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Examining Potential Teachers' Capabilities for Creative Thinking in Geometry Problems Using Analytical Framework NEA

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ABSTRACT

In classroom practice, the use of problems that require students to engage both in higher-order thinking and creative reasoning has been recognized as among the most effective strategies for meaningful learning. Within this context, the present study was designed to investigate in depth the types of errors committed by mathematics education students, who are also prospective teachers, in demonstrating their creative thinking abilities when dealing with geometry-related tasks. The analytical framework employed was Newman Error Analysis (NEA), which provides a systematic way to examine mistakes in problem-solving processes. A qualitative approach with a descriptive case study design was selected in order to capture a detailed picture of the phenomena under investigation. The participants consisted of 22 mathematics education students from a university located in Surakarta. Several methods were used to gather data, including direct classroom observation, the administration of diagnostic tests specifically developed to measure mathematical creative thinking, and in-depth interviews. The data analysis followed the model proposed by Miles and Huberman, involving three interrelated steps: data reduction, data display, and the formulation of conclusions. The findings revealed that the most frequent and significant errors occurred during the transformation and encoding stages of problem solving. This study concludes that strengthening prospective teachers' exposure to non-routine geometry problems and explicitly addressing common error patterns are essential for improving creative mathematical thinking.

Keywords: Creative Thinking Skills, Geometry Problem, Newman Error Analysis, Prospective Teachers.

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Introduction

In recent years, improving the quality of mathematics education has remained a central concern in Indonesia and many other educational systems. Ongoing curriculum reforms, including the implementation of the Independent Curriculum, emphasize the development of higher-order thinking skills (HOTS), creativity, and flexibility to prepare learners for the complex demands of the twenty-first century (Kemendikbudsaintek RI, 2024). Within this context, mathematics learning is expected not only to transmit procedural knowledge but also to cultivate students' abilities to reason, explore multiple solution strategies, and apply mathematical ideas meaningfully in diverse situations (Mukuka et al., 2023).

Despite these curricular intentions, mathematics continues to be perceived as a difficult subject by many learners. Empirical evidence indicates that students often struggle with mathematics due to its abstract nature, heavy reliance on rules and formulas, and instructional practices that prioritize memorization over conceptual understanding (Guner, 2020). These difficulties are further compounded by the increasing emphasis on HOTS-oriented tasks, which require learners to engage in complex reasoning and problem solving. While the integration of HOTS into problem-based learning is theoretically intended to deepen understanding, in practice it can become problematic when students lack sufficient conceptual foundations, strategic competence, or prior experience with non-routine problems. As a result, instead of supporting learning, HOTS-based problem-solving tasks may amplify students' cognitive load and expose weaknesses in their mathematical thinking processes (OECD, 2024).

This issue is particularly evident in geometry learning. Geometry problems demand the coordination of multiple forms of representation, including textual descriptions, diagrams, and symbolic expressions, as well as the ability to reason spatially and logically (Xiao et al., 2024). Many students encounter difficulties when transforming geometric situations into appropriate mathematical models or when applying relevant concepts and formulas accurately (Zhang & Jia, 2024). Consequently, errors frequently arise not only from a lack of procedural skill but also from deeper problems related to understanding, reasoning, and decision-making during problem solving.

One important competency that is closely related to success in solving non-routine geometry problems is mathematical creative thinking. Creative thinking in mathematics involves fluency in generating multiple ideas, flexibility in adopting different strategies, originality in producing uncommon solutions, and elaboration in developing and communicating ideas in detail. These abilities are increasingly recognized as essential components of effective mathematics learning and teaching, particularly in the context of HOTS-oriented instruction (Gunawan et al., 2022). However, developing such abilities remains challenging, as many learners continue to rely on memorized procedures rather than adaptive and reflective thinking.

To better understand students' difficulties in mathematical problem solving, researchers have widely employed Newman's Error Analysis (NEA) as a diagnostic framework. NEA categorizes errors into sequential stages, including comprehension, transformation, process skills, and encoding, thereby allowing researchers and educators to identify where and why learners experience breakdowns in problem solving (Lubis et al., 2021; Makgakga, 2023). Previous studies using NEA have consistently reported that errors often occur at the transformation and encoding stages, indicating that students struggle to translate problems into mathematical forms and to express final solutions accurately (Ashari et al., 2023; Muhassanah & Nurcahyono, 2025).

