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Analysis of students' creative thinking ability in solving quadrilateral mathematical problems

Wharyanti Ika Purwaningsih, Riawan Yudi Purwoko*
Universitas Muhammadiyah Purworejo, Central Java, Indonesia
*Correspondence: riawanyudi@umpwr.ac.id

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Abstract
This study aims to analyse the creative thinking abilities of eighth-grade junior high school students in solving mathematical problems related to quadrilaterals. The study employed a qualitative exploratory descriptive design with purposive sampling, involving two students with high mathematical ability. The test instruments were validated by mathematics education experts to ensure content validity and alignment with creative thinking indicators. Data were collected through problem-solving tests, in-depth interviews, and field notes, and were analysed using the Miles and Huberman model, which consists of data reduction, data display, and conclusion drawing. The results showed that both students met all indicators of creative thinking—fluency, flexibility, originality, and elaboration—by generating multiple alternative solutions, using varied strategies, and presenting unique and detailed answers. These findings indicate strong creative thinking skills in solving non-routine mathematical problems and suggest that future research should involve a larger and more diverse sample, explore different mathematical topics or educational levels, and employ experimental approaches to further examine strategies for enhancing students' creative thinking skills.

Keywords: Creative thinking, Junior high school, Mathematical problems, Problem-solving, Quadrilateral,

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Introduction

Creative thinking is a key competence in mathematics education emphasized in both international and national frameworks. International assessments such as PISA reveal students' difficulties in solving non-routine problems that require creative thinking, while the NCTM highlights the importance of fostering problem solving, reasoning, and creativity in mathematics instruction. In Indonesia, the national curriculum and Permendiknas No. 23 of 2006 stress the development of higher-order thinking skills, including creative thinking, through mathematics learning. Therefore, developing students' creative thinking skills is a fundamental objective of school mathematics education.

Mathematics is one of the basic disciplines that plays an important role in developing logical, systematic, critical, and creative thinking skills (Sulistyowati et al., 2019). Mathematics learning is not only oriented towards the final result in the form of correct answers, but also towards the thinking process that occurs during problem solving

(Miftakhudin et al., 2019). Therefore, mathematics is taught at all levels of education, from elementary school to university, as a means of developing *higher order thinking skills* (Purwoko, Purwaningsih, et al., 2023; Tanujaya et al., 2017). This is in line with the mandate of Permendiknas No. 23 of 2006 concerning *Graduate Competency Standards,* which states that after studying mathematics in junior high school, students are expected to be able to demonstrate logical, critical, creative, and innovative thinking skills, learn independently according to their potential, and be able to analyze and solve problems in everyday life (Kemendikbud, 2017). Thus, one of the main objectives of mathematics learning in school is to develop students' creative thinking skills.

Creative thinking skills are not merely complementary to mathematics learning but constitute the core of mathematical thinking processes (Schindler & Lilienthal, 2020). Through creative thinking, students are able to generate new ideas, apply various solution strategies, and view problems from multiple perspectives (Sujarwo & Yunianta, 2018). Creative thinking is defined as the ability to produce multiple alternative solutions based on given information and to develop novel and meaningful ideas to solve problems (Abramovich & Freiman, 2023; Hursen, 2021). However, several studies and large-scale assessments indicate that students' creative thinking skills remain relatively weak. Results from PISA and the Indonesian Minimum Competency Assessment (AKM) reveal that many students experience difficulties in solving non-routine and open-ended mathematical problems that require originality and flexibility. Previous research also shows that students tend to rely on routine procedures and struggle to generate diverse or innovative solutions. These findings highlight the need for deeper investigation into students' creative thinking abilities and instructional practices that can effectively foster creativity in mathematics learning.

In the context of mathematics learning, there are four indicators of creative thinking, namely: (1) *fluency*, the ability to generate many ideas or alternative solutions; (2) flexibility, the ability to see problems from various perspectives; (3) *originality*, the ability to generate unique and unusual ideas; and (4) elaboration, the ability to describe and enrich ideas in detail (Puspitasari et al., 2019).

However, in classroom learning practices, students' creative thinking skills tend to be underdeveloped. Students are often directed to solve math problems in one way that is considered the most correct, generally in accordance with the solution examples provided by the teacher (Mwei, 2017; Tyas & Pangesti, 2018). This situation causes the learning process to become mechanistic and less cognitively challenging (Gilmore et al., 2025; Koskinen & Pitkäniemi, 2022). Many students are accustomed to imitating the steps provided by the teacher without trying to find other alternatives. As a result, students do not have sufficient experience in exploring various possible solutions and are not trained to think creatively.

