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Cognitive Obstacles and Textbook Praxeological Limitations Underlying The Low Mathematical Creative Thinking of Elementary Students

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Abstract: The importance of mathematical creative thinking skills in the 21st century differs from the creative thinking skills of current elementary school students. A 5th-grade student at a public elementary school in West Bandung Regency, Indonesia, has low levels of creative thinking. This study aimed to analyze fifth-grade students' mathematical creative thinking skills during problem-solving, identify the underlying causes of their low performance, and propose instructional strategies to foster their development. The method used was qualitative, with a descriptive–interpretive design. Participants comprised 15 fifth-grade students from a single public elementary school in West Bandung Regency, Indonesia, selected via convenience sampling. The primary research instrument was the researcher, supported by a creative thinking skills test instrument and an interview guide. The results of this study are 1 student had a high level of creative thinking skills able to achieve indicators of flexibility, originality, awareness, and elaboration; 1 student had a moderate level of creative thinking skills able to achieve indicators of originality, awareness, and elaboration; and 13 students had low levels of creative thinking skills able to achieve indicators of fluency/originality/awareness/originality and awareness/ had not even achieved all indicators of mathematical creative thinking skills. Further analysis revealed fundamental misconceptions, particularly confusion between area and perimeter, fragmented procedural reasoning, and limited metacognitive verification during mathematical problem-solving. To improve students' creative thinking skills, it is recommended to use learning activities oriented towards problem- and project-based learning, realistic mathematics, and mathematics textbooks that also support the problem-solving process. In conclusion, most fifth-grade students demonstrate low levels of mathematical creative thinking skills, shaped by conceptual misconceptions and limited metacognitive regulation, underscoring the importance of targeted, conceptually grounded, and problem-oriented instructional interventions.

Keywords: creative thinking skills, mathematics, problem-solving.

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INTRODUCTION

The education curriculum in Indonesia focuses on mathematics, problem-solving, and the development of effective problem-solving strategies. The Pancasila Student Profile also emphasizes the importance of critical and creative reasoning, which must be integrated into elementary mathematics instruction (Wibowo et al., 2025). Therefore, strengthening mathematical creative thinking skills (CTS) should begin in elementary school as a foundation for students to navigate the complexities of challenges in both learning and everyday life in an adaptive and meaningful way.

This ability to think mathematically in the 21st century includes thinking creatively mathematically. Mathematical creative thinking involves solving problems innovatively, structuring thinking, and expressing ideas (Nufus et al., 2024). Mathematical creative thinking is the ability to solve mathematical problems and to develop conceptual relationships to bring together important ideas in mathematics (Bicer et al., 2024). Mathematical CTS are evident when proposing new and diverse concepts in solving mathematical word problems (Suherman & Vidákovich, 2025). Thus, mathematical CTS is a person's proficiency in developing novel approaches to solving mathematical word problems.

Mathematical CTS is related to the problem-solving process (Anggorowati et al., 2024; Zakaria et al., 2025). Mathematical CTS is necessary when a problem lacks a direct solution or requires a non-simple approach; it involves many complex constraints and calls for new approaches or more efficient simplifications (Olsson & Granberg, 2024). Problems in the CTS must be open-ended, as creative thinking involves fluent, flexible, original, and elaborative thinking, along with awareness, to generate diverse problem-solving solutions (Parlak et al., 2024). International educational frameworks such as those promoted by the Organization for Economic Co-operation and Development and the National Council of Teachers of Mathematics also emphasize creative mathematical reasoning, multiple-solution strategies, and conceptual understanding as core competencies for elementary learners (Barbot & Kaufman, 2025). These perspectives highlight that mathematical CTS is a central component of the globally required meaningful mathematical literacy.

CTS in students will develop if they have several characteristics or supportive conditions, such as high curiosity, learning independence, math package books, and teachers' teaching strategies (Setyaedhi et al., 2025). Problem-solving activities that demand mathematical CTS occur when students apply mathematical concepts in new situations and find multiple solutions to mathematical problems (Suryanti et al., 2024). Mathematical problem-solving helps students think in a structured way and understand the relationships between concepts (Rehman et al., 2025). Several countries, such as Finland, Singapore, and Australia, explicitly integrate creative problem-solving and mathematical CTS into their elementary mathematics curricula. Learning tasks are designed to be exploratory, open-ended, and connected to real-life contexts so that students actively construct knowledge and develop flexible thinking (Nieminen et al., 2022). This international curriculum orientation further reinforces the urgency of cultivating mathematical CTS from early schooling. Therefore, mathematical creative thinking plays a crucial role in fostering students' ability to think innovatively and critically in mathematics.

