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Creative Thinking in Solving Similarity Problems Middle School Students' Learning Motivation and Keirsey Personality Type

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Abstract

Research on mathematical creative thinking has examined various creativity indicators, but the use of multiple solution representations and the limitations of independent verification in solving similarity problems warrant further investigation. This study aimed to describe the creative thinking profile of a junior high school student with high learning motivation and an Idealist personality type when solving similarity problems. A qualitative approach with a case study design was employed. One participant was purposively selected from 32 students based on personality type identified using the Keirsey Temperament Sorter (KTS), learning motivation measured using the Mathematics Motivation Questionnaire (MMQ), and good communication skills. Data were collected through questionnaires, written tests, interviews, and documentation, then analyzed using the Miles and Huberman model. The results showed that the participant generated and applied two solution procedures: the scale factor method and the ratio method. However, both procedures relied on the same principle of proportionality and therefore did not provide sufficient evidence of flexibility in using distinct mathematical approaches. The novelty of the strategy also remained undetermined because no comparative data from other students were available. During the looking-back stage, the participant relied solely on the agreement between the results without conducting independent verification. These findings highlight the importance of distinguishing procedural success from metacognitive evaluation. Pedagogically, teachers can use reflective prompts to encourage students to check equations, similarity conditions, and the reasonableness of their answers. As the study involved only one case, the findings are not intended to be generalized to students with similar characteristics.

Keywords: Creative thinking; Problem solving; Learning motivation; Keirsey personality type

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INTRODUCTION

Mathematics learning requires students not only to master procedures and obtain correct answers but also to develop the ability to generate ideas and select solution strategies appropriate to the problem at hand. This ability is related to mathematical creative thinking, namely the capacity to produce diverse solutions, employ different approaches, and develop relatively novel ideas within a mathematical context (Sbaih, 2023; Sipahi & Bahar, 2025). Mathematical creative thinking is generally examined through three indicators: fluency, which refers to the ability to generate several ideas or solutions; flexibility, which refers to the ability to employ different strategies or approaches; and novelty, which pertains to the uniqueness of solutions within the context of the problem encountered. These three indicators provide a basis for identifying the characteristics of the solutions students produce. However, diversity of answers alone does not fully explain how students understand a problem, select a strategy, carry out the solution, and assess the correctness of the result. Therefore, the study of mathematical creative thinking needs to attend not only to the solution product but also to the process students undergo in generating and evaluating solutions.

This process can be examined through the stages of Polya's problem solving, which comprise understanding the problem, devising a plan, carrying out the plan, and looking back at the solution obtained. These four stages provide a framework for tracing how students develop strategies from understanding the information in the problem through to evaluating the results obtained. The looking back stage is particularly important because students need to assess the accuracy of their steps, check whether the answer corresponds to the conditions of the problem, and consider whether the strategy employed can genuinely be justified (Leong et al., 2012; Stacey, 2022). These activities are related to metacognition, particularly the monitoring and evaluation of one's own thinking processes during problem solving (William & Maat, 2020). A student may produce two strategies that yield the same answer, yet the equivalence of the results does not guarantee correctness if both strategies contain the same assumptions or errors. Thus, the ability to generate solutions and the ability to verify solutions are aspects that need to be analysed separately.

Previous research has examined mathematical creative thinking from various perspectives. Van Hooijdonk et al. (2023) examined creative problem solving in geometry education, whereas Khoiriyah and Purwanti (2021) discussed creative thinking ability in mathematical problem solving. The systematic review by Sipahi and Bahar (2025) mapped definitions, conceptual frameworks, and assessment practices for mathematical creativity, while Br Ginting et al. (2025) identified various factors associated with mathematical creative thinking ability. On the other hand, Kurniawan and Wijayanti (2022) examined students' metacognition in mathematical problem solving, and Luthfiatunnisa and Hardi (2024) discussed learning obstacles and students' errors in solving mathematical word problems. These studies provide a foundation for understanding creativity, the factors associated with it, and students' thinking processes. However, the focus of each study differs, so an integrated analysis is needed that traces the emergence of creativity indicators at each stage of problem solving, particularly the relationship between strategy diversity and independent verification of results.

Learning motivation is one affective characteristic relevant to examining this process. A number of studies have linked learning motivation to the processes and outcomes of mathematics learning, including mathematical communication ability and mathematical creative thinking (Khairunnisa et al., 2021; Marniati et al., 2021; Rosmawati et al., 2023). Sari and Ristontowi (2020) also serve as one of the references in the discussion of learning motivation in this study. Motivation can provide a context for understanding students' persistence and effort when encountering difficulties, but motivation, learning engagement, and creativity are distinct constructs. A persistent student does not necessarily produce diverse strategies, while a student who actively solves problems does not necessarily examine their answers critically. Therefore, high learning motivation in this study is not treated as evidence that a student necessarily satisfies all indicators of creative thinking, but rather as a characteristic of the subject that is taken into account when examining the solution process.

In addition to learning motivation, this study considers personality types based on Keirsey's temperament framework. Keirsey (1998) classified temperament into four types, namely Guardian, Artisan, Idealist, and Rational. In previous research, Keirsey's personality types have been used to examine students' errors in solving word problems as well as numeracy literacy ability in mathematical problem solving (Zaeny et al., 2021; Zarkasih & Meilasari, 2025). This framework can help describe the characteristics of subjects, including Idealist-type students. Nevertheless, temperament descriptions cannot be used directly to conclude that a particular type causes higher creative thinking ability or determines the mathematical strategies students employ. The literature on personality structure also indicates the need for caution in treating individual differences as entirely separate categories (Haslam et al., 2020). Accordingly, the Idealist type in this study is used as a context for selecting and describing subjects, whereas the interpretation of creative thinking ability is based on evidence from written work and interviews.

To clarify the position of this study, Table 1 compares a number of relevant studies based on scope, variable focus, topic, method, and contribution. The comparison is used to identify areas of study that still require exploration, not to assert that previous research has not addressed creativity, motivation, personality, or metacognition at all.

Table 1. Comparison of Previous Studies and the Position of This Study

Study	Population or scope	Focus on personality and motivation	Topic and method	Relevant findings or contribution
Sipahi and Bahar (2025)	Empirical studies on mathematical creativity in K–12 educational contexts included in the systematic review	Not specifically focused on the Idealist type and high learning motivation	Definitions, frameworks, and assessment of mathematical creativity; systematic review	Maps conceptual approaches and assessment practices for mathematical creativity. Serves as a foundation for examining how creativity is defined and assessed.
Br Ginting et al. (2025)	Research articles on factors associated with mathematical creative thinking	Discusses various factors, not the specific combination of the Idealist type and high motivation	Factors of mathematical creative thinking; systematic review	Indicates that creative thinking ability is associated with various factors and needs to be understood multidimensionally.
Van Hooijdonk et al. (2023)	Primary school students in the context of geometry education	Not specifically focused on the combination of Keirsey personality types and high motivation	Creative problem solving in geometry; empirical study	Provides an empirical context for creative problem solving in geometry learning.
William and Maat (2020)	Research literature on metacognition in mathematical problem solving	Not specifically focused on the combination of personality types and motivation	Metacognition in mathematical problem solving; systematic review	Serves as a foundation for understanding the importance of monitoring and evaluating thinking processes during problem solving.
Leong et al. (2012)	Case study of a student's problem-solving process	Not specifically focused on the Idealist type and high learning motivation	Problem solving with the Polya model; case study	Discusses the looking back stage and demonstrates the importance of examining the process after an answer has been obtained.
Zaeny et al. (2021)	Students working on mathematical word problems	Keirsey personality types as a review variable; not specifically focused on cross-stage creativity with high motivation	Errors in solving word problems; empirical study	Provides an example of using Keirsey personality types to examine characteristics of problem solving.
Zarkasih	Junior high	David Keirsey's	Numeracy	Provides a research

Study	Population or scope	Focus on personality and motivation	Topic and method	Relevant findings or contribution
and Meilasari (2025)	school students in mathematical problem solving	personality types; not specifically focused on the combination of Idealist and high motivation	literacy in problem solving; empirical study	context on differences in problem-solving characteristics based on personality types.
This study	One junior high school student with high learning motivation and the Idealist type	Learning motivation and the Idealist type are used as descriptive characteristics of the subject, not as causes to be tested	Similarity problems; qualitative case study through written tests and interviews based on the four Polya stages	Describes the emergence of fluency, flexibility, and novelty at each stage, including the distinction between generating multiple strategies and independently verifying results.