In fact, creative thinking skills are very important when students are faced with non-routine problems. Problem solving in mathematics learning is a series of complex thinking processes to find solutions to problems that cannot be solved directly with routine procedures (Han et al., 2017). Non-routine problems require students to use new strategies, make connections between concepts, and think reflectively and flexibly. Non-routine problems are problems that cannot be solved using methods that have been learned or by following existing examples (Nguyen et al., 2020; Ozan Gavaz et al., 2021). On the other hand, non-routine mathematics encourages students to develop creative thinking strategies because there are no explicit steps available for solving them (Purwoko, Kusumaningrum, et al., 2023).

In this study, quadrilaterals were deliberately selected as the research context because this topic possesses strong potential to elicit students' creative thinking processes. Conceptually, quadrilaterals involve multiple interrelated properties, such as side lengths, angle relationships, symmetry, and area formulas, which allow problems to be approached through various strategies and representations. From a pedagogical perspective, quadrilaterals are commonly introduced at the junior high school level and are suitable for constructing non-routine problems that require students to explore, compare, and generalise mathematical ideas rather than merely apply memorised procedures. Furthermore, quadrilateral issues can be designed to encourage flexibility and originality by allowing multiple solution paths, such as using algebraic reasoning, geometric visualisation, decomposition, or transformation. Therefore, quadrilaterals provide an appropriate and meaningful context for examining how students with high mathematical ability employ creative thinking skills when solving non-routine mathematical problems.

In daily learning, teachers often emphasize routine exercises to achieve curriculum and exam results. This condition means that students are given fewer opportunities to experiment with new ideas or use alternative approaches to solve problems. As a result, students' creative potential is not developed optimally. On the other hand, the development of the national curriculum that emphasizes Higher-Order Thinking Skills (HOTS), such as in the National Curriculum, requires teachers to facilitate students to be able to think creatively, reflectively, and critically in solving problems.

Various studies have emphasized the importance of creative thinking skills in mathematics learning and have shown that students' levels of creative thinking vary according to their mathematical abilities. Research indicates that students with higher mathematical ability tend to demonstrate greater fluency, flexibility, and originality in problem solving, as they are able to generate more ideas and apply diverse strategies compared to students with moderate or low abilities (Schindler & Lilienthal, 2020; Setiana & Purwoko, 2020). In contrast, students with lower mathematical ability often rely on routine procedures and exhibit limited creative responses when faced with non-routine problems. This suggests a close relationship between students' initial mathematical ability and their creative thinking performance. Although previous studies have examined creative thinking across different ability levels, most research has focused on identifying creative thinking levels or comparing students with moderate and low abilities. Studies that specifically explore the creative thinking processes of students with high mathematical ability, particularly in solving non-routine geometry problems, remain limited.

This gap indicates the need for in-depth qualitative investigations to better understand how high-ability students employ creative thinking in mathematical problem solving. Therefore, this study aims to analyze the creative thinking abilities of eighth-grade junior high school students with high mathematical ability in solving quadrilateral problems. The findings are expected to provide insights into students' creative thinking processes and serve as a reference for teachers in designing learning experiences that challenge and develop students' creative potential.

Methods

This study uses a qualitative approach with a phenomenological research type. This approach was chosen because it aims to understand and describe in depth the students' creative thinking experiences in the context of solving mathematical problems. The phenomenological approach allows researchers to explore the meanings and processes experienced by students when they interact with non-routine mathematical problems, rather than simply assessing the final results or answers obtained (Hafidhoh et al., 2023). Thus, this study focuses on a deep understanding of the phenomenon of creative thinking as experienced by the research subjects.

Research Location and Subjects

The research was conducted at a junior high school in Purworejo Regency, Central Java, from March to April 2024**.** The location was selected purposively because the school had representative academic characteristics and teachers who were open to research activities. The research subjects were determined using purposive sampling, which is the selection of subjects based on certain considerations relevant to the research objectives (Kurniawati et al., 2023; Sinaga et al., 2022). The main consideration in selecting subjects was the students' high mathematical ability. Mathematical ability classification was determined based on the results of a mathematics test analyzed using a standard deviation formula to group students into high, medium, and low categories. Two students with high mathematical ability were selected as the main subjects of the study. The selection of these two subjects was intended to obtain in-depth and detailed data on the characteristics of creative thinking in high-ability students in the context of mathematical problem solving. The selection of two subjects is methodologically justified in phenomenological research, as the primary goal is to obtain rich, detailed, and nuanced descriptions of the phenomenon under investigation rather than to achieve statistical generalization.