In addition to cognitive and instructional factors, the development of mathematical CTS is also influenced by the quality of mathematics textbooks used in classrooms. In Indonesia, mathematics textbooks are widely utilized as primary learning resources by teachers and students (Fardian et al., 2025). The structure of tasks, techniques, and conceptual explanations presented in textbooks determines how students construct mathematical knowledge and explore problem-solving strategies. From a praxeological perspective (Chandra et al., 2025), incomplete or limited representations of tasks and techniques in textbooks may restrict students' opportunities to develop creative and flexible thinking in mathematics. Experts consistently argue that mathematical creative thinking is a key predictor of students' long-term mathematical success, adaptive reasoning, and ability to transfer knowledge to unfamiliar situations (Nilimaa, 2023; Niu et al., 2022). Without well-developed CTS, students tend to rely on routine procedures and have difficulty with non-routine or contextual mathematical problems. Hence, strengthening CTS at the elementary level is essential to building a strong foundation for higher-level mathematical learning.

However, the importance of mathematical CTS is not yet reflected in elementary school students' actual abilities (Kattou et al., 2026). Results from international assessments such as PISA indicate that Indonesian elementary and lower secondary students still perform relatively poorly in problem-solving and creative mathematical thinking, particularly in solving contextual word problems (OECD, 2023). Recent trends in several cities and regencies in Indonesia also indicate that students' creative thinking in mathematical problem-solving remains in the low-to-moderate range (Rahayuningsih et al., 2023; Surmilasari et al., 2022; Sutarni et al., 2023). Similar findings were reported in several elementary schools in West Java, including the West Bandung Regency, where students demonstrated limited originality, flexibility, and fluency in solving mathematical word problems (Samsudin et al., 2025). Many students rely on single-solution procedures and struggle to interpret problem contexts, generate alternative ideas, and connect mathematical concepts. Consequently, key indicators of mathematical CTS—originality, fluency, flexibility, elaboration, and awareness—are not optimally developed. Therefore, it is necessary to conduct a deeper analysis of fifth-grade students' mathematical CTS in the problem-solving process. Accordingly, this study addresses the following research questions: (1) What are the mathematical CTS of fifth-grade students in the problem-solving process? (2) What are the underlying causes of students' low mathematical CTS? and (3) What strategies can foster the growth and development of students' mathematical CTS?

■ METHOD

Research Design

This study employed a qualitative research method with a descriptive–interpretive design. It aimed to provide a comprehensive understanding of students' mathematical CTS. In addition, the study generated conceptual insights into how CTS are manifested and constrained within the mathematical problem-solving process and the praxeological structure of textbooks (Hall & Liebenberg, 2024).

Data Search Procedures

The research procedure began with administering the CTS test to students, followed by interviews with selected students and the teacher. The mathematics textbook used in the classroom was also analyzed using praxeological theory to examine aspects of tasks, techniques, technology, and theory (Chandra et al., 2025). The overall research procedure followed the data processing framework proposed by Li and Zhang (2022), which includes data selection, data reduction, data presentation, and data verification.