The comparison in Table 1 shows that research on mathematical creativity, metacognition, problem solving, and personality types has provided a relevant conceptual and empirical foundation. However, these studies have different foci and have not directly addressed the question of how the indicators of fluency, flexibility, and novelty emerge at each Polya stage in a single case of a student with high learning motivation and the Idealist type, particularly in the topic of similarity. The gap addressed by this study is not merely the combination of subject characteristics, but rather the need to describe the profile of creative thinking stage by stage and to identify whether the ability to generate multiple strategies is accompanied by the ability to conduct independent verification.

Based on this gap, this study is positioned as a pedagogical case study that produces a description of the creative thinking profile across the stages of problem solving. Its contribution lies in illustrating how creativity indicators appear in the processes of understanding the problem, planning a strategy, carrying out the solution, and looking back at the result, as well as how the ability to generate multiple strategies may emerge alongside limitations in independent verification. This study is not intended to test the causal influence of motivation or personality, nor to generalise the results to all Idealist-type students or students with high learning motivation.

Based on the foregoing, this study aims to explore the creative thinking profile of a junior high school student with high learning motivation and the Idealist personality type according to Keirsey in solving similarity problems based on Polya's problem-solving stages. The research question posed is: "How does a student with high learning motivation and the Idealist personality type according to Keirsey demonstrate fluency, flexibility, and novelty at each stage of Polya's problem solving in solving similarity problems?"

METHOD

This study employed a qualitative approach using an instrumental case study design to examine the mathematical creative thinking processes of a student solving similarity problems in the context of learning motivation and personality type (Yin, 2018). The study focused on a Grade VII student with high mathematics learning motivation and an Idealist personality type, identified by the code IT. The unit of analysis was the participant's creative thinking process when solving two similarity problems, as reflected in written responses and semi-structured interviews. The case study design facilitated an in-depth examination of the participant's reasoning, strategy selection, solution implementation, and evaluation processes across Polya's four problem-solving stages.

Participant selection was conducted purposively through an initial screening of 32 Grade

VII students at SMP Kristen Bala Keselamatan Palu. Personality types were identified using the Keirsey Temperament Sorter (KTS), which classified 14 students as Guardian, 10 as Artisan, six as Idealist, and two as Rational. Mathematics learning motivation was assessed using the Mathematics Motivation Questionnaire (MMQ), adapted from Fiorella et al. (2021). Among the six students classified as Idealist, one student obtained a motivation score of 93, categorized as high, and was selected as the research participant. The selection also considered the mathematics teacher's recommendation regarding the student's communication ability and willingness to articulate mathematical reasoning during interviews. Communication ability was treated as a supporting criterion for obtaining detailed verbal explanations rather than as an indicator of mathematical creativity.

The research instruments consisted of the KTS, MMQ, two similarity problem-solving tasks, a semi-structured interview guide, and supporting documentation. The KTS was used to identify the participant's personality type, while the MMQ assessed mathematics learning motivation. The similarity tasks examined mathematical reasoning and creative thinking processes through problem situations involving proportional relationships between geometrically similar objects. The first task concerned the dimensions of a photograph and its frame, whereas the second involved the dimensions of a carpet and a room. Both tasks required the participant to interpret similarity relationships, determine unknown dimensions, and explain the mathematical procedures used. Semi-structured interviews explored the participant's understanding of the problems, formulation of solution strategies, implementation of mathematical procedures, and evaluation of the obtained answers. Written solutions and interview records constituted the primary sources of qualitative evidence.

Data collection was conducted in two sessions separated by one week. During the first session, IT completed the first similarity problem (M1), followed by a semi-structured interview addressing the information identified in the problem, the mathematical relationships recognized, the strategies selected, and the procedures used to obtain and evaluate the solution. During the second session, IT completed the second similarity problem (M2) and participated in a follow-up interview addressing the same analytical dimensions. The two tasks provided complementary evidence concerning the participant's mathematical reasoning and consistency in applying similarity concepts across different problem contexts. Written responses were documented, and interview data were used to clarify the reasoning underlying the participant's mathematical procedures.

Data analysis followed the interactive qualitative analysis framework of Miles et al. (2014), comprising data condensation, data display, and conclusion drawing and verification. Initially, written responses and interview transcripts were organized according to Polya's four problem-solving stages: understanding the problem, devising a plan, carrying out the plan, and looking back (Pólya, 1945). Within each stage, the evidence was examined using three indicators of mathematical creative thinking: fluency, flexibility, and originality. Fluency referred to the generation of relevant mathematical ideas or solution procedures, flexibility concerned the use of substantively different mathematical approaches, and originality referred to the relative novelty of a solution strategy within the problem context. These indicators were interpreted based on the mathematical characteristics of the participant's responses rather than solely on the number of procedures produced.

The analysis distinguished conceptual understanding, procedural variation, and creative thinking indicators. The use of multiple solution procedures was examined to determine whether the procedures represented substantively different mathematical approaches or alternative representations of the same underlying principle. Similarly, obtaining identical answers through different procedures was distinguished from independently verifying mathematical correctness. Verification practices were examined through observable evidence of recalculation, substitution, examination of proportional relationships, and evaluation of the consistency between the solution and the conditions of the problem. This analytical distinction

enabled a more precise interpretation of the participant's mathematical reasoning and evaluation processes.

The findings were organized into analytical matrices connecting the problem-solving stages, creative thinking indicators, empirical evidence, and interpretations. Written mathematical solutions served as the primary evidence of procedural and conceptual activity, while interview excerpts provided additional explanations of the participant's reasoning and decisions. The first problem (M1) provided the principal evidence for detailed analysis, whereas the second problem (M2) was used to examine the consistency of the participant's responses and reasoning across the two sessions. Interpretations were developed by considering both supporting evidence and observations that did not fully satisfy the operational criteria for individual creative thinking indicators.

The credibility of the qualitative findings was examined through comparisons between written responses and interview explanations, together with temporal comparisons of data collected during the two sessions. These comparisons were used to identify consistencies and differences in the participant's understanding, planning, implementation, and verification of mathematical solutions. Consistent responses across sessions were interpreted as supporting the stability of observed reasoning patterns, while differences were considered in relation to the characteristics of the problems and the explanations provided during interviews. Conclusions were drawn from the available empirical evidence without assuming that consistency between responses necessarily demonstrated originality, conceptual flexibility, or independent mathematical verification. The interpretation remained specific to the selected participant and the two similarity problems examined.

RESULTS AND DISCUSSION

Subject Selection

Subject selection in this study was carried out through two stages of identification involving the entire population of Grade VII students, totaling 32 individuals. First, the administration of the Keirsey Temperament Sorter (KTS) questionnaire resulted in the classification of personality types, with details of 14 students of the Guardian type, 10 students of the Artisan type, 6 students of the Idealist type, and 2 students of the Rational type. Second, the administration of the Mathematics Motivation Questionnaire (MMQ), adapted from Fiorella et al. (2021), indicated that among the six students of the Idealist type, one student fell into the high motivation category with a score of 93. The selection of the subject was not solely based on these quantitative criteria but also took into consideration the recommendation of the subject teacher, who assessed the student's communication skills and willingness to articulate their thought processes orally, in order to support the smooth collection of data through in-depth interviews. Based on all these considerations, one subject with the code IT (Idealist with high motivation) was selected as the focus of analysis in this study.

Exposure and Credibility Testing of Data for Subject IT

Exposure and Credibility Testing of Data for Subject IT in Understanding the Problem

- Exposure of Data for Subject IT in Understanding the Problem

At the stage of understanding the problem, data were collected through interviews after subject IT read Problem 1 (M1) and Problem 2 (M2). The interviews focused on the information known, what was being asked, and the subject's understanding of the geometric relationships in both problems. In M1, IT explained the known information and what was being asked as follows.

PITM105: Try rereading the problem; what do you understand?

SITM106: From the problem, sir/ma'am, it is known that the photo size is 114×96, the remaining right and left margins are 9.5 cm. Then we are asked to find the remaining top and bottom margins.

PITM107: What else do you understand?

SITM108: The frame and the photo are similar, the photo is in the center. The width of the frame I calculated = 96 + 9.5 + 9.5 = 115 cm. Then I imagined this photo being enlarged into the frame. So I thought of using a scale.
PITM109: Did the idea of scale come to mind right away?
SITM110: Yes, sir/ma'am, from the beginning I saw it as an enlargement. Different from my friends who used comparison.

