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Exploring students' creative thinking processes in solving non-routine mathematical problems

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ABSTRACT

Creative thinking is an essential 21st-century skill that plays a significant role in mathematics learning, especially when students encounter non-routine problems. Unfortunately, learning practices still predominantly use routine questions that emphasize algorithmic procedures, limiting students' opportunities to develop their creative potential. This study aims to analyze the types of creative thinking students employ when solving non-routine mathematical problems and to describe their cognitive characteristics. Using an exploratory qualitative approach and a case study design, the research involved 108 eighth-grade students, with three representative subjects selected for analysis through written tests and in-depth interviews. The findings reveal variations in students' creative thinking in solving non-routine math problems. Most (48.15%) are replicative, imitating solutions with limited flexibility; 37.96% are adaptive, adjusting strategies to context; and 13.89% are constructive, creating original solutions independently. This highlights the need for non-routine problems, creativity-based learning, and STEM integration to enhance flexibility, advanced creativity, and contextual analytical skills. The study contributes by demonstrating how non-routine problems and creativity-focused, STEM-integrated learning can cultivate diverse creative thinking types, enhance cognitive flexibility, and foster students' ability to generate original, contextually informed solutions in mathematics education.

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INTRODUCTION

Creativity is a fundamental 21st-century skill and a critical focus in education, particularly in mathematics learning at junior and senior high school levels (Newton & Newton, 2014; Suyitno, 2020; Szabo et al., 2020). In mathematics, student creativity is reflected not only in obtaining correct answers but also in producing diverse, original, adaptive, and meaningful problem-solving strategies (Kholil et al., 2024; Supena et al., 2021; Villanova & Cunha, 2020). Mathematical creativity involves fluency in generating ideas, flexibility in changing perspectives or strategies, and originality in formulating non-routine solutions (Silver, 1997; Villanova & Cunha, 2020). However, empirical evidence indicates that non-routine problems in classrooms remain underrepresented, often below 20%, while learning largely emphasizes procedural and algorithmic tasks (Kholid et al., 2024; Öztürk et al., 2020; Schoevers et al., 2021). This limited exposure constrains the development of students' creative potential. Therefore, investigating how students construct and express creativity when solving non-routine problems is crucial, providing both theoretical insights and practical guidance for designing adaptive learning strategies to foster higher-order thinking skills.

Research on creativity in mathematics education has grown significantly over the past two decades and can be categorized into several areas. First, creativity is seen as a general competency, involving cognitive skills and dispositional traits influencing students' learning in mathematics (Leikin & Lev, 2013). Second, non-routine problem-solving studies show that such tasks stimulate innovative strategies and divergent thinking, encouraging multiple solution approaches beyond procedural knowledge (Kablan & Uğur, 2021; Schoevers et al., 2020). Third, research on creative thinking focuses on cognitive processes, such as fluency in generating ideas, flexibility in shifting perspectives, and originality in formulating solutions (Kholil, 2020; Sriraman, 2008). Fourth, creativity-based learning designs, including problem-based learning, open-ended tasks, and Technology-Enhanced Mathematics (TEM) integration, promote creative reasoning and higher-order thinking (Bicer et al., 2020; Ďuriš et al., 2023; Rahayuningsih et al., 2021). Despite this progress, there is limited research analyzing specific types of creative thinking demonstrated by students in non-routine problem-solving contexts, leaving a critical gap that warrants further exploration to better understand and foster mathematical creativity.

Although previous studies have extensively examined creativity in mathematics education, most have focused on enhancing creative thinking skills through instructional interventions or developing creativity assessment instruments. However, research that specifically investigates the types of creative thinking students exhibit in the context of solving non-routine problems remains very limited. This gap is significant because the types of creative thinking reflect the variety of cognitive strategies employed by students, ranging from the ability to adapt procedures to generating innovative and original solutions (Lu & Kaiser, 2021; Subanji et al., 2021, 2023). Existing studies generally assess creativity levels without identifying the underlying thinking patterns (Borg Preca et al., 2023; Donzallaz et al., 2023; Suryanto et al., 2021). In this context, further research is needed to explore how mathematical creativity emerges in non-routine problem-solving, providing an empirical basis for more adaptive and responsive instructional strategies that accommodate diverse student abilities.

Aligned with this research gap, the primary objective of this study is to analyze the types of creative thinking exhibited by students when solving non-routine mathematical problems and to describe in depth the cognitive characteristics accompanying each type. By mapping the variation in students' creative thinking patterns, this study aims to provide a more comprehensive understanding of how mathematical creativity manifests in non-routine problem-solving contexts. Theoretically, the study is expected to enrich the literature by offering new perspectives on the variation and indicators of creative thinking in mathematics, while practically, the findings are expected to support teachers and instructional designers in formulating more adaptive and responsive learning strategies that foster the optimal development of higher-order thinking skills.