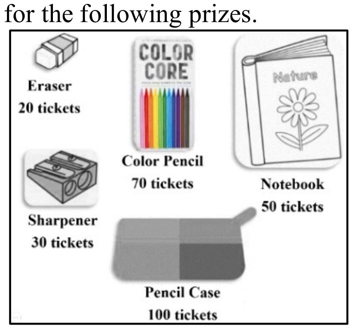
Participants Criteria

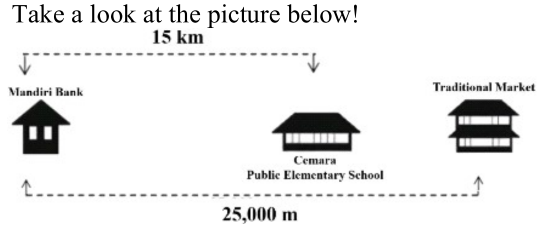
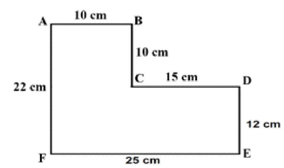
This study was conducted in a public elementary school in West Bandung Regency, West Java Province, Indonesia. The participants were 15 fifth-grade students selected through convenience sampling in a single school. From these participants, three students representing low, moderate, and high levels of CTS were selected for in-depth interviews. In addition, one fifth-grade elementary school teacher was interviewed to obtain information about teaching strategies and the mathematics textbooks used in the classroom. This study is limited by a small sample size (N = 15) and by convenience sampling from a single school, which restricts the generalizability of the findings. Therefore, the results should be interpreted as context-specific qualitative insights into students' mathematical CTS within the studied environment. Despite its limited external validity, the study offers valuable exploratory and conceptual directions for future research with larger, more diverse samples.

Data Analysis

Data analysis in this study began with an examination of the usability of the research instruments used to capture students' mathematical CTS. The primary research instrument was the researcher, supported by a CTS test instrument and an interview guide. The CTS test instrument consisted of five essay items related to circumference and area of rectangles, least common multiple, reduction in number operations, distance problems, and the combined area of a square and a rectangle. The CTS test instrument was validated through expert judgment involving mathematics education experts, education practitioners, and professional elementary school teachers. Their evaluations ensured the instrument's content validity with respect to relevance, clarity, and suitability for assessing CTS. The CTS indicators used in this study included fluency, flexibility, originality, awareness, and elaboration (Altiner, 2025), as presented in Table 1.

Table 1. Indicators of CTS

No. of Items	Indicators of CTS	Description	Test
1	Fluency	The ability to produce many correct and relevant answers to the given problem.	Mr. Dodi has a wire that is 16 meters long. The wire is used to fence a rectangular duck pond. a. Write down the various possible sizes of the length and width of the pool! b. What is the largest possible size of the rectangular pool?
2	Flexibility	The ability to use various approaches or different ways of thinking in solving problems.	The following is Asep's extracurricular schedule for August 2024.  **Figure 1.** Asep's extracurricular activity schedule in august 2024 Mr. Asep participates in futsal extracurriculars every 3 days, scouts every 5 days, and basketball every 6 days. On what day does Asep participate in scouting extracurricular activities as well as basketball?
3	Originality	The ability to produce uncommon answers, rarely used by most students, but still correct and logical.	Several tickets from the game results can be redeemed for the following prizes.  **Figure 2.** Problem context of ticket-based prize redemption

			Mr. Budi has 200 tickets. He had exchanged his ticket for a color pencil. What other prizes can Budi redeem to run out his tickets?
4	Awareness	The ability to understand situations, identify important information, and formulate relevant problems or questions.	Take a look at the picture below!  **Figure 3.** Illustration of the distance between cemara public elementary school and the traditional market What is the distance from Cemara Public Elementary School to the Traditional Market?
5	Elaboration	The ability to develop answers in a detailed, clear, and structured manner.	Look at the picture below!  **Figure 4.** Composite plane Figure for Area Calculation Calculate the total area of the plane geometry above!

Source: Developed by the authors based on Altiner (2025)

To evaluate students' performance on the mathematical CTS test, an integrated problem-solving scoring rubric was employed. This rubric was designed to ensure consistent, objective, and indicator-specific assessment across all dimensions of mathematical CTS. The scoring criteria ranged from 0 to 4, representing varying levels of completeness, accuracy, appropriateness of solution strategies, and the quality of explanation. In addition, the rubric incorporates analytic criteria for each CTS indicator, namely fluency, flexibility, originality, awareness, and elaboration, to provide a more detailed evaluation of students' responses. The detailed scoring rubric is presented in Table 2.

Following the scoring process, qualitative data were collected to provide deeper insight into students' mathematical CTS performance and to

Table 2. Integrated problem-solving and mathematical CTS scoring rubric

Score	General Criteria Adapted from Wei (2025)	Fluency	Flexibility	Originality	Awareness	Elaboration
4	The answer is completely correct; the solution strategy is appropriate and logically structured; calculations are accurate; and the explanation is clear and comprehensive.	Generates ≥5 correct and varied responses.	Uses ≥2 appropriate, distinct strategies.	Produces unique/uncommon and correct solutions.	Identifies all relevant information accurately and interprets the problem correctly.	Provides a complete, detailed, and well-structured explanation.

