

DIAGNOSTIC PROFILE OF ELEMENTARY SCHOOL STUDENTS' MATHEMATICAL CREATIVE THINKING IN PROBLEM SOLVING THROUGH NEWMAN ERROR ANALYSIS

Sumardi W. Ndolu^{1a*}, Yuliana^{2b}, Julien Chintya^{3c}

¹²³Elementary School Teacher Education, Faculty of Education and Psychology, Universitas Negeri Manado, Tomohon, North Sulawesi, 95445

^aE-mail: sumardi.ndolu@unima.ac.id

^bE-mail: yuliana1806@unima.ac.id

^cE-mail: julienchintya@unima.ac.id

(*) Corresponding Author

sumardi.ndolu@unima.ac.id

ARTICLE HISTORY

Received : 21-08-2026

Revised : 04-09-2026

Accepted : 18-09-2026

KEYWORDS

Diagnostic Assessment; Fluency; Flexibility; Novelty; Mathematical Creative Thinking; Newman Error Analysis; Problem Solving

ABSTRACT

Mathematical creative thinking is essential for problem solving because it enables students to generate multiple solutions, apply diverse strategies, and develop relatively novel approaches. However, classifying students' creative-thinking levels does not indicate where difficulties occur during problem solving. This study aimed to describe the diagnostic profile of elementary school students' mathematical creative thinking in problem solving through Newman Error Analysis (NEA). A qualitative multiple-case study was conducted with 29 sixth-grade students at St. Clara Catholic Elementary School in Tomohon. Students completed an open-ended problem-solving task assessing fluency, flexibility, and novelty and were classified into MCTL levels 0–4. One student representing each MCTL level was purposively selected for semi-structured interviews based on the five NEA stages: reading, comprehension, transformation, process skills, and encoding. The findings showed that MCTL 2 was the most prevalent level (34.5%). Students at lower MCTL levels tended to experience difficulties in comprehension and transformation, whereas those at higher levels generally understood and transformed problems appropriately but still experienced procedural and encoding errors. Transformation emerged as an important intersection between mathematical creative thinking, particularly flexibility and novelty, and problem-solving difficulties. Integrating MCTL and NEA provides a more informative diagnostic profile for designing adaptive scaffolding based on students' creative-thinking characteristics and problem-solving needs.

This is an open access article under the CC-BY-SA license.



INTRODUCTION

Mathematical creative thinking is an important ability to be developed in mathematics learning because problem solving requires students not only to obtain correct answers but also to generate alternative solutions, apply diverse strategies, and develop relatively novel approaches (De Vink et al., 2022). In mathematical problem solving, creativity can be manifested through fluency, flexibility, and novelty. Fluency refers to the ability to generate several relevant and correct responses or solutions; flexibility refers to the ability to use different strategies, methods, or representations; and novelty refers to the ability to generate solutions that are relatively new within the students' context. These three characteristics have been widely recognized as important dimensions of mathematical creativity in problem solving and problem posing (Assmus & Fritzlär, 2022; Bruhn & Lüken, 2023; Silver, 1997).

The characteristics of fluency, flexibility, and novelty can be used to distinguish levels of students' mathematical creative thinking. (Siswono, 2011) developed a five-level classification of creative thinking, ranging from MCTL 0 to MCTL 4. This classification reflects differences in the combination and quality of creativity indicators demonstrated by students when solving mathematical problems. Students at MCTL 0 demonstrate none of the three indicators, whereas students at higher levels demonstrate increasingly complex combinations of fluency, flexibility, and novelty. Such a classification is useful for describing the level of students' mathematical creative thinking; however, it primarily indicates what level of creativity students demonstrate rather than where and why difficulties occur during the problem-solving process.

This limitation is important because students who are classified at the same level of mathematical creative thinking may experience different types of difficulties. A student may have difficulty understanding the information contained in a problem, while another student may understand the problem but be unable to transform it into an appropriate mathematical representation or alternative strategy. Therefore, classification of creative-thinking levels needs to be complemented by a diagnostic analysis of the problem-solving process. Such an analysis can provide more specific information for developing feedback and instructional support based on students' individual characteristics and difficulties (Ndolu & Lalang, 2023; Töllner et al., 2025; Van Den Berg et al., 2016).

One framework that can be used to identify difficulties in mathematical problem solving is Newman Error Analysis (NEA). Newman (1977) identified five stages that students need to successfully pass through when solving mathematical problems: reading, comprehension, transformation, process skills, and encoding. These stages provide a systematic pathway for identifying difficulties, beginning with recognizing and interpreting information in the problem, transforming the information into an appropriate mathematical model or strategy, carrying out the required procedures, and communicating the final answer. Recent studies have shown that students' difficulties are not limited to computational procedures but may also arise during comprehension and transformation, particularly when solving contextual mathematical problems (Fatawu et al., 2023; Maghfiroh & Wahyuningsih, 2024; Niluh Lisa Arianti et al., 2025).

The integration of NEA with mathematical creative thinking is particularly relevant at the transformation stage. Transformation requires students to move beyond understanding the information presented in a problem and translate it into a mathematical model, representation, operation, or solution strategy (Lu & Kaiser, 2022). This process is closely related to flexibility because students may need to consider and compare different ways of representing or solving a problem (Bicer, 2021). It may also be related to novelty when students restructure the given information and construct an approach that differs from conventional procedures. (Schoevers et al., 2020) emphasized that mathematical creativity involves an interaction between domain-general creative abilities and domain-specific mathematical skills, while (Elgrably & Leikin, 2021) demonstrated the relevance of problem-solving expertise to the generation of new mathematical problems and strategies. Thus, examining the transformation stage may provide insight into how students' creative-thinking characteristics are manifested in the problem-solving process.

Nevertheless, mathematical creative thinking and NEA represent different analytical perspectives and should not be treated as identical constructs. MCTL is used in this study to describe the characteristics and level of students' mathematical creativity based on fluency, flexibility, and novelty, whereas NEA is used to identify the location and characteristics of difficulties within the problem-solving process. Their integration can therefore provide complementary information: MCTL indicates the quality of students' creative thinking, while NEA indicates the stage at which problem-solving difficulties occur.