Based on preliminary findings from exploring students' responses to solving non-routine mathematical problems, student creativity does not emerge in a single pattern but is divided into several thinking patterns, such as combining routine procedures with new modifications, producing unusual alternative strategies, or creating entirely original solutions. This variation in patterns indicates that mathematical creativity operates through diverse cognitive characteristics and cannot be understood solely in terms of general creativity levels. These preliminary findings led to two main research questions: What types of creative thinking do students demonstrate when solving non-routine mathematical problems? Moreover, what cognitive characteristics are associated with each type of creative thinking? These questions define the scope of the research and explain the focus of the analysis that will be conducted in greater depth.

RESEARCH METHOD

This study uses an exploratory qualitative method with a case study design. A qualitative approach was chosen because the study aims to gain an in-depth understanding of students' creative thinking processes when solving non-routine mathematical problems, a phenomenon that is complex, contextual, and cannot be reduced to numerical data alone. The case study design was considered most appropriate because it allowed the researcher to examine students' cognitive behavior in real situations (Brennen, 2025; Creswell & Creswell, 2023), thereby revealing the characteristics, variations, and dynamics of creativity more naturally. In this context, the researcher acted as the main instrument, collecting data through tests and interviews to capture students' thinking processes directly and in depth. This study focuses on an in-depth analysis of the process by which students solve non-routine mathematical problems, particularly in relation to the type of creative thinking developed, as outlined in Subanji's theory (Subanji et al., 2021, 2023). The following is the framework for creative thinking types in this study.

Table 1
Framework for Creative Thinking Types

Subanji's Creative Thinking Model		Creative Thinking Types in This Study	
Model	**Mathematical Creativity**	**Type**	**Mathematical Creativity**
Imitation	Imitating similar solutions to resolve existing problems	Replicative	Imitating or copying strategies or forms that have been taught without significant changes
Modification	Changing the problem/data/solution procedure to obtain a more efficient solution	Adaptive	Adjusting the image or general strategy according to the context of the problem
Creation	Developing new resolution procedures in line with the demands of the issue	Constructive	Creating new images or strategies that have never been taught before

The subjects in this study were 108 eighth-grade students at a public elementary school in Ajung Village, Jember Regency, Indonesia, comprising 73 female and 35 male students. The students were selected using purposive sampling based on the results of a creative thinking ability test (Leavy, 2017). Three students were chosen to represent each type of creative thinking: one for the replicative type, one for the adaptive type, and one for the constructive type. This selection was guided by the principle of information-rich cases in qualitative research, which emphasizes the depth of information obtained from purposively selected participants rather than the sample size. By choosing one representative per type, researchers could explore the cognitive characteristics and thinking patterns of each type in depth without losing analytical focus. This approach aligns with case study practices in qualitative research, which prioritize intensive understanding of phenomena over broad generalization (Hayashi et al., 2019).

The steps for selecting the research subjects were as follows: first, non-routine math problems were given to all eighth-grade students. Next, the students' work was observed, corrected, and analyzed according to the types of creative thinking. Then, discussions were held with the mathematics teacher to strengthen the analysis and determine the most representative students for each type. Finally, three students were selected as research subjects based on the analysis results, and interviews were conducted to gather further information.

Data were collected using two techniques: written tests and in-depth interviews. The written tests were designed to measure students' creative thinking skills in solving non-routine statistical problems (Evans et al., 2021). The following is the format of the written test used in this study.

Figure 1
Non-routine Problems

A farmer grows curly chili peppers and cayenne peppers from May to January. The graph below shows the harvest yield of curly chili peppers over a period of 5 months. Create a line graph showing the harvest yields of "curly chili peppers" and "cayenne peppers" from May to January in a single graph so that in January the harvest yields of both types of chili peppers are the same.

