processes were performed only partially and procedurally, without demonstrating a deep understanding of the relationships among the figure's elements.

In the initial stage, the student wrote down the side length of the square (10 cm) and correctly calculated its area (100 cm²). However, when determining the triangle's dimensions, the student wrote: "L∆ = 25 cm²; P = √25 = 5 cm," indicating that the student used the triangle's area as the area of a square, then took the square root to obtain the triangle's side length. This indicates a fundamental misconception regarding the concepts of area and dimensional comparison. The student failed to consider that the area of a triangle cannot be directly converted to its side length without information about its height or geometric structure. The results of the students' answers can be seen in Figure 4.



The side length of the square (10 cm) correctly calculated its area (100 cm²).
L∆ = 25 cm²; P = √25 = 5 cm
The possible pairs of points P, Q, and R, (10, r), (r, 10), (r, r), (10, 10)

Figure 4. Results of the Work of Subjects with Low Mathematical Ability in Making Solutions

Next, when determining the possible pairs of points P, Q, and R, students onlywriting a list of possibilities in the form of simple coordinates (10, r), (r, 10), (r, r), (10, 10) without explaining how the value of r was chosen, whether r is a distance variable, or whether it represents a position in the coordinate system. This indicates that the student did not explore geometric constraints, did not examine the relationships among points, and did not understand how the points form a triangle that meets the problem's requirements.

In the final section, the student's verbal explanation of why the triangle cannot meet the requirements indicates that the student provided an inaccurate conceptual justification. The student wrote that a square has a side of 10 cm while a triangle has a side of 5 cm, so they cannot be in the same shape. This statement indicates that the student interpreted the relationship between the shapes statically and did not consider the possibility of representation, similarity, or the triangle's relative position within the square.

Understanding the Challenge

At this stage, students should: identify important information, connect information, clarify questions, and make initial representations. However, research findings show that low-ability students experience several major obstacles (1). Incomplete visual representation, students only redraw squares and triangles without labeling the relationships between points (e.g., points P, Q, R on the sides of the square). An incomplete representation makes it difficult for students to perform structural analysis. (2) Shallow conceptual understanding, students know the formula for the area of a square, but do not understand how the area of a triangle is related to the length of the side. They view the area as a single value that can be directly converted to distance. (3) Minimal elaboration, students do not have a process of clarification, reformulation of problems, or identification of restrictions. This shows very low levels of elaboration at this stage. So it can be concluded that students' abilities are still at the convergent level, not showing Flexibility or exploration of ideas. Students only copy basic information without modeling the relationships between objects.

Generating Ideas

This stage requires students to generate alternative ideas or strategies. In student work, A list of unfounded point pairs was found. Students wrote (10, r), (r, 10), (r, r), (10, 10) without providing context as to whether they were coordinate points or positions on the sides of a plane figure. The students' answers did not show any attempt to try alternative triangle shapes, test the feasibility of positions, or establish relationships between points. Fluency was minimal; only four possibilities were written without any additional explanation. There was no exploration of other possible triangle shapes. Flexibility was very low; students did not try to view the problem from different perspectives, such as using the concept of similarity, viewing the area as ½ × base × height, or considering the relative positions of points on the sides of a square. This confirms that students used an unstructured trial-and-error approach rather than a creative one. Therefore, students did not demonstrate a creative process in generating ideas; they listed numbers without understanding their mathematical meaning.

Planning for Action

At this stage, students were asked to select, evaluate, and test ideas. However, no idea evaluation was conducted. Students concluded that "there is no possible position of points P, Q, and R that meets the requirements" without conducting geometric verification. The justification was illogical; students reasoned that a triangle cannot be formed because its side is 5 cm, whereas a square's side is 10 cm. This shows the misconception that a triangle with a given area must have sides equal to the sides of a square. Originality was very low; no new ideas or alternative strategies emerged. There were no further calculations, no attempts to check the length of the sides, find the height, or match the position of the points mathematically. It can be concluded that students stopped the thinking process before evaluating or improving the strategy. There was no search for an optimal solution, not even a basic validation process.