This distinction provides a basis for developing a more informative diagnostic profile of students' mathematical creative thinking.

Previous research has begun to examine the connection between Newman Error Analysis and mathematical creative thinking. (Kartono & Suciawati, 2025), for example, mapped the five Newman stages onto dimensions of creative thinking in contextual problem solving and found that difficulties were more frequently observed at the transformation, process skills, and encoding stages. Their study provides important evidence that NEA can be considered alongside mathematical creative thinking in examining students' problem-solving processes. However, the study involved 25 eighth-grade students and focused on relations and functions at the junior secondary level. Consequently, less is known about how Newman error patterns are manifested across different levels of mathematical creative thinking among elementary school students, particularly when solving open-ended geometry problems.

The present study addresses this gap by focusing on sixth-grade elementary school students and examining Newman error patterns across MCTL levels 0–4 using fluency, flexibility, and novelty as indicators of mathematical creative thinking. Rather than examining NEA and creativity as separate constructs, this study maps the five Newman stages onto students representing different MCTL levels to identify patterns in the location and type of problem-solving difficulties. The study was conducted at the beginning of the semester, after students had previously learned about the area and perimeter of plane figures but before classroom instruction was specifically directed toward developing mathematical creative thinking. Therefore, the findings are positioned as an initial diagnostic profile or baseline of students' mathematical creative thinking and problem-solving difficulties.

Based on this rationale, this study aims to describe a diagnostic profile of sixth-grade students' mathematical creative thinking in problem solving based on Newman Error Analysis. Specifically, the study examines patterns of reading, comprehension, transformation, process skills, and encoding among students representing MCTL levels 0–4 and identifies possible intersections between the creativity indicators of fluency, flexibility, and novelty and the stages of Newman Error Analysis.

METHOD

This study employed a qualitative approach with a multiple-case study design. The design was selected because the study aimed not only to classify students according to their levels of mathematical creative thinking but also to examine the thinking processes underlying their responses and errors when solving mathematical problems. The multiple-case study design enabled an in-depth analysis (Rashid et al., 2019) of students' mathematical creative-thinking characteristics and problem-solving difficulties using Newman Error Analysis (NEA). 29 sixth-grade students from St. Clara Catholic Elementary School in Tomohon, North Sulawesi, Indonesia, participated in the study during July–August 2026. All students had previously learned the mathematical content addressed in the research task, particularly the area and perimeter of plane figures. Data collection took place at the beginning of the semester, before classroom instruction specifically aimed at developing mathematical creative thinking was implemented. This timing allowed students' performance to be examined as an initial diagnostic profile of their mathematical creative-thinking abilities. All students first completed an open-ended mathematical problem-solving test and were then classified into MCTL levels based on (Siswono, 2011). Subsequently, one student from each MCTL level (MCTL 0–4) was purposively selected as a focal participant for a semi-structured interview, resulting in five focal participants. Selection was based on the completeness of the written responses, the students' ability to explain their problem-solving processes, and their willingness to participate in the interview.

Table 1. Indicators of Mathematical Creative Thinking

Indicator	Description
Fluency	Students can solve mathematical problems with appropriate and correct answers that are not limited to a single response, although the solution method may remain the same.
Flexibility	Students can solve mathematical problems using several different strategies or solution methods while obtaining the same correct answer.

Novelty	Students can find a mathematical solution using a new approach expressed in their own words or different from their peers, an uncommon approach, or a solution that has not previously been taught by the teacher and is constructed by the student.
----------------	--

Source: Researcher, adapted from (Ndolu & Lalang, 2023)

Table 2. Criteria for Classification of Mathematical Creative Thinking Levels

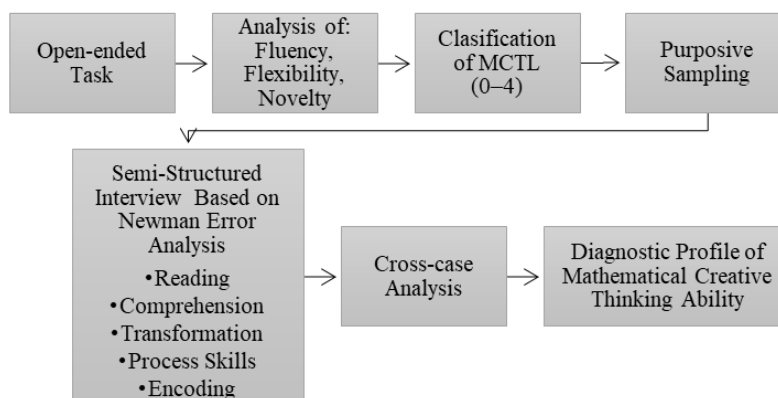
Level	Creativity Characteristic
MCTL 0	Students are unable to demonstrate the three indicators of creative thinking in solving mathematical problems.
MCTL 1	Students demonstrate only fluency in solving mathematical problems correctly.
MCTL 2	Students demonstrate novelty or flexibility in solving mathematical problems correctly.
MCTL 3	Students demonstrate fluency and novelty or fluency and flexibility in solving mathematical problems correctly.
MCTL 4	Students demonstrate all three indicators fluency, flexibility, and novelty in solving mathematical problems accurately and correctly.

Source: Researcher, adapted from (Siswono, 2011)

The research instruments consisted of: (1) an open-ended mathematical problem-solving test developed based on the mathematical creativity indicators of fluency, flexibility, and novelty (Sa'dijah et al., 2019; Silver, 1997); and (2) a semi-structured interview guide referring to the five stages of Newman Error Analysis, namely reading, comprehension, transformation, process skills, and encoding. The test used was adapted from the instrument developed by (Ndolu & Lalang, 2023), with adjustments to the students' context and the research objectives. The content suitability and readability of the problems were examined before use through expert review and a limited readability test.