Nevertheless, a critical limitation of existing research is that most NEA-based studies have focused on primary and secondary school students (Fineldi et al., 2025; Makgakga, 2023; Muhassanah & Nurcahyono, 2025; Nufus et al., 2024). While this body of work has provided valuable insights into learners' difficulties, it has paid relatively little attention to university students, particularly those enrolled in mathematics education programs who are being prepared as future teachers (Beissembayeva et al., 2025; Jailani et al., 2023). This represents an important research gap, as prospective mathematics teachers are expected to possess strong conceptual understanding and creative problem-solving abilities, as well as the pedagogical capacity to foster these skills in their future students. If such competencies are underdeveloped at the pre-service level, difficulties in implementing HOTS-oriented and creative mathematics instruction may persist in schools.

Furthermore, although previous studies have examined either mathematical creative thinking or error patterns in problem solving, limited research has explicitly integrated these two perspectives. Specifically, little is known about how different types of errors, as identified through NEA, manifest in relation to specific indicators of mathematical creative thinking when prospective teachers solve geometry problems. This lack of integrated analysis constrains our understanding of the underlying cognitive and pedagogical challenges faced by future teachers.

Addressing this gap is both theoretically and practically important. From a theoretical perspective, examining prospective teachers' creative thinking through the lens of NEA can enrich existing models of mathematical problem solving by linking error patterns with dimensions of creativity (Muhassanah & Nurcahyono, 2025). From a practical perspective, such analysis can inform the design of targeted instructional interventions in teacher education programs, particularly those aimed at reducing reliance on memorization and enhancing engagement with non-routine, creativity-oriented tasks (Beissembayeva et al., 2025). Given the central role of teachers in mediating curriculum reforms and HOTS implementation, understanding and improving their creative mathematical thinking is an urgent priority.

Based on these considerations, the present study aims to investigate the mathematical creative thinking abilities of prospective mathematics teachers in solving geometry problems by analyzing their errors using Newman's Error Analysis framework. Specifically, this study seeks to answer the following research questions: (1) What types of errors do prospective mathematics teachers make at each stage of problem solving when addressing geometry problems that require creative thinking? (2) How are these errors related to the indicators of mathematical creative thinking, namely fluency, flexibility, originality, and elaboration? By addressing these questions, this study contributes new empirical evidence on the intersection of creative thinking and error analysis in pre-service mathematics teacher education.

Methods

This study adopted a qualitative research design with a descriptive method to examine students' errors in creative thinking when solving geometry problems through Newman's Error Analysis (NEA).

Descriptive research focuses on portraying existing phenomena and presenting them clearly without extending interpretations beyond the observed facts. To achieve this, a case study approach was employed (Nassaji, 2015). A case study enables researchers to investigate specific issues or problems within a limited context, emphasizing detailed exploration over a defined period. Cassidy et al. (2013) explain that such an approach requires collecting comprehensive and in-depth data through various techniques, including observation, testing, and interviews. Within this framework, the researcher aimed to identify how errors emerge during the problem-solving process and how NEA categorizes these mistakes into different stages. The results were expected to provide insights into the common difficulties faced by students, which could serve as a valuable reference for improving teaching practices in mathematics education.

The research was carried out at a Surakarta university in the 2024/2025 odd semester, involving 22 geometry students in their third semester, including 5 men and 17 women. This study used purposive sampling to select subjects, setting specific criteria in line with the study objectives. These criteria included: (1) mathematics education students enrolled in the odd semester of 2024–2025, (2) those with a background in mathematics, and (3) their willingness to participate in all stages of the study, including diagnostic tests and interviews. The selection of subjects with these characteristics was considered relevant because they were more likely to experience difficulties in solving geometry problems. This was expected to produce more comprehensive and diverse information about the types of errors that occur in the process of mathematical creative thinking in geometry problems.