Table 3. Relationship between CPS Stages and Creative Thinking Aspects of Students with Low Mathematical Ability

CPS – Treffinger Stages	Student Behavior Findings	Aspects of Creative Thinking
Understanding the Challenge	Incomplete visual representation (does not label the relationship between points), Misconception of area with side length, and does not clarify or identify restrictions.	Elaboration (low) Flexibility (low)
Generating Ideas	Writing a list of points "(10, r), (r, 10), (r, r), (10,10)" without geometric context, not exploring alternative triangle shapes, not trying other approaches (triangle height, similarity, point positions).	Fluency (very low) Flexibility (very low)
Planning for Action	Not evaluating written ideas, wrongly concluding that a triangle cannot be in a square due to the ratio of sides, and no verification or testing of the strategy.	Originality (low) Elaboration (very low)

The data in the table 3. Shows that students with low mathematical abilities experience difficulties at each stage of Treffinger's Creative Problem Solving (CPS), resulting in underdevelopment of their creative thinking processes. At the Understanding the Challenge stage, students are unable to fully represent the problem, experience misconceptions about basic concepts, and fail to identify problem boundaries, indicating low elaboration and flexibility. At the Generating Ideas stage, students simply list possibilities randomly without geometric context and do not explore alternative solutions, resulting in very low fluency and flexibility. Furthermore, at the Planning for Action stage, students fail to evaluate or verify their solutions and draw inappropriate conclusions. This indicates low originality and elaboration. Overall, students' creative thinking abilities in this category are still very limited and tend to be procedural without adequate conceptual understanding.

The student showed difficulties at every stage of the CPS-Treffinger model. In the *Understanding the Challenge* stage, the visual representation was incomplete and a misconception about area occurred, resulting in low elaboration and flexibility. In the *Generating Ideas* stage, the student listed several points without geometric context and did not explore alternative triangle forms, indicating very low fluency and flexibility. In the *Planning for Action* stage, the student failed to reassess ideas, drew incorrect conclusions, and did not verify the strategy, demonstrating low originality and elaboration.

DISCUSSION

Students with high mathematical ability can solve non-routine geometry-based problems through a structured creative thinking process that follows the stages of Treffinger's Creative Problem Solving (CPS) model. The solution pattern demonstrates mature representational skills, exploration of alternatives, and strategy evaluation characteristics that Lithner (2006) identified as key characteristics of creative problem solving in high-ability students. Verification results confirm that students with high mathematical ability use non-routine strategies independently, rather than conventional procedures. They combine multiple mathematical concepts, such as plane geometry and coordinates. They demonstrate high flexibility, as demonstrated by exploring several triangle configurations. They can evaluate solutions argumentatively, rather than simply completing calculations. This demonstrates the characteristics of Creative Mathematical Reasoning (Lithner, 2008), because strategies are built from understanding, not imitation.

Students demonstrate the ability to comprehensively identify and interpret important information, including the area of a square, the length of a side, the area of a triangle, and possible relationships between the positions of points. This ability aligns with the demands of the first stage of CPS, which is to clarify the problem and build an initial understanding through information analysis (Treffinger & Isaksen, 2005). This ability is included in the elaboration and flexibility indicators according to Sternberg (1974), because students can transform information from sketches into more analytical coordinate models. The use of dual representations (visual-coordinate) also shows advantages in constructing mathematical meaning, consistent with research stating that high-ability students have more adaptive representational capacity in solving complex problems (Stylianou, 2013). The ability to create clear and structured sketches indicates a good level of Fluency, because students can generate multiple initial representations as a basis for exploring ideas. This is in line with Leikin (2013) view that Fluency of ideas is the foundation for higher creative thinking processes. Students' ability to generate several valid alternative solutions also indicates a high level of Fluency, because it can expand the solution space and avoid being fixated on a single approach. Furthermore, the selection of several point configurations in a square shows a strong spatial imagination, which, according to Leikin (2013), is an important marker of mathematical creativity. Originality is clearly visible when students independently transform the problem into a coordinate system without guidance from the problem. This strategy can be considered an unconventional solution, demonstrating novelty in the way the problem is modeled. This aligns with Torrance (1973) definition of originality, which emphasizes the uniqueness of approach as a hallmark of high creativity. This finding is also consistent with the literature, which shows that students with advanced representational abilities are more likely to produce unique solutions to non-routine geometry tasks (Bergqvist, 2007).