The research was conducted through four stages: (1) administration of the problem-solving test; (2) analysis of creative thinking to determine the MCTL level; (3) selection of research participants; and (4) interviews based on Newman Error Analysis. Data were analyzed sequentially by identifying mathematical creativity indicators (Ndolu & Lalang, 2023), classifying MCTL levels (Siswono, 2011), analyzing errors using Newman Error Analysis (Newman, 1977; Singh et al., 2010), and then conducting cross-case analysis to construct a diagnostic profile of mathematical creative thinking at each MCTL level.

Data trustworthiness was maintained through technique triangulation by comparing test and interview results, member checking with participants, and peer debriefing with a mathematics education expert to enhance the credibility of the findings. The following presents the research implementation flow.



Picture 1. Research Implementation Flow

Source: Authors' design based on the research procedures.

RESULT AND DISCUSSION

Results

Profile of Mathematical Creative-Thinking Levels (MCTL)

Test analysis showed that students’ mathematical creative thinking varied across MCTL levels. Of the 29 respondents: 2 students were classified as MCTL 0; 7 as MCTL 1; 10 as MCTL 2; 6 as MCTL 3; and 4 as MCTL 4. The distribution of students’ creative-thinking levels is presented below.

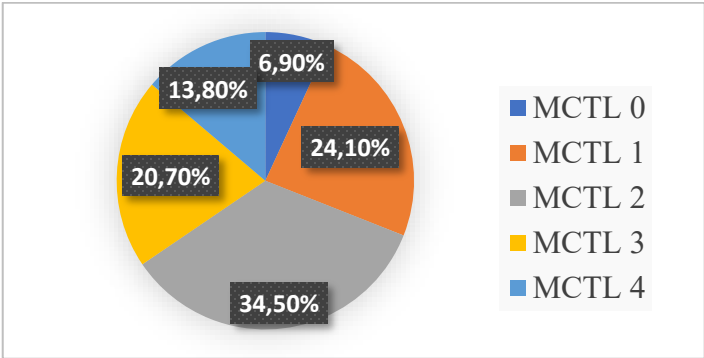


Diagram 1. Level of Mathematical Creative Thinking Ability
Source: Authors’ Analysis Based on the Research Data.

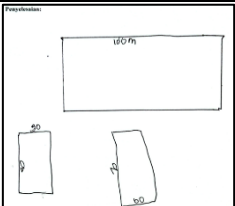
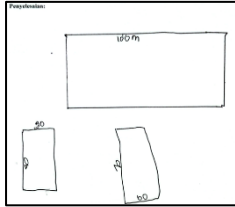
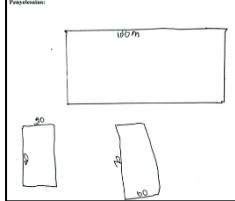
The distribution indicates that students’ mathematical creative thinking at the beginning of the semester was relatively diverse. Because this study is diagnostic in nature, the distribution is not used to represent the creativity level of the elementary-school student population in general.

Error Patterns Based on Newman Error Analysis

The Newman Error Analysis indicated that error patterns differed across levels of creative thinking. Students at lower MCTL levels tended to experience errors beginning at the comprehension and transformation stages, whereas students at higher MCTL levels were generally able to understand and transform the problems but could still make errors at the process skills or encoding stages.

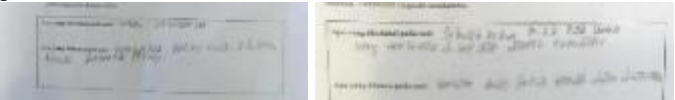
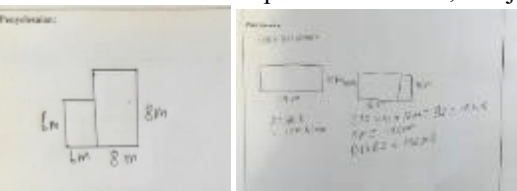
Table 3. Participant 1 with MCTL 0

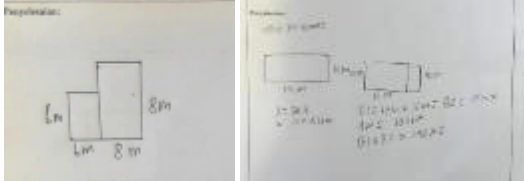
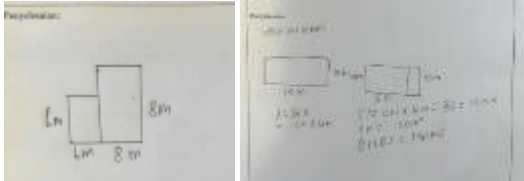
Reading	The student was able to read the problem text; however, inappropriate phrasing while reading made it difficult for the student to recognize and understand the intended meaning of the problem. When asked to read the problem again, the student continued to mis-segment several key parts of the text, particularly around the term “difference” and the measurement symbols. During the interview, the student stated, “I can read all the sentences in the problem, but I am confused about the meaning of the word ‘difference’ and the measurement symbols.”	
Comprehension	Apa yang diketahui pada soal: luas 10 dm² Apa yang ditanya pada soal: menggambar poligonsewajut 2bidang	The student could not understand the purpose of the problem and could not accurately identify what was given and what was asked. The student stated: “I read the problem repeatedly, but I was confused about what to write as the given information. I did not really understand what was being asked.”

Transformation		The student could not transform the verbal problem into an appropriate mathematical model or formula and was unsure which operation to use. The student stated: "I did not know which formula to use, so I just added the numbers for the measurements as I remembered."
Process Skills		The student made fundamental calculation errors and could not proceed correctly. The student stated: "I just calculated the numbers without really knowing what to do. I filled in the answer, but when I multiplied, the result was wrong."
Encoding		The student stopped at the final numerical calculation and did not provide a complete conclusion or appropriate unit. The student stated: "I only stopped at the last number. I did not know how to write the final conclusion or the unit."