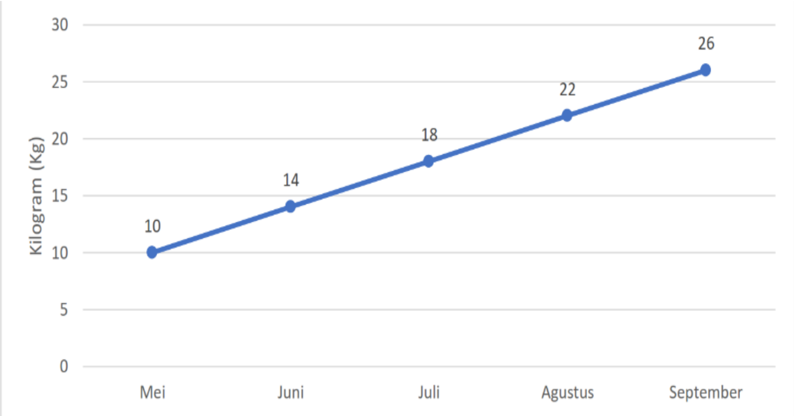

Figure 1 shows the questions used in the written test. Based on the test results, students' answers were classified according to indicators of creative thinking, namely fluency, flexibility, and originality (Kholil, 2020; Panglipur et al., 2025; Silver, 1997; Utami et al., 2019). To minimize subjectivity in the classification process, this study used an assessment rubric developed from Silver's (1997) indicators of mathematical creativity and adapted to the context of the non-routine questions provided. The rubric contains clear operational descriptions for each level of achievement on each indicator, so that assessments can be carried out consistently and verifiably. Subsequently, in-depth interviews were conducted to further explore the types of creative thinking among students. The interviews were structured with a set of validated questions.

The data were analyzed using the Miles, Huberman, and Saldana model (Miles et al., 2014), which consists of three stages: a) data reduction: filtering and summarizing test results and interview transcripts to focus the analysis on relevant data. b) data presentation: compiling data in tables and descriptive narratives to facilitate interpretation of the results. c) drawing conclusions: summarizing findings based on students' thinking patterns according to their level of creative thinking ability. Data validity was ensured through source and technique triangulation, which involved comparing test and interview results to check for consistency of information (Ruth et al., 2024). In addition, the research instruments underwent content, construct, and language validity tests and were consulted with experts to ensure their suitability for students' creative thinking types (Creswell & Poth, 2018).

RESULTS AND DISCUSSION

Results

Students' creative thinking abilities

Based on the data obtained, researchers analyzed students' creative thinking when solving non-routine math problems. The test was given to 108 eighth-grade students, and the results were used to identify each student's creative thinking abilities and explore the various types of creative strategies they applied. This analysis included the ability to think flexibly, find patterns, develop alternative solutions, and apply creative logic in the context of non-routine problems. The results of the identification of students' creative thinking abilities are presented in detail as shown in Figure 2.

Figure 2
Diagram of creative thinking abilities

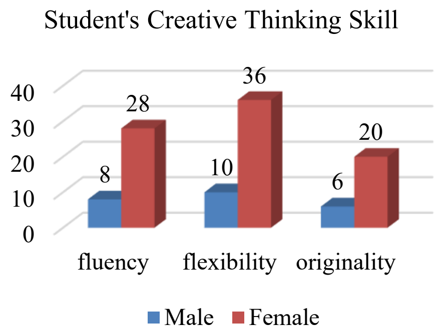

Figure 2 shows that 33.33% of students have fluency skills, 42.59% have flexibility skills, and 24.07% have originality skills. These results indicate that some students meet all three indicators of creative thinking, while others meet two indicators, and still others meet only one. These results were further analyzed to explore the types of creative thinking among students. The exploration of students' work produced three types of creative thinking: replicative, adaptive, and constructive, as shown in Figure 3.

Figure 3
Results of creative thinking type exploration

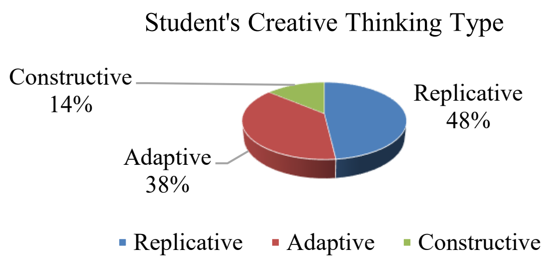

Figure 3 shows that 52 students exhibit replicative, 41 adaptive, and 15 constructive creative thinking. From this distribution, three students AN, ZLQP, and ARH were selected as research subjects to explore the three types of creative thinking in depth..

Replicative creative thinking type

Based on the results of the students' creative thinking ability test in solving data graph questions on crop yields, subject AN was identified as having a replicative creative thinking type. AN solved the questions by copying the existing graph with minimal modifications. Figure 4 shows the results of subject AN's work.