Data on students' mathematical creative thinking ability were collected through the use of test instruments. To guarantee the validity and reliability of the results, the instruments were carefully developed in advance. The exam questions are designed with reference to four main indicators of creative thinking with the following sub-indicators (Piirto, 2011):

Table 1. *Mathematical Creative Thinking Ability Test Guidelines*

Questions	Question Specifications	Indicator	Sub Indicator
1	A problem is presented about the basic concepts of polygons and triangles. If there is a rectangle that will be formed from regular hexagons and equilateral triangles, students can determine which design is aesthetically pleasing and efficient.	Fluncy	The ability to generate multiple solutions
2	A problem about the perimeter and area of a quadrilateral is presented. If there is a rectangle whose perimeter is known, students can construct another congruent square from the rectangle with the largest possible area.	Flexibility	Provides many alternatives or different directions
3	A sketch is presented showing a square with a shaded area. Students can determine how to obtain the length of one of the lines in detail.	Originality	Thinking of unusual ways

4	A sketch is presented showing a square containing an n-sided shape with a shaded center. Students can determine how to calculate the shaded area in their own way.	Elaboration	Elaborating on the details of an idea, object, or situation to make it more interesting

There are four essay problems used in the test, each of which represents one indicator and is validated by two experts. The results of the Aiken Diagnostic Test coefficient calculations for students are presented in the following table:

Table 2. *Aiken's Coefficient V Scale Conversion on Diagnostic Tests*

Question Number	V	Criteria
1	0,825	Valid
2	0,950	Valid
3	0,800	Valid
4	0,875	Valid

Based on the expert assessment, each test item was evaluated by two experts using a five-point rating scale. The resulting Aiken's V coefficients ranged from 0.80 to 1.00, indicating that all test items met the criteria for validity (Aiken, 1985). The questions were then tested on students to determine their empirical validity, which was found to be valid with a moderate level of difficulty and sufficient discriminating power. An unstructured interview method was then used after a diagnostic test to obtain in-depth data on the types and causes of errors made by students in solving geometry problems. A total of six students were selected for interviews, each representing high, medium, and low levels of mathematical creative thinking ability.

The study of students in solving geometry problems based on mathematical creative thinking abilities was processed through an analysis developed by Milles and Huberman, namely data reduction, data presentation, and data conclusions (Miles & Huberman, 1994). This process was used to ensure methodological accuracy in interpreting the data obtained in the diagnostic test and in-depth interviews. In the reduction stage, researchers calculated data based on test results that were categorized and coded using manual coding assisted by Excel, filtering and grouping data based on NEA categories, namely errors in understanding, transforming, mathematical processes, and encoding.

The presentation stage is carried out by transforming the data into a classification table of errors, making it easy to see the patterns of errors and the relationship between each type of error. The final stage is verification and conclusion drawing by interpreting the meaning of each pattern found. This process is not only about finding the proportion of each type of error, but also about deciphering the reasons for the errors made by students. Thus, explicitly, this analysis provides a strong basis for developing recommended and targeted learning for the 21st century (Miles & Huberman, 1994).

Results and Discussion

The results of research on prospective teachers' mathematical creative thinking abilities in solving geometry problems based on Newman's analysis were processed according to Milles and Huberman, namely data reduction, data presentation, and data conclusion.

Data Reduction

After the assessment process, the data analysis process began with data reduction by presenting the distribution of each student's score in solving the mathematical creative thinking problem on plane geometry problems, as shown in Table 2.

Table 3. *Distribution Scores and Answer Categories for the Mathematics Creative Thinking Ability Test Overall*

Answer Categories	Number of Students Scored	Question				percentage (%)
		1	2	3	4	
Correct Answer	4	2	2	2	1	9
Correct but Incomplete Answer	3	3	4	7	4	20
Incorrect Answer	2	5	4	2	5	18
Not Completed Answer	1	6	9	5	3	26
No Answer	0	6	3	6	9	27
Jumlah		88				

Table 3 presents the distribution of students' scores across the four test items representing the indicators of mathematical creative thinking and reveals uneven performance with generally low achievement. For Item 1 (fluency), most students obtained low scores, indicating difficulty in generating multiple valid solutions. Items 2 and 3 showed slightly better outcomes, although only a small number of students achieved high scores. In contrast, Item 4 (elaboration) demonstrated the weakest performance, with the majority of students scoring zero. These findings indicate that students experienced the greatest difficulty when tasks required them to develop and clearly communicate their ideas. From the perspective of Newman's Error Analysis (NEA), low performance in fluency and elaboration reflects limitations in idea generation and refinement, which are closely associated with breakdowns at the transformation and encoding stages of the problem-solving process.