In M2, IT demonstrated an understanding of the known information, what was being asked, and the relationship between the carpet size and the room. This is evident in the following interview excerpt.

PITM205: Try rereading the problem; what do you know and understand from the problem?
SITM206: From the problem, I know the carpet size is 180×120, then the distance to the right and left walls is 20 cm. Then what is asked is the distance between the edge of the carpet and the wall at the top and at the bottom.
PITM207: Is there any other information?
SITM208: There is, sir/ma'am. The carpet and the room are similar, the carpet is in the center. The width of the room I calculated = 120 + 20 + 20 = 160 cm. I immediately imagined this as an enlargement too, just like the photo frame problem the other day.
PITM209: So from the beginning you already thought of using scale again?
SITM210: Yes, sir/ma'am, the concept is the same. The carpet is enlarged into the room. So my main plan is to use the scale factor.

- Credibility Testing of Data through Time Triangulation

Time triangulation was carried out by comparing IT's interview data on M1, administered in the first week, and M2 in the following week. The comparison results showed that IT consistently identified the known information, determined the quantities being asked, recognized the similarity relationship, and interpreted both situations as enlargement. In both problems, IT also connected this understanding to the use of the scale factor.

This consistency of response supports the credibility of the interpretation regarding IT's understanding of the similarity problems. M1 was used as the primary data for detailed analysis, while M2 was used as comparative data to examine the consistency of the subject's responses. The consistency of responses across the two problems supports the interpretation regarding the stability of IT's understanding, but does not by itself prove that the approach chosen is creative or novel.

- Data Analysis of Subject IT at the Stage of Understanding the Problem

The analysis of the stage of understanding the problem was carried out by connecting the interview evidence and IT's written answers. The analysis results are presented in a matrix that connects Polya's stages, analytical dimensions, empirical evidence, and interpretation to reduce repetition between data exposure and discussion. The analysis also considers conceptual representation so that the characteristics of the subject's understanding are not directly categorized as creativity without adequate supporting evidence.

Table 2. Analysis Matrix of Subject IT at Polya's Stage of Understanding the Problem

Analytical Dimension	Empirical Evidence	Interpretation
Conceptual understanding	IT identified the size of the photo or carpet, the distance of the right-left sides, and the distance of the top-bottom sides being asked.	IT was able to identify relevant information and understand the purpose of problem solving.
Conceptual representation	IT stated that the photo and frame, as well as the carpet and room, are similar. IT also interpreted both situations as processes of	IT connected the problem context with the proportional relationship between dimensions. The interpretation of enlargement shows

Analytical Dimension	Empirical Evidence	Interpretation
	enlargement.	how IT represented the relationship of sizes.
Fluency	IT explained the known information, what was being asked, and the initial reason for choosing the scale factor.	IT was able to express relevant information in a directed manner. However, the evidence at this stage is not yet sufficient to ascertain fluency in the sense of generating many ideas or alternative solutions.
Flexibility	In M1, IT mentioned the use of scale and compared it with the use of comparison by his/her friends. In M2, IT again chose the scale factor.	The statement regarding friends' strategies is IT's perception, not empirical evidence about the strategies actually used by other students. The scale factor and comparison may also represent the same proportional structure, so this evidence is not yet sufficient to conclude conceptual flexibility.
Originality	IT stated that he/she imagined the photo or carpet being enlarged into the frame or room.	The interpretation of enlargement demonstrates IT's conceptual representation, but cannot be called original merely because it differs from the strategy that he/she perceived his/her friends to use. The assessment of originality requires clear criteria and adequate comparative evidence.

Based on Table 2, IT demonstrated an understanding of the known information, the quantities being asked, and the geometric relationships in M1 and M2. The representation of enlargement put forward by IT indicates that he/she understands the proportional relationship between the dimensions of the object and the environment containing it. This understanding is evident from his/her ability to identify the similarity relationship and connect it to the use of the scale factor. Although IT mentioned the scale factor and comparison as different approaches, both may represent the same proportional relationship. Therefore, the evidence at the stage of understanding the problem primarily indicates IT's conceptual understanding, while the determination of flexibility and originality requires more specific evidence.

IT's statement that his/her friends used comparison was not used as a basis for concluding the novelty of the strategy because this study does not present the collection and analysis of other students' answers as a comparison group. Thus, IT's ability at the stage of understanding the problem is mainly reflected in conceptual understanding and the representation of proportional relationships, while the characteristics of creative thinking are further examined at the stages of planning, implementation, and looking back.

Presentation and Credibility Test of Data on IT Subjects in the Solution Planning Phase

- *Presentation of Data on IT Subjects in the Solution Planning Phase for M1*

At the planning stage of problem solving, the interview focused on the approach IT would use, the sequence of solution steps, and the reasons for choosing the main approach. In M1, IT planned two methods to determine the distance between the top and bottom sides of the photo and the frame, as explained in the following interview.

PITM111 : So, what's your plan for the solution?

SITM112 : I'm planning two methods. The main one uses a scale, because it better reflects the concept of magnification. Here's how: first, I find the scale factor from the width that is, the frame width divided by the photo width. After that, I calculate

the frame height by multiplying the photo height by that scale factor. From there, I can determine the total remaining space at the top and bottom, then divide it in half to get the distance for each side

PITM113 : Then what about the second method?

SITM114 : For the second method, I'll use ratios. So, the ratio of the photo's length to its width is equal to the ratio of the frame's length to its width. The frame's length is the photo's height plus twice the distance we're looking for. Then I'll solve the equation

PITM115 : Why is scale the key factor?

SITM116 : Because I think it's more logical. The photo is enlarged proportionally, so you just need to find the scaling factor for the width and then apply it to the height. Many of my friends forget that concept

In M2, IT again explained the plan for using the scale factor and comparison to determine the distance between the carpet and the upper and lower walls.

PITM211 : The question asks you to solve it in two ways. What other method did you use?

SITM212 : Yes, I did. I used a ratio again for the second method

PITM213 : Try to explain your plan for solving it.

SITM214 : I found the scale factor from the width that is, the room's width divided by the carpet's width. After that, I found the room's length by multiplying the carpet's length by that scale factor. From there, I could determine the total remaining length at the top and bottom, then divide by two to get the distance for each side.

PITM215 : What about the plan using the ratio method?

SITM216 : I'll use a direct ratio: the length of the carpet divided by the width of the carpet equals the length of the room divided by the width of the room. The length of the room is 180 plus twice the distance we're looking for. Then I'll solve the equation.

PITM217 : Why is the scale still the main focus?

SITM218 : Because I think it's more conceptual. Also, I feel like this is different from what my other classmates are using.

- *Credibility Testing of Data through Time Triangulation*

Time triangulation was carried out by comparing IT's interview data on M1, administered in the first week, and M2 in the following week. The comparison results showed that IT consistently planned the use of the scale factor as the main approach and comparison as the alternative approach. In both problems, IT explained a similar sequence of plans, namely determining the scale factor from the known dimension, using it to determine the other dimension, calculating the difference in size, and dividing that difference into two equal parts.

This consistency supports the interpretation regarding IT's pattern of solution planning. M1 was used as the primary data for detailed analysis, while M2 was used as comparative data to examine the consistency of the subject's responses. Although the planning pattern in both problems is consistent, this similarity does not by itself prove that IT used a conceptually different strategy or produced an original approach.

- *Data Analysis of Subject IT at the Stage of Planning the Solution*

The analysis of the stage of planning the solution was carried out by connecting the plans expressed by IT through the interviews with the relevant dimensions of creative thinking. The analysis results are presented in a matrix to connect Polya's stages, analytical dimensions, empirical evidence, and interpretation without repeating the entire interview excerpts. The analysis also considers conceptual representation and procedural variation so that the number of solution forms is not directly regarded as evidence of flexibility or originality.