Source: Student Work, Research Documentation (2026)

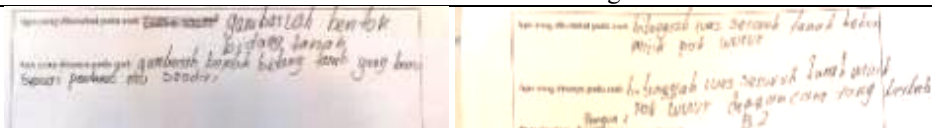
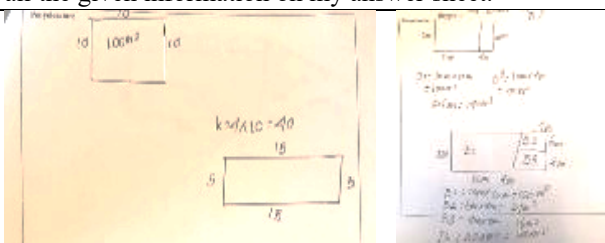
Table 4. Participant 2 with MCTL 1

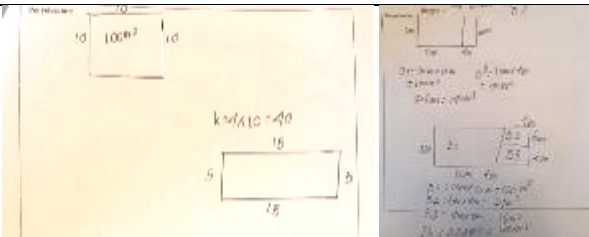
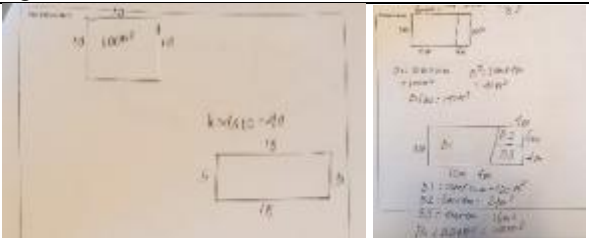
Reading	No error was identified. The student could read and identify the basic information in the problem.
Comprehension	 An error was identified. The student did not fully understand the relationships among the information in the problem and tended to use the available numbers without explaining their meaning. This was consistent with the interview response: "I was confused about what the numbers in the problem were for, so I just put the numbers into a calculation."
Transformation	 An error was identified. The student had difficulty transforming the contextual problem into a mathematical model and determining how to separate or combine the parts of the figure. This was consistent with the interview response: "I was confused about how to cut the picture, so I just wrote the formula without separating it into two figures."

Process Skills	 An error was identified. The student made errors in applying the area formula and performing calculations. This was consistent with the interview response: "I was in a hurry when calculating and was not careful, so there were numbers and formulas that I calculated incorrectly."
Encoding	 An error was identified. The student was unable to state a final conclusion in accordance with the problem context. The student stated: "I was confused about how to write the answer sentence, so I just calculated to the bottom and stopped."

Source: Student Work, Research Documentation (2026)

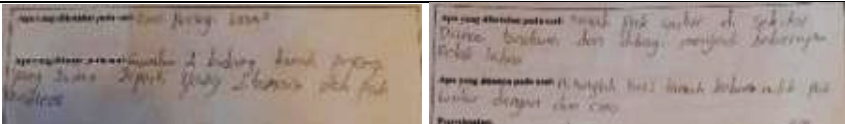
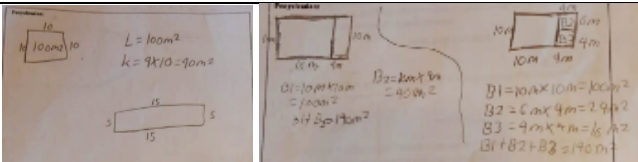
Table 5. Participant 3 with MCTL 2

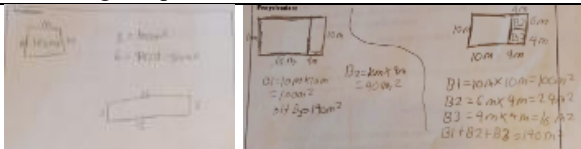
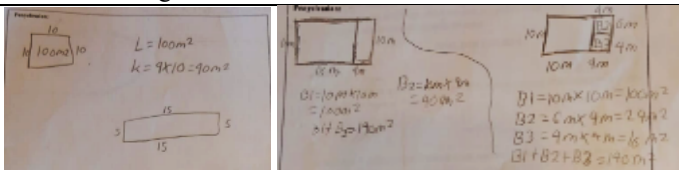
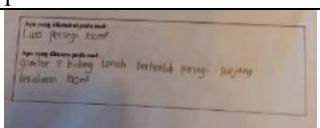
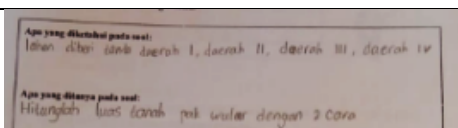
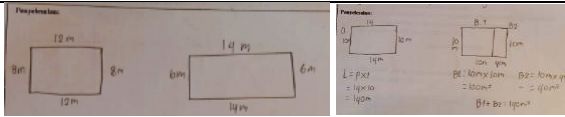
Reading	No error was identified. The student could read and recognize relevant information.
Comprehension	 No error was identified. The student understood the given and requested information. The student stated: "I understand the problem because the lengths and widths of each figure are given, and what is asked is the area of the combined figure, so I immediately wrote all the given information on my answer sheet."
Transformation	 An error was identified. The student still had difficulty determining a creative solution. Although the student understood the problem, an alternative strategy for finding the area of the composite figure was not developed. The student stated: "I know the given measurements and that I have to find the total area, but I was confused about using another way to divide the figure, so I used the one way that is usually taught."

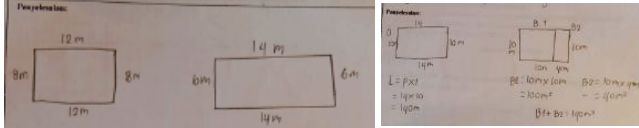
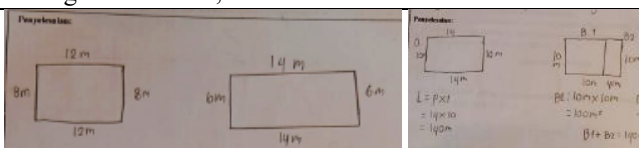
Process Skills	 An error was identified. During the work, the student made errors in applying formulas and performing calculations. The student stated: "I know the problem gives the length and width, but when I calculated the area by multiplication, one of the numbers was calculated incorrectly. I was also not careful when adding the areas of the first and second figures."
Encoding	 An error was identified. The student did not present the final answer completely. The conclusion did not state the solution corresponding to the question. The student stated: "I only calculated the numbers down to the bottom, but I did not write the final conclusion for the question about the area of the figure."