3	The solution strategy is generally correct, but minor errors appear in the calculations, or the explanation is incomplete.	Generates 3–4 correct responses.	Uses one appropriate strategy with limited variation.	Produces correct but common solutions.	Identifies most relevant information with minor errors.	Provides a fairly clear but less detailed explanation.
2	Partial understanding is demonstrated; the strategy is less appropriate or incomplete; and significant errors occur in calculations or reasoning.	Generates 1–2 correct responses.	Uses one limited or partially correct strategy.	Produces standard or partially correct solutions.	Identifies only part of the relevant information.	Explanation is incomplete and less structured.
1	A minimal attempt is shown, with an inappropriate strategy or unclear reasoning that does not lead to a correct solution.	Responses are mostly incorrect or not varied.	Strategy is unclear or inappropriat e.	No evidence of originality.	Misinterprets the problem.	Very limited explanation
0	No meaningful response is provided, or the answer is irrelevant to the problem.	No valid responses.	No relevant strategy used.	No valid solution.	No understanding shown.	No explanation provided.

reveal the underlying factors influencing their problem-solving difficulties. The interview guide was semi-structured, enabling in-depth exploration while maintaining consistency across guiding questions. Student interviews focused on identifying difficulties in understanding mathematical word problems and exploring students' cognitive and metacognitive processes during problem-solving. The interviews examined how students interpreted the problem context by identifying the given and required information, as well as their understanding of linguistic elements such as words, phrases, and sentence structures, including the coherence between statements and questions. Furthermore, the interviews explored students' ability to develop solution plans, select appropriate mathematical strategies, and execute these strategies systematically to obtain a solution. Particular attention was given to how students articulated their reasoning during the solution process and how they monitored their progress. In addition, the interviews investigated students' ability to verify and evaluate their answers, including their awareness of possible errors and consideration of alternative solutions. Students' prior experiences with mathematical word problems were also explored to understand their familiarity with similar tasks. The interviews further examined students' efforts to overcome difficulties encountered during problem-solving. Finally, students' mastery of basic arithmetic operations, including addition, subtraction, multiplication, and division, was assessed as a foundational component supporting their overall problem-solving performance. Teacher interviews explored teaching experience; instructional constraints in mathematics learning; instructional strategies and methods; experiences providing mathematical word problems; students' responses; and learning difficulties, as well as proposed solutions to overcome these difficulties. Interviews were conducted with three selected students and one teacher to explore students' CTS and problem-solving processes. The indicators of students' problem-solving abilities included understanding mathematical problems, planning strategies, implementing strategies, and reviewing problem-solving steps (Wei, 2025).

■ RESULT AND DISCUSSION

Mathematical CTS of Fifth-Grade Students in the Problem-Solving Process

The data were presented descriptively to provide an overview of the mathematical CTS of 5th-grade elementary school students, as shown in Table 3.

Table 3. Overview of mathematical CTS of 5th-grade students

Number of Students	Minimum Score	Maximum Score	Mean
15	0	80	30.67

Based on Table 3 above, the minimum score for the mathematical CTS was 0, and the maximum was 80. The average score of mathematical CTS was 30.67. Next, the mean scores of the mathematical CTS by indicator for 5th-grade students (N = 15) are presented in Figure 5.

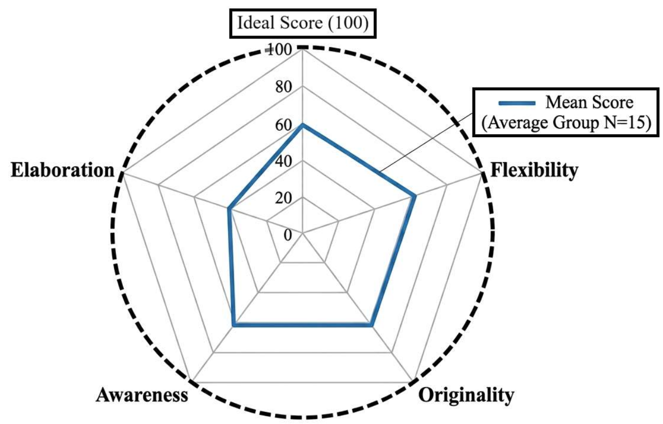


Figure 5. Mean scores of mathematical CTS by indicator for 5th-grade students (N = 15)