Table 3. Analysis Matrix of Subject IT at Polya's Stage of Planning the Solution

Analytical Dimension	Empirical Evidence	Interpretation
Conceptual representation	IT planned to determine the scale factor from the ratio of widths, then apply it to the other dimension.	IT connected the concept of similarity with a multiplier that preserves the proportion between dimensions.
Procedural variation	IT planned to use the scale factor as the main method and comparison as the alternative method.	IT planned two procedural forms to solve the problem. However, these two forms need to be examined based on their mathematical processes before being declared as different strategies.
Fluency	IT explained the sequence of the plan, starting from determining the scale factor to calculating the distance being sought.	IT was able to explain the solution plan in a directed and relevant manner. However, fluency in explaining the plan is not yet sufficient to ascertain fluency in the sense of generating many solution ideas.
Flexibility	IT planned the scale factor and comparison and explained the reason for prioritizing the scale factor.	The data show a variation in the procedural forms planned, but the scale factor and comparison may represent the same proportional structure. Therefore, conceptual flexibility cannot be ascertained solely from the difference between these two forms.
Originality	IT stated that the scale factor is more logical and conceptual and considered his/her approach different from his/her friends' approaches.	This statement shows IT's consideration in choosing the approach, but does not yet prove originality. The assessment of originality requires clear criteria and adequate comparative evidence.

Based on Table 3, IT was able to plan the solution in a directed manner by choosing the scale factor as the main approach and comparison as the alternative. The choice of the scale factor was based on IT's understanding of the proportional relationship in enlargement. Planning two procedures shows that IT was able to consider alternative solutions and explain the reasons for choosing the strategy. This demonstrates IT's ability to connect the chosen approach with his/her understanding of the concept of similarity.

Exposure and Credibility Testing of Data for Subject IT in Carrying Out the Plan

- *Exposure of Data for Subject IT in Carrying Out the Plan*

The following presents the interview results and answers of subject IT at the stage of carrying out the plan for M1.

PITM119: Earlier you already worked on the problem. Now, try to explain the steps of your work.

SITM120: First, for the scale factor method, I first set it up like this, sir/ma'am = 115/96. The height of the frame = 114 × 115/96. Then I multiplied it so that it gives = 13,110/96. After that I got the result = 136.56 cm. The total remaining top and bottom margin = 136.56 − 114 = 22.56 cm. Each is divided by 2 to become = 22.56/2 = 11.28 cm.

PITM121: Now explain the second method.

SITM122: For the second method I used comparison. So I first set up the proportion, namely 114/96 = height of frame/115. After that I substituted the value of the height of the frame to become 114/96 = (114 + 2x)/115. The next step I did cross multiplication to become 114 × 115 = 96 × (114 + 2x). From the result 13,110 = 10,944 + 192x I

moved the term to the other side to become 192x = 2,166 and for the final result x = 11.28 cm. The result is the same.

PITM123: So the final answer is 11.28 cm, right?

SITM124: Yes, sir/ma'am.

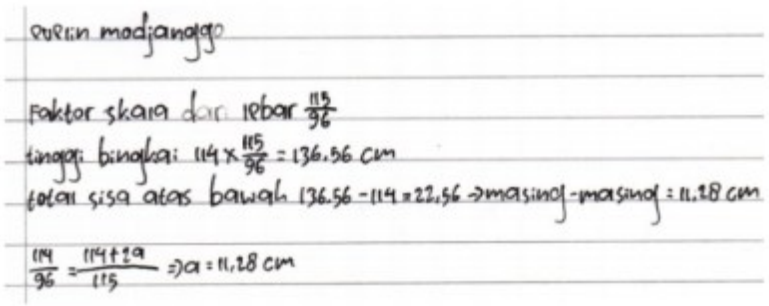


Figure 1. Subject IT's Answer at the Stage of Carrying Out the Plan for M1

The following presents the interview results and answers of subject IT at the stage of carrying out the plan for M2.

PITM221: Earlier you already worked on the problem according to the plan you explained in the interview earlier.

SITM222: Yes, sir/ma'am, I have.

PITM223: Try to explain the steps of the work you have done.

SITM224: For the first method, that is, using scale. I find the scale factor from the width, that is, the width of the room divided by the width of the carpet. The width of the room is 160, the width of the carpet is 120, so the scale factor is 160/120 = 4/3. Then I calculate the length of the room by multiplying the length of the carpet, which is 180, by the scale factor 4/3. So 180 × 4/3 = 720/3 = 240 cm. After that, the total remaining length of the room minus the length of the carpet: 240 − 180 = 60 cm. Because the top and bottom margins are equal, each is 60/2 = 30 cm.

PITM225: How about the second method?

SITM226: For the second method I first set up the proportion, namely 180/120 = (180 + 2x)/160. Then I cross-multiplied 180 × 160 = 120 × (180 + 2x). The result: 28,800 = 21,600 + 240x. I moved 21,600 to the left side to become 28,800 − 21,600 = 240x, so 7,200 = 240x. And for the final result, that is, 7,200 divided by 240 gives 30 cm.

PITM227: So the result of the two methods you used is 30?

SITM228: Yes, sir/ma'am. From the two methods I used, the result is the same, namely 30 cm.

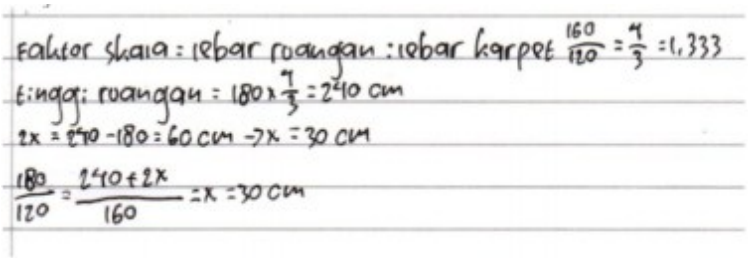


Figure 2. Subject IT's Answer at the Stage of Carrying Out the Plan for M2

- *Credibility Testing of Data for Subject IT in Carrying Out the Plan*

Time triangulation was carried out by comparing the results of IT's interviews and work on M1, administered in the first week, with M2 in the following week. In both problems, IT applied the scale factor and comparison, explained the sequence of calculations, and obtained the same result through both procedures. In M1, IT obtained a distance of 11.28 cm for each side, while in M2 a distance of 30 cm was obtained.

This consistency supports the interpretation that IT was able to carry out the solution plan

with a directed procedure in both problems. Nevertheless, the similarity of results from the two procedures indicates agreement of answers, but does not fully prove the accuracy of reasoning independently, because both procedures depart from related proportional relationships. M1 was subsequently used as the primary data for detailed analysis, while M2 served as comparative data to examine the consistency of IT's strategy implementation.

- *Data Analysis of Subject IT in Carrying Out the Plan*

Based on the written answers and interview results, IT was able to carry out the solution steps according to the plan that had been formulated. In M1, IT determined the scale factor from the ratio of the frame width to the photo width, used it to calculate the frame height, and then determined the distances at the top and bottom. In the alternative procedure, IT used a proportion equation based on the similarity relationship. Both procedures produced a distance of approximately 11.28 cm for each side. A similar pattern was observed in M2, when IT obtained a result of 30 cm through both the scale factor and comparison.

The implementation of both procedures demonstrates IT's ability to apply the concept of proportion, carry out calculation operations in sequence, and connect the calculation results with the quantities being asked. To clarify the interpretation of IT's thinking process, the analysis at this stage is summarized in Table 4.

Table 4. Analysis of Creative Thinking of Subject IT at Polya's Stage of Carrying Out the Plan

Analytical Dimension	Empirical Evidence	Interpretation
Conceptual understanding	IT used the scale factor to determine the dimensions of the environment based on the dimensions of the object in M1 and M2.	IT was able to apply proportional relationships in solving similarity problems.
Procedure implementation	IT carried out the scale factor calculations and proportion equations to obtain the final result in both problems.	IT was able to carry out the solution procedure in a directed manner and demonstrated traceable calculation stages.
Fluency	IT explained the steps of both procedures and completed M1 and M2.	The data show the ability to carry out and explain procedures, but coherence of explanation alone is not yet sufficient to establish fluency as the smooth generation of relevant ideas.
Flexibility	IT used the scale factor and proportion equation in each problem.	There is procedural variation, but both procedures may represent the same proportional relationship, so this is not yet sufficient to ascertain conceptual flexibility.
Originality	IT used the scale factor as the main approach and comparison as the alternative.	The choice of the scale factor shows a strategy preference based on conceptual understanding, but does not yet prove novelty without adequate criteria or comparative data.
Result checking	IT stated that the results of both procedures were the same, namely 11.28 cm in M1 and 30 cm in M2.	IT compared the results of the two procedures, but this evidence does not yet indicate an independent examination of all steps and assumptions of the solution.