Figure 4
AN's work results

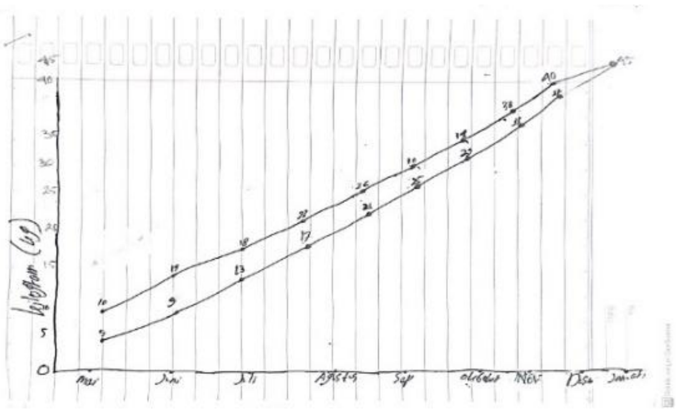

Figure 4 shows that the subject's graph exhibits the same upward pattern and is consistent with the initial graph. The trend line for cayenne pepper follows the pattern of the curly pepper graph with only slight differences in value. The graph shows visual imitation, not data-based mathematical processing.

To provide a deeper analysis of AN's work, the researcher examined the four stages AN went through in solving non-routine math problems. First, identifying the problem in the question. AN understood the question in general. When asked, he explained that the question asked him to make a new graph and determine the same harvest in January. Second, developing a mathematical model. At this stage, the researcher (R) interviewed with AN, as shown in the interview results in Table 2.

Table 2

Transcript of interview R and AN

		Transcript of Interview
R	:	What is the first step you think of in solving the problem?
AN	:	From what I understand, the problem asks us to continue the graph of the harvest results for curly chili peppers, then create a new graph showing the harvest results for bird's eye chili peppers, but with the same harvest results in January.
R	:	How do you make assumptions to simplify and predict the known data?
AN	:	I just copied the data graph from the problem.
R	:	So, you did not use mathematical theory in the data model for this problem?
AN	:	No, I just followed the graph in the problem by increasing the harvest by 4 kg each month.

Based on the interview in Table 2, the subject solved the problem by creating a graph of chili pepper harvest results based on an existing pattern. AN did not use an appropriate mathematical approach; instead, they copied the pattern from the graph in the question by repeatedly increasing the harvest amount. This indicates that AN relied more on visual patterns than conceptual understanding in data modeling. Third, the researcher (R) interviewed AN about the strategies used to solve the problem, as shown in Table 3.

Table 3

Transcript of interview with R and AN about strategies used to solve the problem

		Transcript of Interview
R	:	Do you feel that you presented the solution steps correctly?
AN	:	Yes, sir.
R	:	Did you use information that was relevant to the problem in the question?
AN	:	Yes, the graph I made was relevant to the problem in the question. I copied the graph from the question, which shows a linear trend indicating an increase from month to month.

Based on these results, the respondent applied the correct strategy to solve mathematical problems. AN stated that the solution steps presented were appropriate and the information in the question was used accurately. One of the strategies applied was to replicate the graph shape based on the question and to display an upward trend month to month.

Fourth, an interview was conducted between the researcher (R) and AN to determine how AN arrived at the answer, as shown in the interview results in Table 4.

Table 4

Transcript of interview R and AN about how AN arrived at the answer

		Transcript of Interview
R	:	How did you solve the problem?
AN	:	As I mentioned earlier, I copied the data provided in the problem and increased it by 4 kg per month. So, in January, the harvest yield was maintained at the same level, as required by the problem. I chose the exact weight of 45 kg.
R	:	Why did you choose 45 as the exact harvest yield for January?
AN	:	That number is just random, sir.
R	:	Oh, so you just used that number randomly, without referring to any specific data or measurement results?
AN	:	Yes, that is correct, sir.

Table 4 shows that AN solved the problem by imitating the upward trend in the data and increasing the harvest by 4 kg each month. In January, AN chose 45 kg randomly to match the question's requirement. Although AN understood the question and identified known information, the solution relied on visual strategies and mechanical application of patterns without proper mathematical reasoning. Therefore, AN's creative thinking is classified as replicative.

Adaptive creative thinking type

ZLQP was identified as having adaptive creative thinking skills. ZLQP made changes to the given graph pattern. ZLQP demonstrated a good understanding of the question and produced a graph that combined upward and downward patterns, rather than simply copying the original graph. The results obtained by ZLQP are shown in Figure 5.

Figure 5
ZLQP Work Results

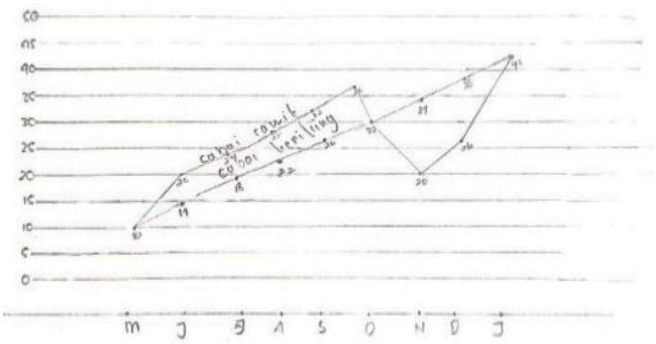

Figure 5 shows that ZLQP's chili pepper yield graph has an irregular, up-and-down pattern, characteristic of the adaptive type, as it combines and adjusts existing graphs. For deeper analysis, the researcher examined the four stages ZLQP followed in solving non-routine problems, starting with problem identification. Table 5 presents the interview results between the researcher and ZLQP.