Instruments and Data Collection Techniques

Research data were collected using three main techniques: written tests, in-depth interviews, and field notes. The written test consisted of two open-ended, non-routine contextual problems related to quadrilaterals, designed to elicit students' creative thinking. The test items were developed based on four indicators of creative thinking fluency, flexibility, originality, and elaboration and were validated by two experts in mathematics education to ensure content validity, clarity, and alignment with the research objectives. Revisions were made according to the experts' feedback before the test was administered. Each item allowed students to provide multiple solution strategies and explanations, enabling an in-depth analysis of their creative thinking processes.

In depth interviews were conducted after the written test to explore students' reasoning, decision-making processes, and strategies for solving the problems. The interviews were semi-structured, guided by an interview protocol developed from the creative thinking indicators, and included probing questions to clarify students' written responses and uncover underlying thought processes. Each interview lasted approximately 30–45 minutes and was audio-recorded for transcription and analysis. Field notes were used to document students' nonverbal behaviours, expressions, and contextual situations during the test and interview sessions, providing additional insights and supporting data triangulation.

Data Analysis Techniques

Data analysis was carried out continuously from the beginning of data collection to the final stage of the research, referring to the Miles and Huberman analysis model (Nafaridah et al., 2023; Setiana & Purwoko, 2020) which includes three main stages, namely 1) Data reduction, which is the process of selecting, focusing attention, simplifying, and transforming raw data from test results, interviews, and field notes into a more organized form. At this stage, researchers select data relevant to indicators of students' creative thinking. 2) Data display, which is the process of organizing data into narratives, matrices, or charts to facilitate understanding and interpretation. Data presentation is carried out in the form of a detailed description of the students' thinking process when solving mathematical problems. 3) Conclusion drawing/verification, which is the process of interpreting the meaning of data and drawing conclusions supported by strong evidence from field data. The conclusions obtained are then verified repeatedly to ensure their validity and consistency.

Data Validity Test

To ensure the credibility of the research results, technical triangulation was carried out by comparing the data obtained from the test results, interviews, and field notes. In addition, the researcher also conducted member checking by asking the subjects to review the researcher's interpretation of their answers and explanations. This step was taken to ensure that the meaning captured by the researcher was in accordance with the actual experiences intended by the students.

Research Procedure

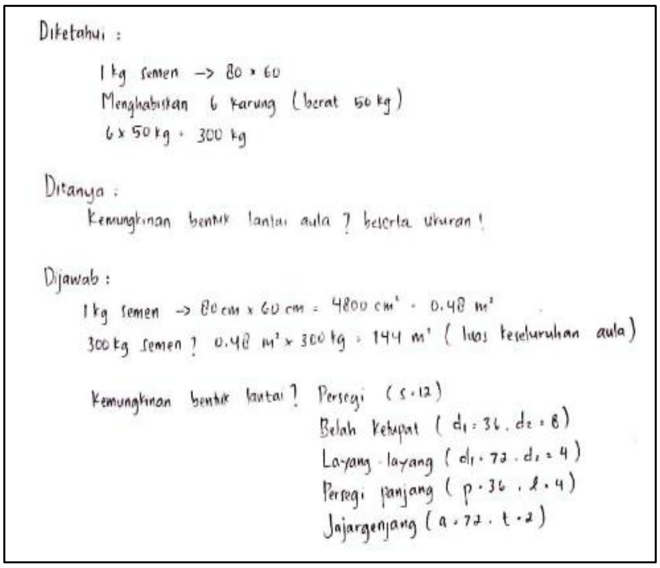
The research was conducted in three main stages, namely: 1) The preparation stage, which included the preparation of research instruments, content validation by experts, and coordination with the school and mathematics teachers. 2) The implementation stage, which included the implementation of mathematics problem-solving tests, in-depth interviews with selected subjects, and field observation notes. 3) The analysis and reporting stage, in which the data obtained was analyzed in depth and compiled into a research report describing the creative thinking abilities of students with high mathematical abilities in solving mathematical problems.