Based on Table 4, IT demonstrated the ability to apply the concept of similarity and carry out the solution procedure in a directed manner. The use of the scale factor and proportion

equation produced the same answer in both problems, thereby demonstrating consistency in strategy implementation. Overall, the stage of carrying out the plan demonstrates IT's ability to apply proportional relationships, carry out alternative procedures, and compare calculation results. The interpretation of fluency, flexibility, and originality remains based on the characteristics of the available evidence, without equating procedural variation with conceptual differences in strategy or regarding similarity of results as fully independent verification.

Exposure and Credibility Testing of Data for Subject IT in Looking Back

- *Exposure of Data for Subject IT in Looking Back*

The following presents the interview results with subject IT at the stage of looking back for M1.

PITM125: Are you already confident with your answer?
SITM126: I am confident, sir/ma'am.
PITM127: After you found the final result, did you do any checking again?
SITM128: I saw that both methods already matched, so I am confident it is correct. There is no need for me to recalculate.
PITM129: So there is no further checking?
SITM130: No, sir/ma'am, I am already confident.

Then the interview results with subject IT at the stage of looking back for M2 are presented.

PITM229: After that, did you check again?
SITM230: I saw that both methods already matched, so I am confident it is correct. There is no need to check again.
PITM231: So there is no additional checking?
SITM232: No, sir/ma'am, I already trust it.

- *Credibility Testing of Data for Subject IT in Looking Back*

Time triangulation was carried out by comparing the results of IT's interviews on M1, administered in the first week, and M2 in the following week. In both problems, IT stated confidence in the answer because the two procedures used produced the same value. IT also consistently stated that no further examination was carried out after comparing the results.

This consistency of response supports the credibility of the data regarding the way IT looked back at the answer. M1 was used as the primary data for detailed analysis, while M2 was used as comparative data to examine the consistency of responses. However, this consistency indicates the stability of the way IT carried out the examination, not that the answer had been verified thoroughly.

- *Data Analysis of Subject IT in Looking Back*

Based on the interview results, IT checked the solution results by comparing the answers obtained through the scale factor and comparison. This is evident from the statement, "I saw that both methods already matched, so I am confident it is correct" (SITM128). A similar response also appeared in M2 (SITM230). Both responses indicate that IT used the agreement of results as the basis for believing the answer.

The examination carried out by IT shows an attempt to compare the results of two solution procedures. However, when asked about further examination, IT stated that there was no need to recalculate or re-examine the answer (SITM128, SITM130, SITM230, SITM232). IT did not explain any examination through back-substitution, ratio checking, review of the similarity assumption, or assessment of the reasonableness of the result. To clarify the characteristics of the looking-back examination carried out by IT, the analysis is summarized in Table 5.

Table 5. Analysis of Subject IT at the Stage of Looking Back

Analytical Dimension	Empirical Evidence	Interpretation
Result checking	IT compared the results from the scale factor and comparison, then	IT carried out an initial examination through comparing the results of the

	stated that the two results matched (SITM128, SITM230).	two procedures.
Depth of verification	IT stated that there was no need to calculate or carry out additional examination after obtaining the same result (SITM128, SITM130, SITM230, SITM232).	IT's examination was still limited to the agreement of results and did not yet include independent verification of the calculation steps or the assumptions used.
Metacognitive awareness	IT stated confidence in the answer because the two procedures produced the same value.	IT used the agreement of results as the basis for confidence, but did not yet show consideration of the need for further examination.

Based on Table 5, IT showed an attempt to check the answer through comparing the results of two procedures. However, the examination was still limited because the similarity of results does not by itself guarantee that all calculation steps and mathematical assumptions are correct. The two procedures are also based on related proportional relationships, so the comparison of their results cannot yet be regarded as fully independent verification.

Thus, the stage of looking back shows that IT had compared the solution results, but had not carried out in-depth mathematical verification. This characteristic indicates a distinction between ensuring the agreement of results and examining the correctness of the solution process thoroughly. Therefore, the evidence at this stage is stronger for explaining the way IT carried out the examination and assessed confidence in the answer than for determining whether all indicators of creative thinking were fulfilled.

Creative Thinking Profile of Subject IT in Solving Problems

- *Conceptual and Procedural Representation of Similarity*

The results of the study show that IT was able to represent similarity problems through proportional relationships between the dimensions of objects and their corresponding geometric environments. In the first problem, IT interpreted the relationship between the photograph and its frame as an enlargement process, whereas in the second problem, the participant applied a similar interpretation to the relationship between the carpet and the room. These representations enabled IT to identify relevant dimensional relationships, determine scale factors, and calculate unknown quantities using proportional procedures. Such reasoning reflects the conceptual understanding required to recognize and coordinate multiplicative relationships between corresponding dimensions. Research on proportional reasoning emphasizes that mathematical understanding involves more than applying proportional algorithms, as students must recognize relevant quantitative relationships and connect these relationships to appropriate mathematical representations (Carney et al., 2023). Similarly, evidence from mathematical problem-solving research suggests that domain-specific mathematical knowledge contributes substantially to students' ability to interpret problem conditions and construct appropriate solutions (Amalina & Vidákovich, 2023). Accordingly, IT's performance provides evidence of conceptual understanding and procedural competence, although these characteristics do not independently establish the originality of the mathematical representations employed.

The distinction between conceptual understanding and mathematical creativity is particularly important when interpreting students' successful solutions. Mathematical creativity involves not only applying existing mathematical knowledge but also generating, connecting, and evaluating ideas in ways that demonstrate meaningful variation or novelty. Silver (1997) conceptualized mathematical creativity through fluency, flexibility, and novelty, emphasizing the development of diverse mathematical ideas through problem-solving activities. Similarly, Sriraman (2005) argued that mathematical competence and creativity represent related but distinguishable characteristics, indicating that successful mathematical performance should not automatically be interpreted as creative achievement. More recently, Lu and Kaiser (2022) demonstrated the importance of evaluating creative mathematical performance using criteria

that distinguish the adequacy of mathematical approaches from their fluency and originality. These perspectives suggest that IT's appropriate use of proportional reasoning should primarily be understood as evidence of mathematical competence, whereas claims concerning creativity require additional evidence regarding the diversity and originality of the strategies produced.

This finding is consistent with Oostveen-de Vink et al. (2023), who examined support for creative problem solving in geometry education through the development of divergent and convergent thinking. Their research highlights the importance of observing how mathematical ideas are generated and evaluated rather than assessing creativity solely through the correctness of completed solutions. A related perspective emerges from Schindler and Lilienthal (2020), whose qualitative investigation of students' work on multiple-solution tasks demonstrated the analytical value of examining the processes through which mathematical ideas emerge. Their findings suggest that students' written solutions may not fully capture the reasoning processes involved in developing mathematical approaches. Although these studies involved different participants and research contexts, they provide a conceptual basis for interpreting IT's written responses alongside interview explanations. In the present case, the available evidence indicates that IT recognized proportional relationships and selected mathematically appropriate procedures, but it does not establish that the participant developed a fundamentally new mathematical representation.

The study by Pakpahan and Wijayanti (2025) also examined secondary school students' mathematical creative thinking through the indicators of fluency, flexibility, and novelty. Their findings reinforce the importance of distinguishing among the three indicators rather than treating them as interchangeable manifestations of mathematical achievement. Similarly, Sadak et al. (2022) examined mathematical creativity through problem posing and problem solving, demonstrating that creative abilities can be assessed through distinct but related mathematical activities involving fluency, flexibility, and originality. Research by Lu et al. (2025) further indicates that creativity assessment requires attention to the characteristics and appropriateness of mathematical responses, with originality representing a particularly important dimension. These studies support the interpretation that IT's ability to apply scale factors correctly indicates understanding of similarity and proportionality, while the originality of the approach remains undetermined without clearly defined criteria and suitable comparative evidence. Consequently, the present findings are more appropriately interpreted as demonstrating conceptual and procedural competence than as establishing a comprehensive profile of mathematical creativity.

- *Limitations in Interpreting the Use of Multiple Methods as Flexibility*

IT planned and implemented two solution procedures, namely the scale factor method and the ratio method. The participant explained that the scale factor approach was preferred because it represented the enlargement relationship more directly and was considered mathematically logical. This explanation demonstrates an ability to articulate reasons for selecting a particular procedure and to connect procedural decisions with an underlying mathematical concept. However, the presence of two solution procedures does not necessarily establish conceptual flexibility, particularly when both procedures rely on equivalent mathematical relationships. Leikin (2009) emphasized the importance of examining multiple solutions according to their mathematical characteristics rather than relying exclusively on the number of solutions generated. In this perspective, fluency concerns the production of appropriate solutions, whereas flexibility requires meaningful differences among the mathematical approaches used. Accordingly, IT's two procedures provide evidence of procedural variation but not sufficient evidence of fundamentally different mathematical strategies.