Table 5
Transcript of interview R and ZLQP

		Transcript of Interview
R	:	What do you understand about the question?
ZLQP	:	I understand that the question is about statistics, which can also be referred to as data processing.
R	:	What do you know about the question?
ZLQP	:	The question asks us to determine the line graph of the cayenne pepper harvest and continue the line graph of the curly pepper harvest.

Based on Table 5, ZLQP understood the researcher's question on statistics, successfully identifying and continuing the line graph of harvest results for cayenne and curly peppers. In the second stage of non-routine problem solving, the researcher explored ZLQP's thought process in constructing a mathematical model through a guided interview, as presented in Table 6..

Table 6
Transcript of interview with R and ZLQP about exploring ZLQP's thinking process

		Transcript of Interview
R	:	What is the first step you think of in solving the problem?
ZLQP	:	By imitating the pattern in the problem, and creating a downward and upward trend.
R	:	How do you make those assumptions in simplifying and predicting known data?
ZLQP	:	When creating the first graph, my assumption was to adjust the same pattern. For the second graph, I created an upward and downward pattern, slightly mimicking the pattern in the problem.
R	:	How do you determine the mathematical theory in the data model for the graph you created?
ZLQP	:	In the graph I created, I did not apply mathematical theory. Instead, I observed the patterns in the question and slightly modified them into upward and downward patterns.
R	:	Why did you choose to modify the upward and downward patterns?

ZLQP	:	Because, as far as I know, graphs do not always show an increase but can also show a decrease.

Based on the interview results in Table 5, it can be concluded that ZLQP uses an observational approach to analyze graphs by imitating the patterns in the questions and adjusting them into upward or downward patterns. The subject does not apply mathematical theory; instead, it makes assumptions based on visual trends in the graphs, since graphs are not constantly increasing; they can also decrease, in accordance with an intuitive understanding of data representation.

Third, the researcher (R) evaluated how the problem-solving strategy was applied based on ZLQP's results on the creative thinking ability test.

Table 7
Transcript of interview with R and ZLQP about problem-solving strategy

		Transcript of Interview
R	:	Do you feel that you have presented the solution steps correctly?
ZLQP	:	Yes, sir. I feel that I have presented the solution steps correctly.
R	:	Did you use information that was relevant to the problem in the question?
ZLQP	:	Yes, sir, because as far as I know, crop yields do not always increase with each harvest. Yields may decrease because many chili peppers are rotting due to disease, pests, and rainy weather.

Based on the interview results, ZLQP felt it had presented the steps correctly and used relevant information, arguing that harvest yields do not always increase from one harvest season to the next, as they can be affected by external factors such as pest attacks, disease, and unfavorable weather conditions. In the final stage, the researcher asked ZLQP to explain its entire answer to Figure 5. The interview results between R and P are shown in Table 8 below.

Table 8
Transcript of interview with R and ZLQP about the result of their work

		Transcript of Interview
R	:	How did you solve the problem?
ZLQP	:	I replicated the chili pepper graph with a 4 kg monthly increase, while the bird's eye chili graph followed an up-and-down pattern. Yields intersected in May, rose June–September, decreased October–November, and increased again in December–January.
R		Why did you choose to use the up-and-down pattern only for the chili pepper harvest graph? Why not both graphs?
ZLQP	:	I wanted to distinguish the growth patterns of the curly chili pepper and chili pepper harvests by slightly altering the pattern.

Based on Table 8, ZLQP created the curly chili graph with a fixed 4 kg monthly increase and the bird's eye chili graph with an up-and-down pattern to show growth differences. Using an observational approach, ZLQP imitated and adjusted patterns without formal mathematical theory, relying on visual intuition and contextual logic. This adaptive thinking demonstrates flexibility, imagination, and the ability to modify existing information to produce logical, relevant solutions.

Constructive Creative Thinking Type

The ARH subject demonstrated constructive creative thinking by independently creating a new graph pattern based on logical assumptions about factors affecting crop yields, rather than imitating or adapting existing patterns (Figure 6).