Source: Student Work, Research Documentation (2026)

Table 6. Participant 4 with MCTL 3

Reading	No error was identified. The student could read and identify important information in the problem.
Comprehension	 No error was identified. The student understood the meaning of the problem and could determine the concept to be used. The student stated: "I understand the problem because the length and width are already given, and what is asked is the area of the figure. So I know I have to use the area formula."
Transformation	

	No error was identified. The student could construct an appropriate solution model, such as dividing the composite figure into several simpler parts to determine the area. The student stated: "The figure is a composite, so I divided it first into several smaller square or rectangular parts so that it would be easier to calculate each area one by one."
Process Skills	 An error was identified. The error occurred during calculation. The student had an appropriate strategy but was not sufficiently accurate in carrying out mathematical operations, so the final result was incorrect. The student stated: "The way I divided it was correct, but when calculating length times width, I got one number wrong, so the total area was wrong."
Encoding	 An error was identified. The student was unable to communicate the final result adequately. The answer was not accompanied by a conclusion clarifying the meaning of the calculation. The student stated: "I only calculated the numbers down to the bottom, but I forgot to write the final conclusion of the answer to the area problem." Source: Student Work, Research Documentation (2026)
Table 7. Participant 5 with MCTL 3	
Reading	No error was identified. The student could understand the information presented in the problem.
Comprehension	  No error was identified. The student understood the concept and purpose of the problem. The student stated: "I understand the problem. It says that the areas of Regions I, II, III, and IV are given, and we are asked to calculate the area of Mr. Wullur's land using two different methods."
Transformation	 No error was identified. The student could select an appropriate strategy and demonstrate more than one possible solution. The student stated: "I can make two methods. First, I calculate the area of each region one by one and then add them. Second, I combine the measurements first and then calculate the total area."

Process Skills	 An error occurred occasionally. The student generally carried out the procedures correctly, but a small technical calculation error occurred because of insufficient accuracy. The student stated: “Actually, I know the steps, but when multiplying and adding the numbers, I made a small mistake because I was not careful.”
Encoding	 An error was identified. Although the student had obtained the result, the final conclusion was not written completely. The student stated: “I have calculated the area to the end and obtained the result, but I forgot to write the conclusion sentence answering the question about the area of the land.”

Source: Student Work, Research Documentation (2026)

Table 8. Summary of the Comparison of the Five Cases

MCTL Level	Reading	Comprehension	Transformation	Process Skills	Encoding
0	Dominant	Dominant	Dominant	Dominant	Dominant
1	Not dominant	Dominant	Dominant	Consequential	Consequential
2	Not dominant	Not dominant	Dominant	Dominant	Consequential
3	Not found	Not found	Not found	Dominant	Dominant
4	Not found	Not found	Not found	Occasional	Dominant

Source: Authors' Processed Data (2026)

Notes:

Dominant = the main location of difficulty in the case;

Occasional = a technical error or lack of accuracy;

Consequential = an error that may occur as a consequence of a difficulty at an earlier stage.

Diagnostic Profile of Mathematical Creative Thinking

Cross-case analysis indicated a tendency for the location and complexity of problem-solving difficulties to differ across MCTL levels. Students at MCTL 0-1 showed difficulties in understanding information and constructing mathematical models, which limited their ability to generate diverse solution strategies. In contrast, students at MCTL 3-4 were able to generate several solution strategies and demonstrated flexibility in thinking, although some remained insufficiently accurate in calculation or in writing the final answer.

These findings produce a diagnostic profile showing a relationship between indicators of mathematical creativity and stages of error in problem solving. As fluency, flexibility, and novelty increase, fewer errors appear at the reading, comprehension, and transformation stages. Errors that remain among students with high creativity are generally procedural (process skills) or administrative (encoding).

Discussion

The findings of this study indicate that students' problem-solving difficulties varied across levels of mathematical creative thinking. Students at MCTL 0-1 tended to experience difficulties at the comprehension and transformation stages,

whereas the MCTL 2 case showed a more specific difficulty at transformation, and students at MCTL 3-4 were generally able to understand and transform the problem but still experienced difficulties in process skills and encoding. This pattern suggests that the location of problem-solving difficulties may shift as students demonstrate increasingly developed characteristics of mathematical creative thinking. However, because the study employed a qualitative multiple-case design with five focal participants, this pattern should be interpreted as a case-based tendency rather than as evidence of a causal relationship between creativity and error patterns.

Lower MCTL Levels: Difficulties in Comprehension and Transformation

The difficulties observed among the MCTL 0 and MCTL 1 participants were concentrated mainly in comprehension and transformation. The MCTL 0 participant had difficulty identifying the meaning of important terms, determining what information was given and what was being asked, and selecting an appropriate mathematical operation. Similarly, the MCTL 1 participant was able to read the problem but had difficulty understanding the relationships among the given quantities and transforming the contextual situation into a mathematical model. These findings indicate that difficulties at the early stages of problem solving can constrain students' subsequent ability to generate and apply alternative solution strategies. This finding is consistent with research showing that understanding the meaning and structure of a mathematical problem is an important foundation for successful problem solving. (Utami et al., 2024), for example, found that students could experience errors beginning with difficulties in understanding the meaning and context of mathematical problems when analyzed using the Newman procedure. Their study, however, focused on three senior high school students solving trigonometric problems from the perspective of mathematical resilience. In contrast, the present study identifies similar comprehension difficulties among elementary school students and further connects those difficulties to their MCTL levels.