Both procedures employed by IT were based on proportional reasoning. The scale factor method involved determining a multiplicative relationship between corresponding dimensions and applying it to an unknown dimension. The ratio method expressed essentially the same

relationship through a proportional equation. Although the written representations and calculation sequences differed, both procedures depended on the preservation of proportional relationships between similar figures. This distinction is consistent with Levav-Waynberg and Leikin (2012), who investigated the use of multiple-solution tasks in geometry and examined mathematical creativity through fluency, flexibility, and originality. Their findings highlight the importance of evaluating differences among solution strategies and the mathematical connections underlying those strategies. Research by Lu and Kaiser (2022) similarly supports the need to distinguish the number of appropriate mathematical responses from the originality and conceptual characteristics of those responses. In the present study, therefore, the two procedures should be classified as alternative procedural representations of proportionality rather than as conclusive evidence of conceptual flexibility.

An additional methodological consideration concerns the instruction provided in the problem-solving tasks. The tasks explicitly requested solutions using two methods, meaning that the production of two procedures cannot be interpreted independently of the task requirements. Studies employing multiple-solution tasks frequently use explicit instructions to encourage students to explore alternative mathematical approaches (Leikin, 2009; Levav-Waynberg & Leikin, 2012). Consequently, generating several procedures under such conditions may reflect responsiveness to task demands rather than spontaneous strategic flexibility. Schindler and Lilienthal (2022) further demonstrated that mathematical creative processes can involve complex transitions between ideas, highlighting the importance of examining how mathematical approaches emerge during problem solving. The present study did not independently establish whether IT would have generated multiple methods without the explicit task requirement. Thus, the evidence supports the participant's ability to implement alternative procedures but does not demonstrate spontaneous generation of conceptually distinct strategies.

The study by Pakpahan and Wijayanti (2025) provides a relevant comparison because flexibility was examined through alternative mathematical approaches rather than solely through the production of multiple answers. Similarly, research on mathematical creativity assessment emphasizes that flexibility should be evaluated according to differences among mathematical response categories, whereas originality requires additional evidence concerning the novelty or rarity of the resulting approaches (Lu et al., 2025; Sadak et al., 2022). This distinction is important because two mathematically equivalent procedures may produce the appearance of strategic diversity without involving substantially different conceptual resources. IT's statement that the scale factor approach differed from the methods used by classmates also cannot establish originality because the present study did not collect and systematically analyze other students' solutions as comparative evidence. Furthermore, Sriraman (2005) emphasized the importance of distinguishing mathematical creativity from other forms of mathematical achievement, supporting a cautious interpretation of apparently unusual or successful student responses. Therefore, neither the participant's perception of uniqueness nor the production of two procedures provides sufficient evidence to confirm originality.

The interpretation of these findings also requires consideration of individual and contextual characteristics. IT was selected because of high mathematics learning motivation, an Idealist personality type, and the ability to explain mathematical reasoning during interviews. These characteristics describe the research participant but cannot be interpreted as causal explanations for the observed solution procedures. Research by Schukajlow et al. (2022) indicates that motivation associated with specific mathematical strategies can be related to the quality of strategy use and problem-solving performance. However, this relationship does not imply that motivation automatically produces creative mathematical strategies. Similarly, DiNapoli and Miller (2022) demonstrated the importance of conceptual scaffolding in supporting students' perseverance during mathematical problem solving, suggesting that persistence and mathematical strategy development can be influenced by instructional conditions. These findings provide relevant theoretical context but cannot establish why IT

selected the scale factor method.

Additional evidence suggests that mathematical problem-solving performance may depend on several interacting cognitive characteristics. Yu et al. (2022) identified the relevance of spatial processing in mathematical problem solving, while Amalina and Vidákovich (2023) found that domain-specific prior knowledge contributed substantially to students' mathematical problem-solving abilities. These findings indicate that mathematical performance cannot reasonably be attributed to a single learner characteristic without considering prior knowledge, cognitive resources, and task requirements. More recently, Tan and Yang (2026) demonstrated heterogeneity in students' mathematical creative problem-solving processes, indicating that learners may exhibit different behavioral patterns even when engaged in comparable mathematical tasks. Nevertheless, these studies involved different research designs and participant populations. They therefore provide contextual explanations for the possible complexity of IT's performance rather than evidence of specific causal mechanisms in the present case. Given the single-participant design, the influence of learning motivation, Idealist personality type, prior mathematical knowledge, and instructional experience remains undetermined.

- *Incomplete Metacognitive Verification*

At the looking-back stage, IT expressed confidence in the correctness of the obtained answers because the scale factor and ratio methods produced identical numerical results. However, the participant did not perform additional calculations, independently examine the proportional equations, or systematically reconsider the assumptions underlying the solutions. This pattern indicates that the participant engaged in an initial comparison of solution outcomes but did not demonstrate comprehensive mathematical verification. Garofalo and Lester (1985) emphasized that successful mathematical problem solving involves metacognitive monitoring, including the evaluation of decisions and procedures throughout the problem-solving process. Similarly, Artzt and Armour-Thomas (1992) distinguished cognitive activity from metacognitive processes involving planning, monitoring, and verification. These perspectives suggest that obtaining an answer and evaluating the validity of the reasoning leading to that answer represent analytically distinct mathematical activities.

The limitation of IT's verification is particularly significant because both procedures were based on the same proportional relationship. Agreement between their numerical results provides some evidence of procedural consistency but cannot independently confirm that the underlying assumptions, mathematical transformations, or interpretations of the problem conditions were correct. Jacobse and Harskamp (2012) emphasized the importance of metacognitive monitoring and regulation in mathematical problem solving, particularly the assessment of students' judgments about their own performance. Their research also demonstrates that observable problem-solving activities can provide information about metacognitive functioning that may not be fully represented by students' self-reports. In the present study, IT's expressed confidence was not accompanied by observable independent verification. Thus, the findings indicate a discrepancy between confidence in the final answer and the depth of mathematical evaluation actually demonstrated.

This pattern is consistent with Toikka et al. (2026), who investigated metacognitive skills in mathematical problem solving and highlighted the role of reflective questioning in activating students' evaluation processes. Their findings suggest that metacognitive activities do not necessarily emerge with equal frequency throughout the problem-solving process. The present findings also correspond conceptually with research on creative metacognition. Lebuda and Benedek (2023) proposed a framework emphasizing the importance of monitoring, control, and metacognitive knowledge in creative activities, including the evaluation and selection of ideas. Similarly, Urban and Urban (2023) examined metacognition in creative problem solving through processes involving planning, monitoring, regulation, and evaluation. Although these studies addressed broader creative activities and different participant populations, they

reinforce the distinction between producing a solution and critically evaluating its quality. In IT's case, the evidence more strongly supports successful procedural execution than comprehensive metacognitive evaluation.

The absence of independent verification should not be interpreted as evidence that IT lacked mathematical creativity or metacognitive ability in general. The data demonstrate only that additional verification was not performed during the observed problem-solving sessions. Metacognitive processes are context-dependent and may vary according to problem characteristics, prior knowledge, task familiarity, and the opportunities provided for reflection. Jacobse and Harskamp (2012) demonstrated the importance of examining metacognitive processes through task-specific evidence, while Schindler and Lilienthal (2020) illustrated how detailed analysis of mathematical activity can reveal aspects of students' thinking that may remain unclear from written solutions alone. These perspectives reinforce the need to distinguish between the absence of an observed behavior and the absence of the underlying capability. Accordingly, the present study does not establish that IT was unable to perform independent verification, only that such verification was not demonstrated in the available written responses and interview data.

A further distinction concerns the relationship between creative thinking and metacognitive evaluation. Mathematical creativity requires the generation of potentially useful and novel ideas, whereas metacognitive evaluation concerns the monitoring and assessment of how those ideas are developed and justified. These processes may be related but should not be treated as identical constructs. Lu et al. (2025) highlighted the importance of distinguishing different dimensions of mathematical creativity during assessment, while Lebuda and Benedek (2023) emphasized the regulatory role of metacognition in creative thinking. Similarly, Urban and Urban (2023) demonstrated the relevance of evaluating metacognitive processes specifically within creative problem-solving activities. These theoretical perspectives suggest that a student may successfully generate and implement mathematical procedures without necessarily performing an equally thorough evaluation of the reasoning underlying those procedures. Consequently, IT's limited looking-back activity provides evidence concerning verification practices but cannot independently determine the participant's overall level of mathematical creativity.