In the Planning stage, students select a solution by applying systematic mathematical evaluation. Students re-examine the side lengths and areas for each alternative triangle shape and then compare their fit to the problem constraints. This demonstrates strong strategic evaluation skills, which, according to Treffi (2007), are central to the action planning stage in CPS. The decision that the best configuration is a right triangle approximating an equilateral triangle indicates that students prioritized not only the accuracy of calculations but also considered the coherence of the geometric context. This ability reflects mature metacognitive control, as described by Schoenfeld (1982), who found that competent students exhibited reflective and evaluative thinking throughout the problem-solving process. Students' written reflections, which explain the rationale for their solution selection and provide mathematical arguments, represent a very high level of elaboration. This elaboration includes not only detailed steps but also procedural integration.

In the early stages of CPS, students demonstrate good fluency in identifying basic information. This ability aligns with the fluency indicator according to Jaarsveld et al., (2012), which is the ability to generate a large amount of relevant information in a relatively short time. Students also demonstrated considerable elaboration through a complete iterative diagram with vertex labels and side lengths, which aligns with the concept of elaboration as the ability to enrich the details of a representation (Torrance, 1973). However, students' flexibility was still limited because they did not evaluate various possible vertex configurations before creating alternative triangle shapes. This limitation aligns with Persmeg's findings, which indicate that intermediate-ability students tend to focus on direct problem interpretation rather than exploring a broader solution space. In the context of CPS, this stage should serve as a foundation for exploring ideas (Treffinger et al., 2007), so a lack of flexibility in the early stages can impact the creative process in later stages.

Students with moderate mathematical ability. In the idea generation stage, the core of creativity, students generated four alternative visual representations of a triangle and used simple combinatorial calculations. This finding indicates relatively good Fluency, consistent with the theory that the ability to generate many alternatives is a hallmark of Fluency in creative thinking (Torrance, 1973). However, the alternatives generated were still variations on the position of points without expanding the geometric structure or using other mathematical approaches. This resulted in only moderate Flexibility. The lack of strategy variation supports Leung & Silver (1997) claim that students at moderate ability levels tend to get stuck in one representation method and do not easily switch to other strategies. Originality was also low, as the generated ideas did not demonstrate truly unique or unusual creativity, in line with originality criteria that emphasize the novelty of ideas (Runco & Jaeger, 2012). Nevertheless, students' elaboration was evident through fairly structured verbal and visual explanations. Thus, the Idea Generation stage demonstrates the development of basic creativity, but has not yet reached the strategic diversification or innovation of ideas as emphasized in the CPS-Treffinger framework (Treffinger & Isaksen, 2005).

In the action planning stage, students draw a conceptual conclusion that the resulting triangle might be a right triangle or an isosceles triangle, based on the given geometric information. However, students do not conduct numerical verification or further analysis. This low quality of verification indicates weaknesses in the evaluative aspect of creativity, which is a crucial part of the solution implementation stage according to Treffinger et al., (2007). This condition is consistent with previous research findings that students with intermediate abilities often stop at the conceptual level of understanding without proceeding to quantitative analysis or proof (Stylianides, 2007). Flexibility and originality are again low at this stage, indicating that the process of evaluating and refining ideas is not occurring optimally. This aligns with the view of Mumford et al., (2011) that the skills of evaluating, verifying, and revising ideas are often the most challenging aspects of creative thinking, especially in mathematical contexts.