Results

Based on the results of data collection and analysis during the study, an in-depth picture was obtained of the creative thinking abilities of students with high mathematical abilities in solving mathematical problems based on four indicators, namely elaboration, fluency, flexibility, and originality.

Creative Thinking Ability of Subject S1

Figure 1 is a vignette of Subject S1's response.



Diketahui :

1 kg semen -> 80 × 60
Menghabiskan 6 karung (berat 50 kg)
6 × 50 kg = 300 kg

Ditanya :
Kemungkinan bentuk lantai aula ? beserta ukuran !

Dijawab :
1 kg semen -> 80 cm × 60 cm = 4800 cm² = 0,48 m²
300 kg semen ? 0,48 m² × 300 kg = 144 m² (luas keseluruhan aula)

Kemungkinan bentuk lantai ? Persegi (s = 12)
Belah ketupat (d_1 = 36, d_2 = 8)
Layang-layang (d_1 = 72, d_2 = 4)
Persegi panjang (p = 36, l = 4)
Jajargenjang (a = 72, t = 2)

The student begins by identifying the given information. One kilogram of cement can cover an area of 80 cm × 60 cm. The student then notes that there are six sacks of cement, each weighing 50 kg, for a total of 300 kg.

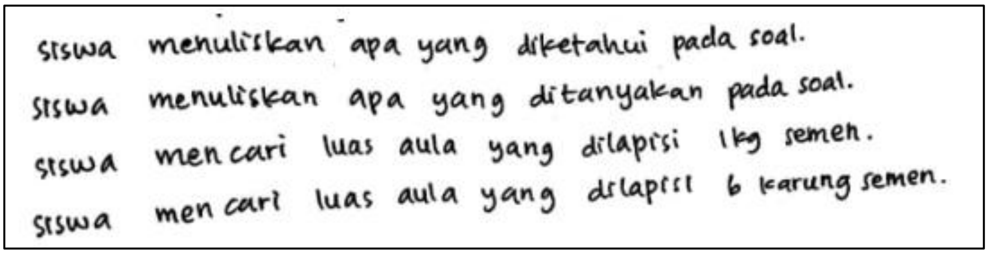
Next, the student determines the area covered by one kilogram of cement. Multiplying 80 cm by 60 cm yields an area of 4,800 cm², which is converted to 0.48 m². Using this result, the student calculates the total floor area by multiplying 0.48 m² by 300 kg, concluding that the total area of the hall floor is 144 m².

After finding the total area, the student explores possible floor shapes with an area of 144 m². Several quadrilateral shapes are proposed, along with their corresponding dimensions. These include a square with side length 12 m, a rhombus with diagonals 36 m and 8 m, a kite with diagonals 72 m and 4 m, a rectangle with length 36 m and width 4 m, and a parallelogram with base 72 m and height 2 m.

Figure 1. Subject S1's Answer Results

Elaboration

Subject S1's answer results (Figure 2) show that he is able to systematically describe the problem by writing down the known and unknown information accurately. The subject can calculate the total area of the hall floor correctly through logical calculation steps. This finding indicates an ability to detail and clarify mathematical ideas well. In line with (Mursidik et al., 2015; Purwaningsih & Supriyono, 2020), students with high mathematical ability tend to have strong elaboration skills because they are able to write down the steps of the solution in detail, logically, and accurately.



siswa menuliskan apa yang diketahui pada soal.
siswa menuliskan apa yang ditanyakan pada soal.
siswa mencari luas aula yang dilapisi 1kg semen.
siswa mencari luas aula yang dilapisi 6 karung semen.

The student begins by clearly writing down the information given in the problem. Next, the student explicitly states what is being asked, showing an understanding of the problem requirements. After that, the student calculates the area of the hall floor that can be covered by one kilogram of cement. Finally, the student determines the total area of the hall floor that six sacks of cement can cover.

Figure 2. Field Notes Results of Subject S1

Based on field notes, Subject S1 wrote that 1 kg of cement could cover a floor measuring 80 cm × 60 cm, with a total of six bags of cement used, each containing 50 kg. The subject then calculated the total area of the hall floor by multiplying the area that could be covered by 1 kg of cement by the total cement used. These results indicate analytical thinking skills that support the elaboration aspect of creative thinking.