Figure 6.
ARH Work Results

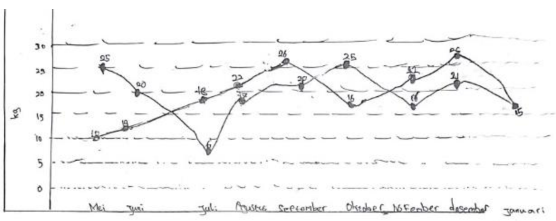

Figure 6 shows chili harvest graphs from May to January with unpredictable fluctuations, reflecting ARH's original pattern creation based on environmental assumptions. The researcher then conducted a four-stage analysis of ARH's non-routine problem-solving, starting with problem identification and initial questioning about ARH's responses. The interview results are shown in Table 9 below.

Table 9
Transcript of interview R and ARH

		Transcript of Interview
R	:	Do you understand the question?
ARH	:	Yes, I understand. This question asks us to make a graph of the harvest results for curly chili peppers and cayenne peppers.
R	:	What do you know about the question?
ARH	:	What I know is that the graph of the curly chili harvest results is provided from March to September, and we are asked to estimate the bird's eye chili graph and continue the curly chili graph, with the condition that the harvest results of both types of chilies must be the same in January.

Based on the interview results in Table 9, ARH's answers were quite accurate in understanding the question. ARH mentioned that the harvest yield graph for curly chili peppers was available from March to September. Therefore, the task was to estimate the harvest yield graph for bird's eye chili peppers and continue the harvest yield graph for curly chili peppers, with the specific condition that the harvest yields for both types of chili peppers must be the same in January. This answer demonstrates that ARH effectively grasped the essence of the question.

Second, observing the mathematical model created by ARH. Based on ARH's answer sheet, a mathematical model was constructed to represent the patterns and relationships among the data elements. The results of the interview are shown in Table 10.

Table 10
Transcript of interview with R and ARH about the Mathematical Model

		Transcript of Interview
R	:	What is the first step you think of in solving this problem?
ARH	:	I need to create a new graph showing the harvest results for curly chili peppers from October to January and for cayenne peppers from March to January, with the graph designed so that the harvest results for both are the same in January. This means that the harvest yield line for curly chili peppers intersects with the harvest yield line for bird's eye chili peppers in January.
R	:	How do you make such assumptions to simplify and predict the data you know?
ARH	:	When creating this graph, I did not use a pattern that steadily increases. I made the harvest yield line go up and down. This is because I assumed that harvest yields are influenced by weather conditions, seasons, and soil fertility, which can change monthly.
R	:	How do you determine the mathematical theory in the data model in the graph you created?
ARH	:	My answer does not use mathematical theory; I only used random data with an upward and downward trend.

ARH solved the problem by creating chili harvest graphs based on personal assumptions about weather, season, and soil fertility, with rises and falls, ensuring equal yields in January. The researcher then evaluated ARH's problem-solving strategy using the creative thinking ability test results. Here is an excerpt from the interview as shown in Table 11.

Table 11
Transcript of interview with R and ARH about the problem-solving strategy

		Transcript of Interview
R	:	Do you feel that you presented the solution steps correctly?
ARH	:	Yes, I feel my presentation was accurate because I adjusted the graph to meet the question's requirements: both types of chili peppers should have the same harvest yield in January. I also did not just show the numbers but tried to explain the reasons behind the changes in the data, whether it was due to weather, season, or plant characteristics.

R	:	Did you use information that was relevant to the problem in the question?
ARH	:	I used all the factual information reflecting possible harvest outcomes, such as the influence of weather, season, or plant characteristics, as I mentioned earlier. I made logical assumptions to solve the problem and created a reasonable graph.

Based on the responses provided, it can be concluded that ARH can provide the correct solution steps by considering information relevant to the problem at hand. The presentation is accompanied by adjustments to the graph tailored to the context and supported by logical assumptions that account for external factors, resulting in a reasonable and scientific solution.

In the final stage, the researcher asked ARH to explain the entire solution to the question in Figure 6. The following is an excerpt from the interview result between the researcher (R) and ARH.

Table 12
Transcript of interview with R and ARH about response to RH's solution

		Transcript of Interview
R	:	How did you solve that question?
ARH	:	I created this graph with an upward and downward trend using random data. From my answer sheet, it is clear that the harvests of the two types of chili peppers varied from month to month. For example, in October, the cayenne pepper harvest was higher because it is better suited to planting at the beginning of the rainy season.
R	:	What about the following months?
ARH	:	In November and December, there were noticeable changes. One type of chili experienced a yield decrease, while the other saw an increase. I think this could be due to weather conditions or perhaps the chili varieties have different growth characteristics.
R	:	Interesting. What about January?
ARH	:	Well, in January, both types of chili peppers have the exact harvest yield. I assume this is because the environmental conditions in January support their balanced growth. Perhaps the temperature and rainfall are just right, so both can grow well.
R	:	Oh, one more thing, I am curious about July. Why does the chili pepper harvest drop drastically in that month?
ARH	:	In my opinion, the drastic drop in July could be due to the dry season. During that month, rainfall is usually very low, the soil dries out, and air temperatures are high. Chili peppers are relatively sensitive to water shortages, so insufficient irrigation can disrupt their growth, leading to a drastic drop in yields.
R	:	So, is it also due to weather conditions?
ARH	:	Yes, it could also be due to pests or plant diseases that typically emerge during the dry season. Plants stressed by heat are more susceptible to attacks, which can reduce yields. So, I assume the environmental conditions in July are not conducive to chili peppers.