Pedagogically, the findings suggest that students who successfully apply multiple mathematical procedures may still benefit from explicit instructional support for independent verification. Mathematics teachers can encourage students to substitute their answers into the original equations, examine the correspondence between dimensions, reconsider similarity conditions, and assess the reasonableness of their results. Such activities can help students move beyond confirming that alternative procedures produce identical numerical answers toward evaluating whether the mathematical reasoning itself is valid. The importance of supporting metacognitive monitoring and verification is consistent with Garofalo and Lester (1985) and Jacobse and Harskamp (2012). Moreover, conceptual scaffolding has been shown to support students' engagement with mathematical problem-solving difficulties (DiNapoli & Miller, 2022), while Toikka et al. (2026) emphasized the instructional relevance of reflective prompts for activating metacognitive evaluation. These findings support the recommendation that looking-back activities should involve explicit examination of mathematical assumptions, procedures, and results rather than relying exclusively on agreement between answers. In this way, the present case illustrates the pedagogical importance of integrating mathematical creativity, conceptual understanding, and independent metacognitive verification without treating them as interchangeable aspects of mathematical performance.

Research Limitations

This study has several limitations that need to be taken into account in interpreting its results. First, the study used a single case, namely IT, so its results cannot be generalized to all students with high learning motivation or the Idealist personality type. Second, the selection of

the participant was carried out purposively based on predetermined characteristics, so there is a possibility of selection bias and the results do not represent the diversity of students' creative thinking abilities. Third, the absence of a comparison group or case limits the study's ability to determine whether IT's strategy is more original than the strategies of other students.

Fourth, the findings depend on the characteristics of the two similarity problems used, including the instruction to solve the problems using two methods. These demands may influence the emergence of the procedural variation observed. Fifth, the interviews and prompting questions from the researcher may influence the way IT articulated the reasons and strategies for solving the problems. Sixth, the interpretation of qualitative data also involves researcher judgment, so the application of transparent analytical criteria is necessary to strengthen the credibility of the interpretation.

In light of these limitations, the results of this study should be understood as an in-depth account of one student's thinking process in solving two similarity problems, rather than as evidence of a causal relationship between motivation, personality type, and creative thinking. Future research could involve several students with variations in motivation and personality type, use the same tasks, apply a transparent creative thinking rubric, and compare strategies and verification processes across participants to obtain a broader understanding.

CONCLUSION

This case study shows that IT generated and applied two interrelated solution representations, namely the scale factor and comparison, in solving similarity problems. The use of these two representations demonstrates mastery of proportional procedures, but is not yet sufficient to prove flexibility because both rest on the same mathematical principle. Evidence of novelty is also contextual in nature because comparative data from other students were not available. At the stage of looking back, IT relied only on the similarity of results from the two procedures without carrying out independent verification of the solution process.

Theoretically, this finding underscores the importance of distinguishing mastery of concepts and procedures from indicators of creative thinking and of assessing each indicator based on appropriate empirical evidence. Pedagogically, students need to be guided to carry out independent verification, including substituting results into the original equation, checking the similarity conditions, and assessing the reasonableness of answers even when several procedures produce the same result.

Because this study involved only one student and two similarity problems, its results are specific to the case studied and cannot be generalized to all students with high motivation or the Idealist personality type. Future research is recommended to use a comparative multi-case study involving students from various categories of motivation and personality type, using the same tasks and a transparent creativity assessment rubric. This approach can provide a stronger empirical basis before formulating learning implications based on motivational and personality characteristics.

RECOMMENDATION

Mathematics teachers are encouraged to provide students with opportunities to solve similarity problems using different strategies and to distinguish between procedural variation and the use of fundamentally different mathematical approaches. Teachers should also guide students to conduct independent verification during the looking-back stage of problem solving by substituting their results into the original equations, re-examining the conditions of similarity, and evaluating the reasonableness of their answers. Reflective questions may help students develop more thorough mathematical reasoning and metacognitive evaluation.

For future researchers, it is recommended that similar studies involve multiple students with varying levels of learning motivation and different Keirsey personality types. Comparative case studies using the same mathematical tasks and a transparent rubric for assessing fluency, flexibility, and originality may provide a broader understanding of students' mathematical

creative thinking. Further research should also examine students' verification processes to clarify the relationship between generating multiple solution procedures and evaluating the validity of their answers. Given the limitations of the present single-case study, future findings should be interpreted cautiously before broader pedagogical conclusions are drawn.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Nurul Hikmah	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	
Sutji Rochaminah	✓	✓		✓	✓		✓			✓		✓		
Nurhayadi	✓	✓		✓	✓		✓			✓		✓		
Anggraini		✓		✓			✓			✓		✓		
Muh Rizal		✓		✓			✓			✓		✓		

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known financial or non-financial competing interests that could have appeared to influence the work reported in this paper.

ETHICAL APPROVAL

This study involved a seventh-grade student as the primary research participant, with preliminary screening conducted among 32 students. Data collection included the administration of mathematics learning motivation and personality-type questionnaires, mathematical problem-solving tasks, and semi-structured interviews. The research procedures considered the protection of participants' privacy, confidentiality, and well-being. The primary participant's identity was anonymized using the code IT, and the collected data were used exclusively for research purposes. The study was conducted in an educational setting with attention to ethical principles concerning voluntary participation, confidentiality, and the responsible handling of research data.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data include students' written responses to mathematical problem-solving tasks and interview transcripts related to their creative thinking in solving similarity problems. To protect the participant's privacy and confidentiality, access to the data may be subject to appropriate restrictions.

REFERENCES

Amalina, I. K., & Vidákovich, T. (2023). Cognitive and socioeconomic factors that influence the mathematical problem-solving skills of students. *Heliyon, 9*(9), Article e19539. https://doi.org/10.1016/j.heliyon.2023.e19539

Artzt, A. F., & Armour-Thomas, E. (1992). Development of a cognitive-metacognitive framework for protocol analysis of mathematical problem solving in small groups. *Cognition and Instruction, 9*(2), 137–175. https://doi.org/10.1207/s1532690xci0902_3

Br Ginting, S. S., Armanto, D., Amry, Z., Dewi, I., & Napitupulu, E. (2025). Factors affecting mathematical creative thinking ability: A systematic review and multidimensional perspective. *Jurnal Eksakta Pendidikan, 9*(1), 18–33. https://doi.org/10.24036/jep/vol9-iss1/949

Carney, M. B., Smith, E., & Hughes, G. (2023). Construct maps and item frameworks: An example in proportional reasoning. *Mathematics Education Research Journal, 35*, 849–877. https://doi.org/10.1007/s13394-022-00415-z

DiNapoli, J., & Miller, E. K. (2022). Recognizing, supporting, and improving student perseverance in mathematical problem-solving: The role of conceptual thinking

scaffolds. *The Journal of Mathematical Behavior, 66*, Article 100965. https://doi.org/10.1016/j.jmathb.2022.100965

Fiorella, L., Yoon, S. Y., Atit, K., Power, J. R., Panther, G., Sorby, S., Uttal, D. H., & Veurink, N. (2021). Validation of the Mathematics Motivation Questionnaire (MMQ) for secondary school students. *International Journal of STEM Education, 8*(1). https://doi.org/10.1186/s40594-021-00307-x

Garofalo, J., & Lester, F. K., Jr. (1985). Metacognition, cognitive monitoring, and mathematical performance. *Journal for Research in Mathematics Education, 16*(3), 163–176. https://doi.org/10.5951/jresematheduc.16.3.0163

Haslam, N., McGrath, M. J., Viechtbauer, W., & Kuppens, P. (2020). Dimensions over categories: A meta-analysis of taxometric research. *Psychological Medicine, 50*(9), 1418–1432. https://doi.org/10.1017/S003329172000183X

Jacobse, A. E., & Harskamp, E. G. (2012). Towards efficient measurement of metacognition in mathematical problem solving. *Metacognition and Learning, 7*, 133–149. https://doi.org/10.1007/s11409-012-9088-x

Keirsey, D. (1998). *Please understand me II: Temperament, character, intelligence*. Prometheus Nemesis.