Based on the four indicators of creativity (Fluency, Flexibility, Originality, Elaboration), the pattern of student performance shows that Fluency is relatively good in the first two stages, indicating the ability to generate basic information and ideas. Flexibility is at a moderate level in the Idea Generation stage, but low in other stages, indicating limitations in switching strategies. Originality is consistently low in all stages, reflecting that the ideas that emerge are still in the conventional category. Elaboration is moderate in the early stages, but decreases in the evaluation stage. This pattern supports the idea that mathematical creativity develops gradually and requires the ability to connect and develop ideas through broader exploration (Date & Type, 1997). Overall, these findings indicate that although students can understand problems and generate some alternative ideas, their creative thinking skills are not optimal, especially in terms of flexibility, originality, and evaluation of solutions. These findings are in line with research by Yuli & Siswono (2011) and Sriraman (2004), which found that middle-level students are generally able to explore ideas but experience limitations in mathematical modeling and justification.

Students with low ability, at the Understanding the Problem stage, were unable to construct complete and functional representations. Visual representations, in the form of squares and triangles, lacked labels for the relationships between points, thus failing to produce meaningful geometric structures. According to Treffinger & Isaksen (2005), this stage requires identifying important information, clarifying the problem, and creating an initial representation as a basis for exploring ideas. Similar misunderstandings have been reported in elementary geometry studies, particularly among students who have not yet mastered the relationships between the dimensions of plane figures (Clements & Sarama, 2011).

At the Generating Ideas stage, students did not explore alternative concepts conceptually or spatially. This stage in the CPS model requires the ability to generate a variety of possible ideas (Fluency) and view the problem from different perspectives (Flexibility) (Treffinger et al., 2007). The limited number of alternatives and the lack of feasibility checks indicate that divergent thinking is not occurring. This finding aligns with research by Torrance (1973), who found that students with low creativity tend to stop at the first alternative that appears and fail to transform ideas. Furthermore, the tendency to write symbolic lists without mathematical meaning indicates weak metacognitive control, a phenomenon often observed in non-routine problem solving (Leikin, 2013).

The Planning for Action phase demonstrated the most significant weaknesses. Students failed to evaluate their written ideas and immediately concluded that no configuration of points could form a triangle with a given area within a square. This justification was provided without geometric verification, recalculating the length of the sides or height, or checking the relative positions of the points. However, evaluating and testing ideas is a key component of the final stage of the CPS (Treffinger & Isaksen, 2005). The low level of originality and lack of further elaboration suggest that the thinking process stalled before reaching the validation stage, a pattern common in students with limited metacognitive control (Schoenfeld, 1985).

Overall, the results indicate that students with low mathematical ability experienced difficulties across all stages of the CPS Treffinger. These difficulties were associated with poor representational skills, geometric misconceptions, minimal exploration of ideas, and a lack of strategy evaluation. Aspects of creative thinking, including fluency, flexibility, elaboration, and originality, appear to be at very low levels. This finding strengthens the argument that developing mathematical creativity requires strong conceptual understanding, visual representation skills, and the support of learning strategies that emphasize exploration and reflection (Treffinger et al, 2007).

CONCLUSION

The conclusion of this study indicates that students' creative thinking processes in solving non-routine mathematical problems using Treffinger's Creative Problem Solving (CPS) model occur in stages and differ significantly based on their mathematical ability level. Students with high ability can optimally complete all stages of the CPS, characterized by a deep understanding of the problem, the ability to generate various flexible and original strategies, and the reflective and argumentative evaluation of solutions. In this group, indicators of mathematical creativity such as fluency, flexibility, originality, and elaboration emerge consistently and support each other at each stage of the CPS. Students with moderate ability demonstrate a developing but unstable creative thinking process; they can understand the problem and generate several alternative solutions, but are still limited to simple variations and are not optimal in verification and evaluation. Meanwhile, students with low ability demonstrate procedural and fragmented thinking processes, characterized by conceptual misconceptions, incomplete representations, minimal exploration of ideas, and the absence of solution evaluation, resulting in insufficient creativity indicators. These findings confirm that the quality of conceptual understanding, representational skills, and divergent and evaluative thinking skills significantly influence the characteristics of students' creative thinking processes at each stage of the CPS-Treffinger. Theoretically, this research enriches the study of the relationship between creativity and mathematical problem solving by emphasizing the importance of analyzing the process, not just the results. Practically, the CPS-Treffinger model has proven relevant for use in non-routine mathematics learning, but requires differentiated pedagogical support so that each student can optimize their creative thinking potential.

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