Based on ARH's graphical analysis, the monthly variations in the yields of curly and bird's eye chili peppers were heavily influenced by environmental factors, particularly weather conditions and seasonal changes. In July, the cayenne pepper yield showed a significant decline due to the dry season, high temperatures, low rainfall, and reduced soil moisture, which also increased the susceptibility of the plants to pests and diseases. In contrast, the yield of bird's eye chili increased in October with the onset of the rainy season, providing favorable conditions for growth. By January, the yields of both types of chili peppers were similarly high, reflecting optimal environmental conditions such as adequate rainfall, suitable temperature, and fertile soil. These patterns illustrate ARH's ability to consider realistic environmental influences when analyzing agricultural data.

The interview results further indicate that ARH effectively understood the core problem and approached it through logical reasoning, relying on personal assumptions rather than formal mathematical theory. ARH considered multiple environmental factors, including weather, season, soil fertility, and pest incidence, to construct graphs that, while fluctuating, remained reasonable and contextually sound. This approach demonstrates flexibility and adaptability in problem-solving, integrating contextual knowledge with analytical reasoning. Overall, ARH's solution was relevant, coherent, and scientifically grounded, effectively linking data patterns to environmental conditions. These findings confirm that ARH exhibits constructive-type creative thinking, capable of generating original solutions informed by logical assumptions and cross-domain understanding.

Discussion

Dominance of replicative creative thinking

The results of the study show that the majority of students (52 students or 48.15%) belong to the replicative creative thinking type, which is characterized by a tendency to imitate existing solution patterns without making significant modifications. This phenomenon indicates that students still rely on procedural strategies taught by teachers and have not developed independent thinking skills (Leibovitch et al., 2025). Dependence on visual representations and previous learning experiences keeps students' creativity at a basic level, where they prioritize pattern repetition over constructing new mathematical models (Chen et al., 2024; Silver, 1997). These findings indicate that although students are able to understand the questions, their limited flexibility in thinking restricts their ability to constructively solve non-routine mathematical problems.

An in-depth analysis shows that although students can recognize known information, they have difficulty adapting or improvising in problem solving, which reflects low cognitive flexibility (Nufus et al., 2024). This confirms the need for teaching strategies that encourage reflection, experimentation, and the application of various solution approaches (Chan et al., 2021). This limitation not only affects mathematics learning outcomes but also limits the development of more complex critical thinking and creative problem-solving skills. Instructional factors, such as procedure-based methods and an emphasis on correct answers, can reinforce students' tendency to be replicative (Ammar et al., 2024). Therefore, the replicative type is considered a starting point in creativity development that requires intensive guidance and innovative learning approaches.

The relationship between problem comprehension, prior learning experiences, and problem-solving strategies influences students' creative thinking types. Problem comprehension acts as a basic variable, enabling students to recognize information and the purpose of questions, but its effect on creativity is mediated by thinking flexibility (Cerdán et al., 2009). Students with low flexibility tend to repeat existing patterns (replicative), while students with high flexibility can adapt strategies (adaptive) or create new patterns (constructive). Previous learning experiences function as a moderating variable; limited experiences encourage replicative patterns, while diverse and rich experiences support the development of adaptive and constructive creativity. Thus, creativity emerges from the dynamic interaction between problem understanding, flexibility of thinking, and the quality of learning experiences.

Cognitive flexibility in non-routine problem solving: Adaptive type

The results of the study show that 41 students (37.96%) belong to the adaptive creative thinking type, which is characterized by the ability to adjust problem-solving strategies based on context. For example, students added an up-and-down pattern to the crop yield graph to reflect non-linear data fluctuations, demonstrating cognitive flexibility. This finding confirms that students' thinking is not limited to reproducing patterns, but is capable of modification based on the situational context. This adjustment of strategy demonstrates an awareness that external factors, such as weather or pests, can affect crop yields, so that the strategies applied are responsive and adaptive to real conditions.