This table further clarifies students' difficulties by presenting the percentage distribution of answer categories. The dominant categories were "not completed answers" (26%) and "no answers" (27%), while fully correct answers accounted for only 9% of all responses. This distribution indicates that many students were unable to complete the problem-solving process, often abandoning their solutions before reaching a coherent conclusion. Such patterns are consistent with difficulties in sustaining reasoning under cognitive demands, particularly when tasks require creative exploration rather than routine procedures.

In general, the analysis of the types of difficulties students encounter in solving the problem requiring creative mathematical thinking through diagnostic tests is based on Newman Errors Analysis (NEA), which has been adapted to the needs of the researcher, including: 1) difficulties in understanding the problem; 2) difficulties in transforming the problem; 3) difficulties in processing the problem; and 4) difficulties in determining the encoding.

Error in comprehension of the problem

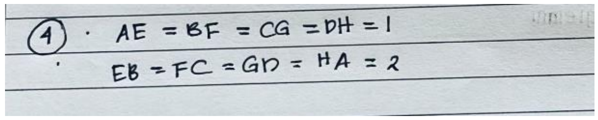

Figure 1. *Student errors in understanding the problem*

Based on the facts in the field, it appears that most students are still unable to determine what information is known in this problem. This can be seen in the following image, where students have provided a brief explanation in their answers, but only for the two pieces of information provided. Meanwhile, there is other information that can be obtained, namely the length of the square and how the triangle will also be congruent. This implies that some students do not yet understand the information provided in the dominant indicator, which is elaboration, namely detailing the details of an idea, object, or situation so that it becomes more interesting.

Error in transforming the problem

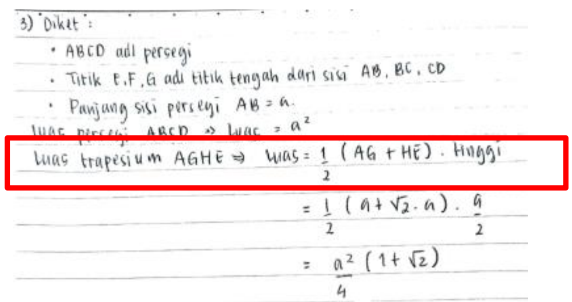

Figure 2. *Students' Error in Transforming the Problem*

In the next picture, it can be seen that the formulation of the trapezoid area has an error where the location is not correct at $\frac{1}{2}(AG + HE)\ x\ height$. It can be said that students in determining problem transformation experience many mistakes in problems in the originality aspect and are identified as having difficulty in solving problem number 3 regarding thinking of unusual ways. These findings indicate limited representational fluency, as students struggled to move flexibly between visual, verbal, and symbolic representations of geometric problems.

Errors in the mathematical process

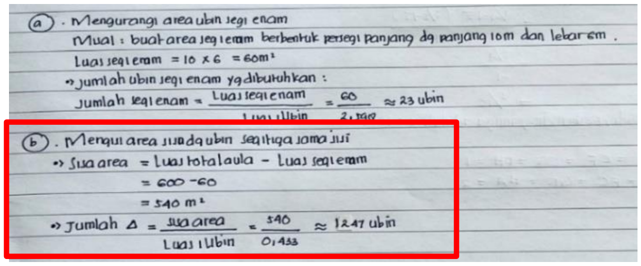

Figure 3. *Student Errors in the Mathematical Process*

prospective teacher's responses differed from step to step, as seen in Figure 3. The mathematical procedure of figuring out how many pieces of each tile are used demonstrates this. Given that there are 1247 triangular tiles in this image, it is evident that the tile requirements are not being met, whereas there are no more than 500 triangular and hexagon tiles. This case shows that even when students identified relevant formulas, they frequently applied them incorrectly or performed inaccurate calculations. Such errors suggest that students relied heavily on memorized procedures without fully understanding the underlying concepts. From an NEA perspective, these weaknesses reflect a breakdown in the procedural execution stage, which in turn compromises creative problem solving.