The findings are also consistent with (Maghfiroh & Wahyuningsih, 2024), who examined 34 fifth-grade students solving mathematical story problems and identified conceptual understanding, operational ability, and problem-solving as important components of students' performance. Their study emphasizes the difficulty elementary students may experience when interpreting contextual mathematical situations. The present study extends this finding by showing that such difficulties are particularly visible among students at lower levels of mathematical creative thinking. Thus, the issue is not merely whether elementary students can solve story problems, but also whether they possess sufficient conceptual understanding to move from the context of a problem toward a mathematical representation. The transformation difficulty found in MCTL 0-1 is further supported by (Jupri & Drijvers, 2016). Their study of 51 Indonesian students found that formulating a mathematical model was a major difficulty in solving algebraic word problems, particularly when students had to transform contextual information into equations, schemas, or diagrams. Although their participants were older students and the mathematical content was algebra, the similarity lies in the role of transformation as a critical point between understanding a problem and carrying out mathematical procedures. The present study contributes a different perspective by showing that transformation difficulties are not only associated with mathematization but also appear prominently among students who demonstrate lower levels of mathematical creative thinking.

MCTL 2 and Transformation as a Critical Point for Flexibility

The MCTL 2 participant demonstrated an important transitional pattern. The student was able to read and comprehend the problem but had difficulty developing an alternative strategy for determining the area of the composite figure. The student understood the mathematical information and knew what had to be calculated, but remained dependent on the conventional strategy that had usually been taught. Thus, the main difficulty was no longer understanding the problem but restructuring the understood information into another possible solution strategy. This finding is particularly relevant to the concept of flexibility in mathematical creativity. (Wang & Star, 2023) distinguish between algorithm-oriented flexibility and structure-informed flexibility and emphasize that procedural flexibility involves selecting strategies that are appropriate to the mathematical situation rather than simply applying standard algorithms. The MCTL 2 participant in the present study appeared to rely primarily on a familiar solution path even though the problem allowed more than one way of decomposing the composite figure. This suggests that the student's difficulty was not primarily procedural knowledge but the ability to reorganize mathematical information and recognize alternative solution structures.

The finding also complements (Elgrably & Leikin, 2021), who investigated mathematical creativity in relation to problem-solving expertise through problem posing and mathematical investigations. Their study demonstrated the relevance

of mathematical expertise to students' ability to generate new mathematical problems and strategies. While their research involved different participants, a different task, and a dynamic geometry environment, the present study similarly suggests that generating alternative approaches requires more than simply understanding the mathematical content. Students need to reorganize existing knowledge and use it flexibly in a new problem situation. The present finding also differs in emphasis from (Kartono & Suciawati, 2025). Their study is the closest previous work to the present research because it explicitly mapped Newman Error Analysis onto mathematical creative thinking among 25 eighth-grade students solving contextual problems on relations and functions. They found that students generally performed better at reading and comprehension, while more substantial difficulties emerged at transformation, process skills, and encoding. The present study similarly identifies transformation as an important difficulty, but it shows a more differentiated pattern across MCTL levels. In particular, transformation was dominant for the MCTL 2 case, while it had already been overcome by the MCTL 3 and MCTL 4 cases. This difference may be related to the age of the participants, the mathematical content, and the analytical purpose of the studies. Whereas Kartono and Suciawati examined the distribution of NEA errors across students, the present study focuses on how the location of errors varies across different levels of mathematical creative thinking.

Higher MCTL Levels: Procedural and Encoding Difficulties

The MCTL 3 and MCTL 4 participants demonstrated a different pattern. Both participants were able to read, comprehend, and transform the problem appropriately. The MCTL 3 participant could decompose the composite figure into simpler parts and construct an appropriate solution model, while the MCTL 4 participant demonstrated more than one strategy for determining the required area. Nevertheless, both participants still experienced difficulties in process skills, particularly through calculation errors. The MCTL 4 participant also experienced an encoding difficulty because the final answer was not communicated in a complete concluding statement. This pattern is consistent with several studies using Newman Error Analysis. (Ramadhani et al., 2024), for example, found that students with different levels of mathematical ability could experience errors in comprehension, transformation, process skills, and encoding when solving linear-program word problems. Similarly, (Fatawu et al., 2023) who examined 70 senior high school students solving algebraic word problems, used NEA to identify errors across the problem-solving process. Their findings demonstrate the usefulness of NEA for distinguishing errors that occur at different stages rather than treating incorrect answers as a single type of failure.

The present study, however, provides a different interpretation of these procedural and encoding errors because they occurred in students who had already demonstrated higher levels of mathematical creative thinking. In other words, the presence of an error did not necessarily indicate a failure to understand the mathematical problem. Instead, the MCTL 3 and MCTL 4 cases suggest that students may possess an appropriate conceptual representation and flexible strategy while still lacking sufficient accuracy or completeness when executing and communicating their solutions. This interpretation is also compatible with the findings of (Firdaus et al., 2026), who reported errors across all Newman stages among 30 Grade XI students solving statistical problems, with transformation, process skills, and encoding accounting for substantial proportions of the identified errors.

A similar pattern is evident in the study by (Lien Malinda et al., 2026), which examined six third-grade elementary school students solving addition and subtraction word problems using the Newman technique. Their study found that elementary students may experience difficulties at different Newman stages when solving contextual problems. The present study differs because its focus is not simply on identifying which Newman errors occur, but on examining how those errors appear in students representing different levels of mathematical creative thinking. Thus, an important contribution of the present study is the distinction between conceptual difficulties that restrict creative problem solving and technical or communicative errors that remain after students have demonstrated more developed creative-thinking characteristics.

Transformation as the Intersection of Creative Thinking and Problem-Solving Difficulty

Across the five focal cases, transformation emerged as the most conceptually significant stage for understanding the relationship between mathematical creative thinking and problem-solving difficulties. At lower MCTL levels, transformation was difficult because students could not determine an appropriate mathematical model or strategy. At MCTL 2, the student understood the problem but could not construct an alternative strategy. At MCTL 3 and MCTL 4, transformation was no longer problematic because the students could construct appropriate solution models and, in the MCTL 4 case, generate more than one strategy.