Flexibility of thinking functions as a mediating variable between understanding the problem and creative problem-solving outcomes; students who understand the context but have high cognitive flexibility are able to adapt strategies (Leikin, 2011; Leikin et al., 2012; Leikin & Lev, 2013; Lu & Kaiser, 2021; Riling, 2020). These findings are in line with Sriraman (2008), who emphasizes that mathematical creativity does not only focus on the final product but also on cognitive processes such as imagination, adaptation, and contextualization of information. Thus, the adaptive type marks a shift from mechanistic reproduction to reflective thinking that considers context, supporting previous literature that highlights the importance of cognitive flexibility in the development of mathematical creativity.

In the context of mathematics education in the classroom, these findings emphasize the need for non-routine learning that provides space for students to adapt strategies to real-life situations. The use of contextual data and external variables, such as environmental conditions or changes in crop yields, increases the relevance of learning and student engagement. This reflects that adaptive problem-based learning can stimulate intermediate-level creativity, encourage students to think critically, reflectively, and sensitively about social and scientific conditions, while strengthening more complex problem-solving skills.

Advanced creativity in non-routine problem solving: Constructive type

The results of the study show that 15 students (13.89%) belong to the constructive creative thinking type, which is characterized by the ability to independently develop new strategies and even create patterns that are not reflected in the initial data. Subject ARH, for example, constructed a graph based on logical assumptions about the influence of weather, season, and soil fertility on crop yields, without relying on formal mathematical theory. This approach demonstrates a high level of creativity, where students are able to generate new solutions with rational consideration and integration of cross-domain knowledge (Bicer et al., 2020; Komarova et al., 2023; Panglipur et al., 2025; Silver, 1997; Sundquist & Lubart, 2022). These findings confirm that non-routine learning can encourage students to think divergently and generate original strategies.

The constructive type emerges from the interaction between conceptual understanding, flexibility of thinking, and the ability to integrate previous learning experiences. Flexibility of thinking acts as a mediator that allows students to modify or create new strategies based on the context of the problem. These findings are in line with Schoevers et al. (2021), who state that non-routine problems encourage the emergence of original strategies and divergent thinking. A comparison with the replicative and adaptive types shows that the existence of the constructive type reflects the highest level of creativity among students, while also indicating that appropriate learning interventions can enhance original innovative thinking skills.

In the context of mathematics education, the existence of constructive types emphasizes the importance of implementing non-routine and open-ended problems, as well as creativity-based learning strategies, such as problem-based learning and STEM integration (English, 2023; Kholid et al., 2024; Titikusumawati et al., 2019; Ulger, 2018). These findings indicate that variations in creative thinking types can serve as a basis for teachers in designing diverse and adaptive learning experiences tailored to students' varying thinking patterns. This approach not only enhances individual creativity but also fosters contextual analysis and cross-disciplinary integration skills, thereby supporting the comprehensive development of higher-order thinking competencies.

CONCLUSION

Based on the findings, it can be concluded that there is a variation in students' creative thinking types when solving non-routine mathematical problems. The majority of students (48.15%) belong to the replicative type, which tends to imitate solution patterns without significant modifications, indicating limited cognitive flexibility and basic creativity. About 37.96% of students are classified as adaptive, capable of adjusting strategies based on context, demonstrating cognitive flexibility and awareness of external factors such as weather or environmental conditions. Meanwhile, 13.89% of students fall into the constructive type, able to independently create new strategies and generate original solutions with rational consideration and cross-domain integration. These findings emphasize the importance of applying non-routine problems, creativity-based learning approaches, and STEM integration to enhance thinking flexibility, advanced creativity, and students' contextual analytical skills comprehensively.

The study highlights the importance of fostering creative thinking in non-routine mathematics learning, identifying three types of creativity replicative, adaptive, and constructive reflecting a spectrum of students' thinking abilities, from pattern imitation to original strategy creation. The results underscore the role of cognitive flexibility and the integration of learning experiences as mediators of creativity emergence, while showing that non-routine learning can stimulate divergent and innovative thinking. Practically, teachers need to design adaptive, open, and contextual learning experiences, aligning challenges with students' creativity types, enabling them to connect mathematical concepts to real-life situations, and enhancing analysis, critical thinking, cross-disciplinary skills, and innovative problem-solving abilities.

This study has limitations, including a sample restricted to a single elementary school and focus on specific non-routine mathematics topics, so generalization of findings should be approached cautiously. Additionally, the measurement of cognitive flexibility and creativity relied on qualitative analysis interpretations, which may introduce subjective bias. Future research could involve larger, cross-curricular samples, explore interactions between creativity types and factors such as motivation, self-efficacy, and school culture, and employ longitudinal designs to assess students' creativity development over time and the effectiveness of creativity-based learning interventions..

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