Fluency

Subject S1 was able to produce five alternative floor plans for the hall, namely square, rectangle, rhombus, kite, and parallelogram, complete with their respective sizes. The subject determined the size of each shape accurately using the relevant quadrilateral area formula. The strategy used was to determine one size as the initial variable to find the other sizes. These findings show that the subject was fluent in generating various solution ideas, in line with the view of (Sujarwo & Yunianta, 2018) that students with high mathematical abilities are able to produce many alternative solutions logically and efficiently.

Interviews with Subject S1 reinforced these findings. The subject explained that he tried various possible sizes based on the known total area. For example, for a square, he rooted the area of 144 m^2 to a side length of 12 m; for a rectangle, he tried a length of 36 m and a width of 4 m; and for rhombuses and kites, he calculated the diagonals using various approaches. This strategy demonstrates the ability to experiment with mathematical ideas and concepts in a flexible and productive manner.

Flexibility

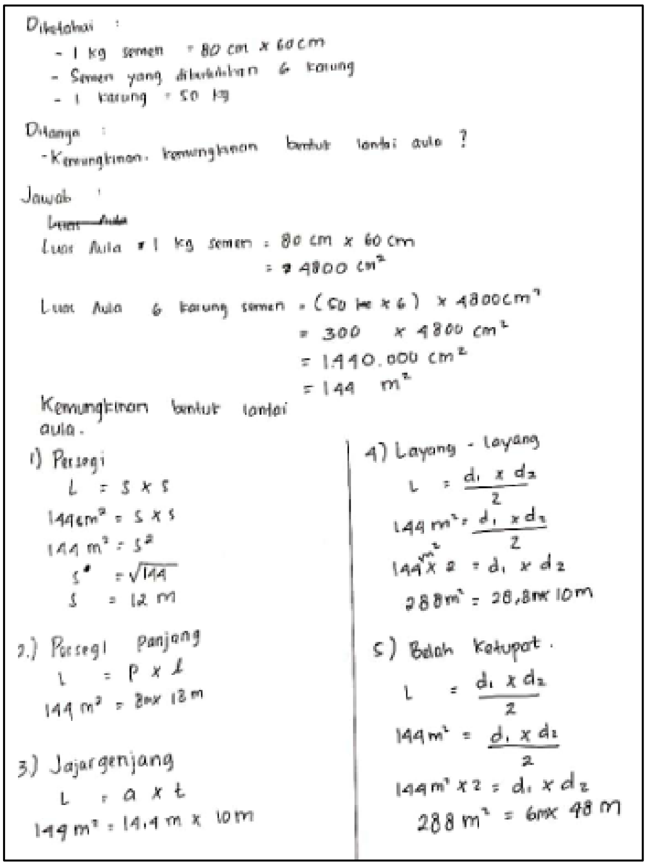
Subject S1 demonstrated the ability to review problems from various perspectives. He understood that the term "quadrilateral" was not limited to squares, but included various other shapes such as rectangles, rhombuses, parallelograms, kites, and trapezoids. This is reflected in the answers and interviews, which show that the subject is able to change strategies and utilize geometric concepts flexibly to produce different alternative solutions. These findings are in line with the results of the study (Nugraheni & Ratu, 2018) states that students' flexibility in thinking is evident when they are able to use a variety of approaches or conceptual representations in solving problems.

Originality

The responses of the S1 subjects showed unique ideas that differed from those of other students. The subject was able to suggest possible shapes for the hall that were not the same size as their friends'. This shows original thinking, which indicates the ability to generate new and unconventional ideas. This finding reinforces the view that students with high mathematical ability tend to more easily display originality because they have a strong conceptual basis for modifying and developing new ideas (Mursidik et al., 2015).

Creative Thinking Ability of Subject S2

Figure 3 is a vignette of Subject S2's response.



The student starts by clearly listing the given information, namely that one kilogram of cement can cover an area of 80 cm × 60 cm, that six sacks of cement are available, and that each sack weighs 50 kg. The student then states the question, which is to determine the possible shapes of the hall floor.