Error in determining encoding

In the following picture, it can be seen that students make mistakes in determining encoding. The following are the results of student answers in the originality indicator in question 3.

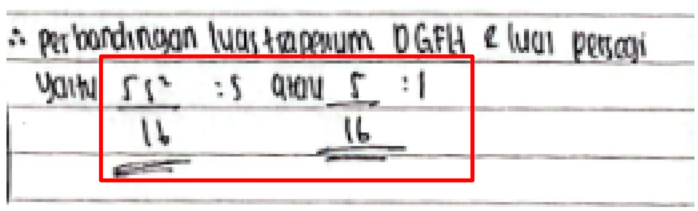

Figure 4. *Student Error in Determining Encoding*

Encoding errors emerged as the most dominant type of error across several indicators, especially originality and elaboration. It can be seen in Figure 4 that it has provided a solution to the final value, but the explanation of the results is wrong. It should produce a ratio of 5: 16, but students make $\frac{5s^2}{16}$: 1, which does not match the actual answer. Some students arrived at numerically plausible results but failed to express their solutions accurately or coherently. This indicates difficulty in articulating mathematical conclusions, even after partial success in earlier stages. Encoding errors therefore represent a critical barrier to demonstrating creative thinking, as ideas that are not clearly communicated cannot be evaluated or extended further.

After analyzing the answers, interviews were conducted with several prospective teachers to resolve issues based on the diversity of difficulties encountered. Based on the interview results, several statements were obtained: "I am confused about writing down what I know and what is being asked because I cannot remember the material being tested" (S8); in addition, in solving problem number 1, there was also a statement: "I am confused whether the tiles must be made in one shape or many" (S5).

The difficulty students had in transforming problems lay in determining the formula to use and creating mathematical models. Prospective teachers did not have a very good memory of the material, which affected the subsequent stages of solving the problems being tested. Based on the interview results, the majority of prospective mathematics teachers said they had forgotten the formulas, and some did not even know the mathematical symbols used in creating mathematical models.

In addition, errors in determining formulas are also a major factor in students' difficulties. The use of mathematical formulas or mathematical models that have been created, up to the point of mathematical operations, are the areas of difficulty experienced by students in the mathematical process. This is due to the students' inability to connect the known and unknown information from the problem, resulting in difficulties in using mathematical models.

Furthermore, students are still unable to design appropriate and logical solution patterns for the problems tested. This is evident when students are not careful in applying mathematical operations from formulas and mathematical models. In addition, students' weak mathematical calculation skills are a major factor in the mathematical process stage. Furthermore, prospective teacher students tend to rush to solve problems, which leads to errors in using mathematical calculations. Students' lack of knowledge of the formulas used even extends to the creation of mathematical models that they cannot use in their answers, so that in the interview session, students fail to use calculations and determine encoding. The interviews yielded various results, such as: "I was able to construct a mathematical model from problem number 3, but I didn't have time to use and operate the formula I made because I was in a hurry" (S2); "Because I was in a hurry to finish the problem, I used the wrong arithmetic operations in problems two and three, resulting in many mistakes" (S8); "I was confident that the rhombus formula I created could be used, but I used the mathematical model I created incorrectly for problem two" (S2).

Data Presentation

The following section presents a synthesized overview of students' performance and error patterns in solving geometry problems that require mathematical creative thinking. The data are organized to highlight trends across creative thinking indicators and Newman's Error Analysis stages, providing a clearer basis for interpreting the observed difficulties. This presentation serves as a bridge between the descriptive results and their subsequent analytical discussion.

Table 4. *Average Score of Each Indicator of Mathematical Creative Thinking Ability*

No.	Indicators of Mathematical Creative Thinking	Maximum Score	Score	
			$\overline{x}$	%
1	thinking with more than one answer (*fluency*).	4	1,50	38
2	diversity of given problem-solving strategies (*flexibility*).	4	1,68	42
3	Thinking of unfamiliar ways (*Originality*).	4	1,73	43
4	Elaborate an idea, object or situation so that it becomes more interesting (*Elaboration*).	4	1,32	33

Table 5 shows each student who has worked on four items of mathematical problems based on creative thinking skills, so a total of 88 student work is obtained with a maximum number of difficulties of 352. With a percentage of 33% of the overall maximum, the elaboration indicator is the innovative thinking skill that is most difficult overall. This indicates that many errors still occur, particularly in encoding. The two main challenges in resolving the tested problems are the mathematical procedure and figuring out the encoding. These results suggest that while some students were able to generate alternative approaches or unconventional ideas, they struggled to develop and communicate those ideas in detail. Table 5 reinforces this interpretation by showing that incomplete and unanswered responses dominated across all indicators, particularly for elaboration.