This pattern provides a more nuanced interpretation of the role of transformation than studies that examine NEA alone. (Jupri & Drijvers, 2016), identified mathematization and mathematical-model formulation as major sources of difficulty, emphasizing the process of transforming contextual information into mathematical form. In the present study, transformation encompasses this representational process but is additionally connected to the creative requirement to consider alternative strategies. Therefore, transformation can be understood as a point at which students must simultaneously interpret mathematical structure and reorganize that structure into a workable strategy.

The pattern is also consistent with the distinction between algorithm-oriented and structure-informed flexibility proposed by (Wang & Star, 2023). A student who merely follows a familiar algorithm may successfully complete a routine procedure but may struggle when a problem requires a different representation or strategy. The MCTL 2 case illustrates this condition: the student understood the mathematical information but remained dependent on one familiar method. By contrast, the MCTL 4 participant could construct two solution methods, indicating greater flexibility in reorganizing the problem structure. This comparison strengthens the interpretation that transformation is not simply a procedural NEA stage but can also reveal important characteristics of mathematical creative thinking.

Theoretical and Practical Implications

The integration of MCTL and NEA in this study provides a complementary diagnostic perspective. MCTL describes the characteristics and level of students' mathematical creative thinking through fluency, flexibility, and novelty, whereas NEA identifies the stage at which difficulties occur during problem solving. The combination therefore provides information that neither framework provides independently. A MCTL classification alone may indicate that a student has limited creative-thinking characteristics, but it does not specify whether the difficulty originates from understanding the problem, constructing a mathematical representation, carrying out procedures, or communicating the answer. Conversely, NEA can locate errors but does not explain how those errors relate to the students' creative-thinking characteristics. This distinction has practical implications for instructional scaffolding. For students at MCTL 0-1, instructional support should prioritize comprehension and transformation through explicit identification of relevant information, visual representations, and guided construction of mathematical models. For MCTL 2, instruction should provide opportunities to compare multiple representations and deliberately generate alternative solution strategies rather than repeatedly applying one conventional procedure. For MCTL 3-4, instructional emphasis can shift toward verification, metacognitive monitoring, procedural accuracy, and mathematical communication. These recommendations are consistent with the diagnostic pattern identified in the present study but should be understood as instructional implications rather than experimentally tested interventions.

Overall, the findings suggest a tendency for problem-solving difficulties to shift from conceptual and representational difficulties at lower MCTL levels toward procedural and communicative difficulties at higher MCTL levels. This does not mean that higher creative thinking eliminates mathematical errors. Rather, the nature of the remaining errors appears to change. The central contribution of the study is therefore not a claim that mathematical creativity causes fewer errors, but the identification of a case-based diagnostic pattern in which MCTL and NEA provide complementary information about students' mathematical thinking and problem-solving processes. This finding extends previous NEA research by linking the location of problem-solving difficulties to different characteristics of mathematical creative thinking, particularly the role of transformation in the development of flexibility and novelty.

CONCLUSION

This study identified a case-based diagnostic pattern of mathematical creative thinking and problem-solving difficulties among sixth-grade elementary school students. Students at lower MCTL levels tended to experience difficulties in comprehension and transformation, whereas students at higher MCTL levels generally demonstrated adequate understanding and transformation but still encountered procedural and encoding errors. Transformation emerged as a critical intersection between mathematical creative thinking, particularly flexibility and novelty, and the stages of Newman Error Analysis. The main contribution of this study is the integration of MCTL and NEA to provide a more comprehensive diagnostic profile that identifies both students' creative-thinking characteristics and the location of their problem-solving difficulties. This profile has practical implications for differentiated instructional scaffolding: students at MCTL 0-1 need support in understanding and representing problems, MCTL 2 needs opportunities to develop alternative strategies, while

MCTL 3-4 requires greater emphasis on verification, procedural accuracy, metacognition, and mathematical communication. Future research should involve more diverse elementary-school populations, mathematical topics, and learning contexts to further examine and validate these diagnostic patterns.

ACKNOWLEDGEMENTS

The authors express their gratitude to the Institute for Research and Community Service (LPPM), Manado State University, for the support and funding provided through the Internal Research Grant of Manado State University. This support made an important contribution to the implementation of the research and the completion of this article. The authors also thank the Principal and Grade VI teacher of St. Clara Catholic Elementary School in Tomohon for providing permission to conduct the research, as well as all parties who provided support and contributions throughout the research process.