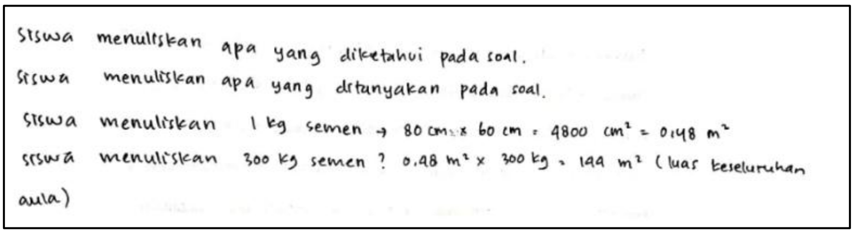
In the solution section, the student first calculates the area covered by one kilogram of cement by multiplying 80 cm by 60 cm to obtain 4,800 cm². The student then determines the total amount of cement by multiplying 50 kg by six sacks, resulting in 300 kg. Using this information, the student calculates the total floor area by multiplying 300 kg by 4,800 cm², obtaining 1,440,000 cm², which is then converted into 144 m².

After finding the total area, the student explores several possible quadrilateral shapes for the hall floor that have an area of 144 m². The student considers a square by applying the formula L=s×s and determines the side length to be 12 m. Next, the student proposes a rectangle with dimensions 24 m × 6 m. The student also considers a parallelogram by using the area formula L=a×t and provides example dimensions that result in the same area. In addition, the student examines a kite shape using the formula L=(d1×d2)/2 and determines suitable diagonal lengths. Finally, a rhombus is also included, again using the diagonal-based area formula to show that different diagonal combinations can yield the same total area.

Figure 3. Subject S2's Answer Results

Elaboration

Subject S2's answer results (Figure 4) show the ability to detail the problem clearly. They were able to write down the known and asked information completely, as well as calculate the total floor area of the hall using the correct procedure. This shows the ability to organize logical and sequential thinking steps.



The student begins by writing down the information given in the problem and clearly states what is being asked. The student then calculates the area that can be covered by one kilogram of cement by multiplying 80 cm by 60 cm, obtaining 4,800 cm², which is converted into 0.48 m². Next, the student determines the total amount of cement used, namely 300 kg, and multiplies it by the area covered per kilogram. From this calculation, the student concludes that the total area of the hall floor is 144 m².

Figure 4. Subject S2's Field Notes

The field notes show that Subject S2 understands the relationship between the amount of cement, the coverage area per kg of cement, and the total floor area to be covered. This finding supports the opinion of (Sujarwo & Yunianta, 2018) that students with high mathematical abilities tend to think systematically in describing their ideas for solutions.

Fluency

Subject S2 produced five alternative shapes: square, rectangle, parallelogram, kite, and rhombus, along with the corresponding measurements. He used a strategy of substituting one measurement to obtain the other, and calculated accurately using the area formula for each shape. In the interview, S2 explained that the process involved exploration and comparison between shapes based on the same area (144 m^2). This strategy demonstrates strong divergent thinking skills, as emphasized by (Mursidik et al., 2015) that students with high mathematical abilities find it easier to generate many ideas relevant to the problem.

Flexibility

Subject S2 also demonstrated flexible thinking by considering various possible shapes of quadrilaterals and applying the appropriate concept to each shape. They understood that quadrilaterals are not limited to squares, but also include other shapes such as rectangles, parallelograms, rhombuses, trapezoids, and kites. Statements in the interviews reinforced this finding, with S2 mentioning that the shape of the hall floor did not have to be square because various types of quadrilaterals have the same number of sides, namely four.

Originality

Subject S2 provided alternative auditorium shapes with different sizes from his friend. This demonstrates the ability to produce unique and unconventional solutions. The aspect of originality in S2 is evident in the way he chooses sizes and combinations of length-width or diagonal that are not uniform with other students, demonstrating creativity in mathematical thinking.

Based on the analysis of the two subjects, it can be concluded that students with high mathematical abilities perform well on all four indicators of creative thinking. They are able to elaborate information clearly (elaboration), generate many alternative solutions (fluency), review problems from various perspectives (flexibility), and propose unique solutions (originality).

These findings reinforce the theory that creative thinking skills are positively correlated with good mastery of mathematical concepts (Purwoko et al., 2019; Sujarwo & Yunianta, 2018).Conceptual knowledge enables students to develop more diverse and in-depth problem-solving strategies. This is in line with the findings (Mursidik et al., 2015; Setiana & Purwoko, 2020; Sujarwo & Yunianta, 2018) that students with high mathematical ability are more capable of displaying creativity in the form of flexibility of thinking, originality of ideas, and breadth of solutions.