Table 6 below shows the results of student work on the tested questions seen from the ability to think creatively mathematically. This is detailed based on the indicators that become the reference so that the details are obtained.

Table 5. *Percentage of Student Mathematical Creative Thinking Ability Test Answer Results*

Aspek KBKM	Student Answer									
	JB		BKL		JS		TSM		TM	
	∑	%	∑	%	∑	%	∑	%	∑	%
1. *fluency*	2	9	3	14	5	23	6	27	6	27
2. *flexibility*	2	9	4	18	4	18	9	41	3	14
3. *originality*	2	9	7	32	2	9	5	23	6	27
4. *elaboration*	1	5	4	18	5	23	3	14	9	41
Total	7		18		16		23		24	

Note:
JB : Correct Answer
BTL : Correct but Incomplete Answer
JS : Incorrect Answer
TSM : Not Completed Answer
TM : No Answer

Information was obtained that showed that the results of each student's work in solving mathematical problems were different, this can be seen in Table 5. Problem number 1, in the fluency aspect, students gave a greater percentage in the element of not answering and not completing the answer with a rate of 27%. In comparison, the correct answer only had a percentage of 9%, and only two students were able to answer correctly. This also happened in the aspects of flexibility, originality, and elaboration, which only gave less than three correct answers.

On the flexibility of the dominant students who did not finish answering, on the originality of the dominant students who have the right answer but incomplete, and on elaboration has the highest percentage of students who do not answer on solving geometry problems. It is identified that there are still many problems that occur in students about their understanding of solving plane geometry problems in 3rd semester students at the University.

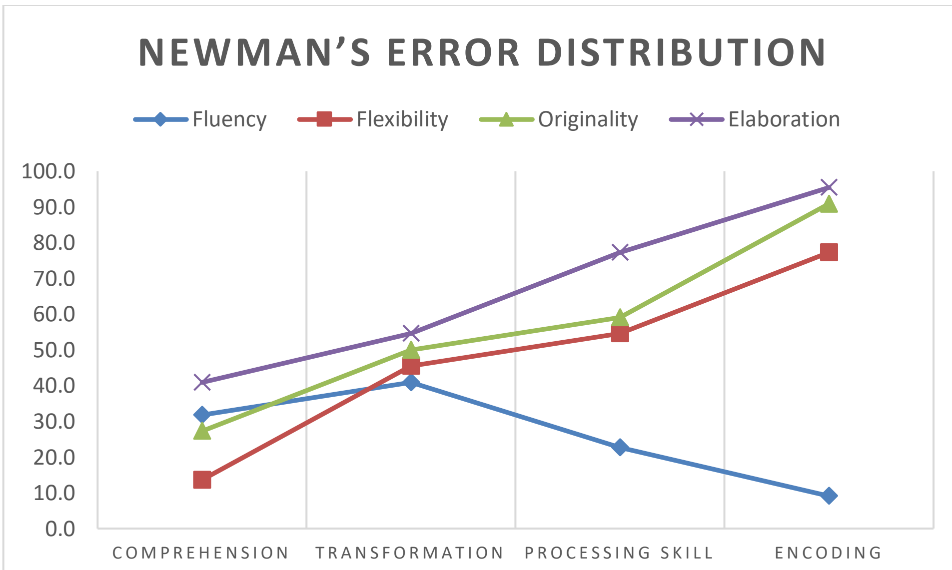

Figure 5. *Indicator of Creative Thinking Based on Newman's Error Distribution*

Figure 5 integrates these findings by illustrating the distribution of NEA errors across creative thinking indicators. Encoding errors were dominant in elaboration, originality, and flexibility, whereas transformation errors were most prevalent in fluency. This pattern highlights a close relationship between creative thinking demands and specific stages of problem-solving failure.