Khairunnisa, I., Ariyanto, L., & Endahwuri, D. (2021). Analisis berpikir kreatif matematis ditinjau dari motivasi belajar siswa. *Imajiner: Jurnal Matematika dan Pendidikan Matematika, 3*(6), 527–534. https://doi.org/10.26877/imajiner.v3i6.8087

Khoiriyah, I. S. A., & Purwanti, K. Y. (2021). The creative thinking ability in elementary school mathematics problem solving. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 10*(1), 229. https://doi.org/10.24127/ajpm.v10i1.3251

Kurniawan, P., & Wijayanti, P. (2022). Profil metakognisi siswa SMA dalam memecahkan masalah matematika materi fungsi komposisi dan fungsi invers ditinjau dari kemampuan siswa. *MATHEdunesa, 11*(3), 644–656. https://doi.org/10.26740/mathedunesa.v11n3.p644-656

Lebuda, I., & Benedek, M. (2023). A systematic framework of creative metacognition. *Physics of Life Reviews, 46*, 161–181. https://doi.org/10.1016/j.plrev.2023.07.002

Leikin, R. (2009). Exploring mathematical creativity using multiple solution tasks. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students* (pp. 129–145). Sense Publishers. https://doi.org/10.1163/9789087909352_010

Leong, Y. H., Toh, T. L., Tay, E. G., Quek, K. S., & Dindyal, J. (2012). Relooking "Look Back": A student's attempt at problem solving using Polya's model. *International Journal of Mathematical Education in Science and Technology, 43*(3), 357–369. https://doi.org/10.1080/0020739X.2011.618558

Levav-Waynberg, A., & Leikin, R. (2012). The role of multiple solution tasks in developing knowledge and creativity in geometry. *The Journal of Mathematical Behavior, 31*(1), 73–90. https://doi.org/10.1016/j.jmathb.2011.11.001

Lu, X., & Kaiser, G. (2022). Creativity in students' modelling competencies: Conceptualisation and measurement. *Educational Studies in Mathematics, 109*, 287–311. https://doi.org/10.1007/s10649-021-10055-y

Lu, X., Kaiser, G., Zhu, Y., Ma, H., & Yan, Y. (2025). Mathematical creativity in modelling: Further development of the construct, its measurement, and its empirical implementation. *ZDM – Mathematics Education, 57*, 365–379. https://doi.org/10.1007/s11858-025-01652-9

Luthfiatunnisa, R., & Hardi, H. (2024). Analysis of learning barriers and elementary school students' errors in solving mathematical story problems. *JENIUS (Journal of Education Policy and Elementary Education Issues), 5*(2), 62–73. https://doi.org/10.22515/jenius.v5i2.8939

Marniati, M., Jahring, J., & Jumriani, J. (2021). Analisis kemampuan komunikasi matematis siswa dalam memecahkan masalah berdasarkan motivasi belajar siswa. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 10*(2), 880. https://doi.org/10.24127/ajpm.v10i2.3523

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications.

Oostveen-de Vink, I. C., Willemsen, R. H., Keijzer, R., Lazonder, A. W., & Kroesbergen, E. H. (2023). Supporting creative problem solving in primary geometry education. *Thinking Skills and Creativity, 48*, Article 101307. https://doi.org/10.1016/j.tsc.2023.101307

Pakpahan, M. R. M., & Wijayanti, P. (2025). Kemampuan berpikir kreatif siswa SMP dalam menyelesaikan soal matematika open-ended. *MATHEdunesa, 14*(1), 129–148. https://doi.org/10.26740/mathedunesa.v14n1.p129-148

Pólya, G. (1945). *How to solve it: A new aspect of mathematical method*. Princeton University Press.

Rosmawati, E., Kania, N., & Nurhikmayati, I. (2023). Influence of learning motivation on high school students' mathematical creative thinking ability. *Union: Jurnal Ilmiah Pendidikan Matematika, 11*(3), 487–495. https://doi.org/10.30738/union.v11i3.15801

Sadak, M., İncikabı, L., Ulusoy, F., & Pektaş, M. (2022). Investigating mathematical creativity through the connection between creative abilities in problem posing and problem solving. *Thinking Skills and Creativity, 45*, Article 101108. https://doi.org/10.1016/j.tsc.2022.101108

Sari, E. N., & Ristontowi. (2020). Pengaruh motivasi belajar terhadap kemampuan berpikir kreatif matematis siswa dalam model problem based learning (PBL) di SMP. *Jurnal Pendidikan Matematika Raflesia, 5*(3), 54–62

Sbaih, A. D. (2023). Creative thinking in students of mathematics in universities and its relationship with some variables. *Perspectives of Science and Education, 64*(4), 108–124.

Schindler, M., & Lilienthal, A. J. (2020). Students' creative process in mathematics: Insights from eye-tracking-stimulated recall interview on students' work on multiple solution tasks. *International Journal of Science and Mathematics Education, 18*, 1565–1586. https://doi.org/10.1007/s10763-019-10033-0

Schindler, M., & Lilienthal, A. J. (2022). Students' collaborative creative process and its phases in mathematics: An explorative study using dual eye tracking and stimulated recall interviews. *ZDM – Mathematics Education, 54*, 163–178. https://doi.org/10.1007/s11858-022-01327-9

Schukajlow, S., Blomberg, J., Rellensmann, J., & Leopold, C. (2022). The role of strategy-based motivation in mathematical problem solving: The case of learner-generated drawings. *Learning and Instruction, 80*, Article 101561. https://doi.org/10.1016/j.learninstruc.2021.101561

Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving and problem posing. *ZDM – Mathematics Education, 29*(3), 75–80. https://doi.org/10.1007/s11858-997-0003-x

Sipahi, Y., & Bahar, A. K. (2025). Mathematical creativity: A systematic review of definitions, frameworks, and assessment practices. *Education Sciences, 15*(10), Article 1348. https://doi.org/10.3390/educsci15101348

Sriraman, B. (2005). Are giftedness and creativity synonyms in mathematics? *Journal of Secondary Gifted Education, 17*(1), 20–36. https://doi.org/10.4219/jsge-2005-389

Stacey, K. (2022). Looking back on Pólya's teaching of problem solving. *Teaching Mathematics and Computer Science, 20*(2), 207–217. https://doi.org/10.5485/TMCS.2022.0533

Tan, Y., & Yang, T. (2026). Cognitive process grouping on students' mathematical creative problem solving: Evidence from clustering analysis, lag sequence analysis, and hidden Markov model. *Computers & Education, 252*, Article 105657. https://doi.org/10.1016/j.compedu.2026.105657

Toikka, S., Eronen, L., Nieminen, J. H., & Havu-Nuutinen, S. (2026). From problem-solving to reflection: Activating diverse metacognitive skills in mathematics. *International Journal of Science and Mathematics Education, 24*(2), Article 10. https://doi.org/10.1007/s10763-025-10643-x

Urban, K., & Urban, M. (2023). How can we measure metacognition in creative problem-solving? Standardization of the MCPS scale. *Thinking Skills and Creativity, 49*, Article 101345. https://doi.org/10.1016/j.tsc.2023.101345

Van Hooijdonk, M., Mainhard, T., Kroesbergen, E. H., & Van Tartwijk, J. (2023). Creative problem solving in primary school students. *Learning and Instruction, 88*, Article 101823. https://doi.org/10.1016/j.learninstruc.2023.101823

William, S. K., & Maat, S. M. (2020). Understanding students' metacognition in mathematics problem solving: A systematic review. *International Journal of Academic Research in Progressive Education and Development, 9*(3), 115–127. https://doi.org/10.6007/IJARPED/v9-i3/7847

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.

Yu, M., Cui, J., Wang, L., Gao, X., Cui, Z., & Zhou, X. (2022). Spatial processing rather than logical reasoning was found to be critical for mathematical problem-solving. *Learning and Individual Differences, 100*, Article 102230. https://doi.org/10.1016/j.lindif.2022.102230

Zaeny, H. N., Sujiran, & Puspananda, D. R. (2021). Analisis kesalahan siswa dalam penyelesaian soal cerita ditinjau dari tipe kepribadian Keirsey. *Journal of Mathematics Education and Science, 4*(2), 51–58. https://doi.org/10.32665/james.v4i2.212

Zarkasih, T., & Meilasari, V. (2025). Kemampuan literasi numerasi siswa dalam pemecahan masalah matematika ditinjau dari tipe kepribadian David Keirsey. *Indiktika: Jurnal Inovasi Pendidikan Matematika, 7*(2), 422–436. https://doi.org/10.31851/indiktika.v7i2.17766