Discussion

The findings of this study indicate that junior high school students with high mathematical ability consistently demonstrate creative thinking across four indicators: elaboration, fluency, flexibility, and originality. This consistency is evident in the problem-solving patterns of the research subjects, which show similarities in both their reasoning processes and the solutions they generated.

First, in the elaboration aspect, both students demonstrated the ability to analyze information coherently, clearly, and systematically. They were able to differentiate between known and questionable information and use appropriate mathematical representations to calculate the floor area of a room. This aligns with findings that students with high mathematical ability possess representational and systematic reasoning skills, enabling them to explain their thinking steps in detail without losing the logical flow (Hafidhoh et al., 2023). Therefore, the elaboration aspect in both students indicates strong metacognitive abilities in controlling and explaining their thought processes.

Second, in the fluency indicator, both junior high school students with high mathematical ability were able to generate numerous alternative geometric shapes with different dimensions but the same area. This ability reflects divergent thinking, as the students produced multiple valid solutions that were relevant to the given problem context. This finding aligns with research suggesting that high-ability students tend to generate multiple solutions to a single problem due to their strategic flexibility and fluency in activating prior knowledge (Zamzam et al., 2024). Thus, the fluency abilities of both subjects confirm that creative thinking not only produces correct answers but also multiple possible correct answers.

Third, the flexibility aspect is evident in the two subjects' ability to change their perspective on the solution by selecting different formulas for the area of a plane figure based on the chosen shape. The subjects did not follow a single standard procedure but could adjust their strategy based on the figure's characteristics. This phenomenon supports the view that flexibility of thinking indicates the ability to adapt strategies, represent concepts in various forms, and connect concepts across mathematical topics (Andira et al., 2022). Thus, the flexibility demonstrated by junior high school students with high mathematical ability reflects strong conceptual mastery and meaningful relationships among geometric concepts.

Fourth, regarding the originality indicator, both subjects demonstrated unique ideas, particularly in their use of variations in size and combinations of geometric shape dimensions, which differed from other students' answers. This indicates that originality is a dimension of creative thinking, reflecting the ability to generate new, unfamiliar ideas. This finding is consistent with research suggesting that students with high conceptual mastery are more likely to demonstrate creative ideas because they possess a knowledge foundation that allows for the exploration of unconventional strategies (Nugraheni & Ratu, 2018; Setiana & Purwoko, 2020).

The ability of students with high mathematical ability to meet all creative thinking indicators can be explained by their strong conceptual understanding and effective metacognitive regulation during non-routine problem solving. Well-organized mathematical knowledge enables these students to flexibly connect concepts and generate multiple valid solution strategies, supporting fluency and flexibility. At the same time, metacognitive control allows them to plan, monitor, and evaluate their reasoning, which facilitates elaboration and encourages originality through the exploration of non-routine and non-standard approaches. This interaction explains both why and how high-ability students consistently demonstrate comprehensive creative thinking.

Overall, this study's findings confirm that students with high mathematical ability demonstrate optimal performance across all indicators of creative thinking. Thus, this study provides empirical evidence that creative thinking ability is not a separate ability from mathematical ability, but rather a component that develops as students' understanding and problem-solving abilities increase.

Conclusion

This study concludes that junior high school students with high mathematical ability are able to demonstrate all four indicators of creative thinking fluency, flexibility, originality, and elaboration when solving non-routine problems on quadrilaterals. The findings highlight that creative thinking is closely intertwined with strong conceptual understanding and flexible problem-solving strategies, rather than functioning as an isolated skill. The main contribution of this study lies in providing empirical evidence on how high-ability students employ creative thinking processes in mathematical problem solving, particularly in the context of non-routine geometry tasks. Pedagogically, these findings imply that mathematics instruction should move beyond routine exercises by incorporating open-ended and non-routine problems that encourage exploration, multiple solution strategies, and reflective reasoning. Such learning experiences are essential for fostering students' creative thinking and for shifting mathematics learning from a result-oriented approach toward a process-oriented and cognitively meaningful practice.

Declarations

Author Contributions	:	WIP: Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing. RYP: Validation, Writing - Review & Editing, Supervision.
Funding Declaration	:	No Funding.
Conflict of Interest	:	The authors declare no conflict of interest.
Additional Information	:	No additional information available.

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