REFERENCES

- Assmus, D., & Fritzlar, T. (2022). Mathematical Creativity and Mathematical Giftedness in the Primary School Age Range: An Interview Study on Creating Figural Patterns. *ZDM – Mathematics Education*, 54(1), 113–131. <https://doi.org/10.1007/s11858-022-01328-8>
- Bicer, A. (2021). Multiple Representations and Mathematical Creativity. *Thinking Skills and Creativity*, 42, 100960. <https://doi.org/10.1016/j.tsc.2021.100960>
- Bruhn, S., & Lüken, M. M. (2023). A Framework to Characterize Young School Children's Individual Mathematical Creativity—An Integrative Review. *Asian Journal for Mathematics Education*, 2(1), 116–144. <https://doi.org/10.1177/27527263231163267>
- De Vink, I. C., Willemsen, R. H., Lazonder, Ard. W., & Kroesbergen, E. H. (2022). Creativity in Mathematics Performance: The Role of Divergent and Convergent Thinking. *British Journal of Educational Psychology*, 92(2), 484–501. <https://doi.org/10.1111/bjep.12459>
- Elgrably, H., & Leikin, R. (2021). Creativity as a Function of Problem-Solving Expertise: Posing New Problems Through Investigations. *ZDM – Mathematics Education*, 53(4), 891–904. <https://doi.org/10.1007/s11858-021-01228-3>
- Fatawu, I. A., Alhassan, M. N., & Darko, I. O.-. (2023). Analysis of Senior High School Student's Errors in Solving Word Problems Using Newman's Error Analysis (NEA) Procedure. *International Journal Of Mathematics And Computer Research*, 11(8), 3685–3693. <https://doi.org/10.47191/ijmcr/v11i8.09>
- Firdaus, A., Subanji, S., & Hafizh, M. (2026). An Analysis of Grade XI Students' Errors in Solving Statistical Problems Based on Newman Error Analysis (NEA) Theory. *PRISMA*, 15(1), 34–47. <https://doi.org/10.35194/jp.v15i1.5845>
- Jupri, A., & Drijvers, P. (2016). Student Difficulties in Mathematizing Word Problems in Algebra. *EURASIA Journal of Mathematics, Science and Technology Education*, 12(9). <https://doi.org/10.12973/eurasia.2016.1299a>
- Kartono, K., & Suciawati, V. (2025). Mapping Newman's Error Analysis to Mathematical Creative Thinking: A Diagnostic Tool for Identifying Cognitive Disruptions. *Jurnal Pendidikan MIPA*, 26(4), 2651–2676. <https://doi.org/10.23960/jpmipa.v26i4.pp2651-2676>
- Lien Malinda, Sufyani Prabawanto, & Rusdiono Muryanto. (2026). Analysis of Students' Errors in Solving Addition and Subtraction Problems Using the Newman Technique. *Jurnal Cakrawala Pendas*, 12(2), 276–288. <https://doi.org/10.31949/jcp.v12i2.17720>
- Lu, X., & Kaiser, G. (2022). Creativity in Students' Modelling Competencies: Conceptualisation and Measurement. *Educational Studies in Mathematics*, 109(2), 287–311. <https://doi.org/10.1007/s10649-021-10055-y>
- Maghfiroh, D., & Wahyuningsih, R. (2024). Elementary School Students' Ability to Solve Mathematical Story Problems. *JENIUS (Journal of Education Policy and Elementary Education Issues)*, 5(2), 106–120. <https://doi.org/10.22515/jenius.v5i2.9372>
- Ndolu, S. W., & Lalang, A. R. (2023). Studi Literatur: Penilaian Pembelajaran Matematika yang Mendukung Kemampuan Berpikir Kreatif. *Journal of Character and Elementary Education*, 1(2), 30–39. <https://doi.org/10.35508/jocce.v1i2.10015>

- Newman, M. A. (1977). An Analysis of Sixth-Grade Pupil's Error on Written Mathematical Tasks. *Victorian Institute for Educational Research Bulletin*, 39, 31–43.
- Niluh Lisa Arianti, Waode Ekadayanti, & Ashari Usman. (2025). An Analysis Of Fifth-Grade Students' Difficulties In Solving Fraction Problems Based On Newman's Error Analysis. *Journal of Education and Learning Sciences*, 5(2), 382–402. <https://doi.org/10.56404/jels.v5i2.434>
- Ramadhani, S., Ismailmuza, D., Sukayasa, S., & Meinarni, W. (2024). Analysis of Students' Errors in Solving Story Problems Based on Newman's Error Analysis (NEA) on the Subject Matter of Linear Program in View of Students' Mathematical Ability. *Prisma Sains: Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, 12(1), 110. <https://doi.org/10.33394/j-ps.v12i1.10310>
- Rashid, Y., Rashid, A., Warraich, M. A., Sabir, S. S., & Waseem, A. (2019). Case Study Method: A Step-by-Step Guide for Business Researchers. *International Journal of Qualitative Methods*, 18, 1609406919862424. <https://doi.org/10.1177/1609406919862424>
- Sa'dijah, C., Fitri Handayani, U., Sisworo, Sudirman, Susiswo, Tejo Dwi Cahyowati, E., & Sa'diyah, M. (2019). The Profile of Junior High School Students' Mathematical Creative Thinking Skills in Solving Problem through Contextual Teaching. *Journal of Physics: Conference Series*, 1397(1), 012081. <https://doi.org/10.1088/1742-6596/1397/1/012081>
- Schoevers, E. M., Kroesbergen, E. H., & Kattou, M. (2020). Mathematical Creativity: A Combination of Domain-general Creative and Domain-specific Mathematical Skills. *The Journal of Creative Behavior*, 54(2), 242–252. <https://doi.org/10.1002/jocb.361>
- Silver, E. A. (1997). Fostering Creativity Through Instruction Rich in Mathematical Problem Solving and Problem Posing. *Zentralblatt Für Didaktik Der Mathematik*, 29(3), 75–80. <https://doi.org/10.1007/s11858-997-0003-x>
- Singh, P., Rahman, A. A., & Hoon, T. S. (2010). The Newman Procedure for Analyzing Primary Four Pupils Errors on Written Mathematical Tasks: A Malaysian Perspective. *Procedia - Social and Behavioral Sciences*, 8, 264–271. <https://doi.org/10.1016/j.sbspro.2010.12.036>
- Siswono, T. Y. E. (2011). Level of Student's Creative Thinking in Classroom Mathematics. *Educational Research and Reviews*, 6(7), 548–553.
- Töllner, F., Kuhl, P., & Besser, M. (2025). Formative Assessment in Inclusive Mathematics Education in Secondary Schools: A Systematic Review. *Education Sciences*, 15(5), 577. <https://doi.org/10.3390/educsci15050577>
- Utami, W. B., Dewi, A. P., & Widodo, S. A. (2024). Students' Errors in Problem-Solving Reviewed From the Perspective of Math Resilience. *JOHME: Journal of Holistic Mathematics Education*, 8(1), 59. <https://doi.org/10.19166/johme.v8i1.8230>
- Van Den Berg, M., Harskamp, E. G., & Suhre, C. J. M. (2016). Developing Classroom Formative Assessment in Dutch Primary Mathematics Education. *Educational Studies*, 42(4), 305–322. <https://doi.org/10.1080/03055698.2016.1193475>
- Wang, H., & Star, J. R. (2023). Investigating Algorithm-Oriented Flexibility and Structure-Informed Flexibility in Mathematics Learning. *Asian Journal for Mathematics Education*, 2(1), 16–41. <https://doi.org/10.1177/27527263231163593>