Discussion

The findings of this study indicate that prospective mathematics teachers demonstrated generally low levels of mathematical creative thinking when solving geometry problems, with significant difficulties emerging at the transformation and encoding stages of problem solving. These results suggest that creative thinking challenges are not limited to generating ideas but are strongly associated with students' ability to represent, process, and communicate mathematical reasoning.

From a theoretical perspective, the dominance of transformation and encoding errors can be interpreted through the lens of cognitive load theory. Geometry problems that require creative thinking impose high intrinsic and extraneous cognitive loads, particularly when students must coordinate multiple representations and devise non-routine strategies (Ekin et al., 2025; Redifer et al., 2021). When students lack well-developed schemas, cognitive resources may be depleted before they reach the encoding stage, resulting in incomplete or inaccurate solutions (Mierop et al., 2020). This helps explain why many students abandoned their answers or failed to articulate final conclusions.

The prevalence of process skill errors further suggests limited conceptual understanding and overreliance on memorization. Although memorized procedures may suffice for routine tasks, they are insufficient for creative problem solving, which demands flexible adaptation of knowledge. This finding aligns with prior research indicating that procedural dominance constrains students' ability to engage in higher-order and creative thinking (Hwang & Riccomini, 2021). However, beyond confirming previous studies, the present results highlight how such limitations manifest specifically among prospective teachers, a group expected to model creative reasoning in future classrooms.

Encoding errors, which were particularly prominent in originality and elaboration tasks, reveal an often-overlooked aspect of creative thinking: representational and communicative competence. Even when students generated viable ideas, they struggled to express them clearly and coherently. This finding underscores the importance of representational fluency the ability to translate internal reasoning into external mathematical expressions as a critical component of creative problem solving(Kristayulita et al., 2020; Maskar et al., 2023; Xu et al., 2022). Without this fluency, creative ideas remain implicit and cannot be effectively evaluated or shared.

The results also raise important implications for mathematics teacher education. If prospective teachers experience persistent difficulties in creative problem solving, especially in geometry, they may be less prepared to design and facilitate HOTS-oriented learning in schools(Jupri & Hidayat, 2022; Zamzam et al., 2023). This underscores the need for instructional approaches that systematically expose pre-service teachers to non-routine problems and explicitly address common error patterns identified through NEA.

Several limitations of this study should be acknowledged. First, the sample size was relatively small and drawn from a single institution, which limits the generalizability of the findings. Second, the focus on plane geometry restricts the extent to which conclusions can be extended to other mathematical domains. Future research could involve larger, multi-institutional samples and explore additional topics to further examine the relationship between creative thinking and error patterns.

Despite these limitations, this study contributes to the literature by integrating mathematical creative thinking indicators with Newman's Error Analysis in the context of pre-service teacher education. By linking specific error types to dimensions of creativity, the study provides a more nuanced understanding of where and why prospective teachers struggle, offering a foundation for more targeted and theoretically grounded instructional interventions.

Conclusion

Based on the results, it can be concluded that overall, the average mathematical creative thinking ability of students in semester 3 with the subject of plane geometry, whose material is in the flat field, is still low, namely 39%. This ability can be seen in each aspect, namely in the aspect of fluency related to thinking of more than one answer, the percentage obtained is 38%, the flexibility aspect related to finding many alternatives or different directions obtained a percentage of 42%, the originality aspect related to thinking of unusual ways obtained 43%, and the elaboration aspect related to detailing ideas, objects, or situations to make them more interesting obtained a percentage of 39%. The biggest mistakes were in transformation and encoding. This happened because of the determination of something that was known and asked from the information due to the inability to remember the material in the test, forgetting the material given, not knowing the systematic solution to the problem, the inability of students to identify the meaning of terms, a lack of technical memory in applying concepts in difficult situations, and the tendency of students to memorize the steps without understanding the concepts used in solving the problem. There needs to be consistent handling in providing non-routine problems for each problem given to improve creative thinking skills. This indicates that a high cognitive load can negatively affect creative thinking performance and suggests that appropriate support for divergent and convergent thinking can improve students' creative thinking skills, although its impact on geometry performance still needs to be further researched.

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