Based on Figure 5, the average scores for mathematical CTS on the fluency and flexibility indicators were 60, indicating that students, on average, demonstrated a moderate level of performance in these areas. This mean score represents the overall tendency of students' performance and should not be interpreted as the number or proportion of students achieving a specific score. Similarly, the average scores for the originality and awareness indicators were also 60, suggesting that students, in general, exhibited moderate abilities in generating unique ideas and understanding problem situations. In contrast, the average score for the elaboration indicator was 20, indicating a low level of performance and suggesting that students had limited ability to develop and elaborate their ideas in detail. Based on the classification used in this study, CTS scores are categorized into three levels: high (67–100), moderate (34–66), and low (0–33). Accordingly, fluency, flexibility, originality, and awareness fall into the moderate category, while elaboration is in the low category. Furthermore, the analysis of the mathematical CTS of 5th-grade students was conducted by reviewing problem-solving. Analysis referred to the stage of solving mathematical problems to determine students' mathematical CTS through the stages of understanding problems, making a solution plan, implementing solution strategies, and reviewing the solution steps.

Fluency Indicator

Based on the CTS fluency indicator, students generate many ideas and answers, enabling them to obtain various solutions when solving problems related to the area of a rectangle. The fluency indicator is in Problem 1 on circumference and rectangular area. Of the 15 students who took the CTS test, only 1 answered Problem 1 correctly. The other 14 students encountered obstacles in solving the problem. Student 1's response demonstrating the fluency indicator is presented below.

Problem 1. Mr. Dodi has a wire that is 16 meters long. The wire is used to fence a rectangular duck pond.

a. Write down the various possible sizes of the length and width of the pool!
b. What is the largest possible size of the rectangular pool?

Student 1's Response

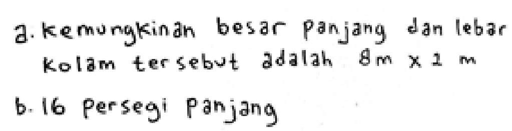


Figure 6. Student 1's Response to those who Completed the Mathematical CTS Test on the Fluency Indicator

Translate: *a. Most likely the length and width of the pond were 8 m × 2 m. b. There were 16 rectangles.*

Based on Figure 6 above, Student 1 had difficulty solving Problem 1. Student 1 proposed a strategy to solve the problem, namely:

"*Answer 1a, 8 m × 2 m was obtained from length × width = 16 meters. This means that the size was 8 m long and 2 m wide. Then answer 1b was obtained from an area of 16 meters, namely 16 rectangles*." (Interview with Student 1).

Based on Student 1's strategy for solving Problem 1, at the stage of understanding the problem, Student 1 was unable to understand the sentence "*The wire was used to fence a rectangular duck pond*," indicating difficulty at the semantic comprehension and problem representation stages in mathematical cognition (Agustin et al., 2024). The command sentence pointed to a "*Write down the various possible sizes of the length and width of the pond!*" and the problem sentence point b was "*What is the largest possible size of the rectangular pool?*".

From a cognitive perspective, this reflects a failure to construct an appropriate situational model, in which the contextual cue "fence" should activate the concept of perimeter, but instead remains unintegrated into the student's mathematical representation. This misalignment suggests a breakdown in the transition from linguistic processing to mathematical modeling, a critical stage in word-problem solving. Furthermore, at the stage of planning a problem-solving strategy in point a, Student 1 planned a strategy using the logic that the 16 meters of information in the problem represented the area of a rectangle, reflecting inappropriate schema activation in which an area schema was retrieved instead of the required perimeter schema (Danesi, 2025). This indicates not merely a conceptual error but a deeper issue of schema dominance, in which familiar formulas override contextual reasoning. Such behavior is characteristic of students with low conceptual control, who rely on procedural recall without validating its relevance to the problem structure. So, Student 1 used the formula for the area of a rectangle: area = length × width. As for the problem-solving strategy at point b, Student 1 rewrote the numerical information in the problem because they thought 16 meters represented a rectangular area, demonstrating surface-level processing rather than deep conceptual understanding (Orhani, 2025). Next, at the stage of carrying out the problem-solving strategy point a, Student 1 found a length of 8 m and a width of 2 cm, obtained from the length × width = 16 m. As for the stage of implementing the problem-solving strategy (point b), Student 1 wrote the numerical information for the problem: 16 rectangles.

The response "16 rectangles" further indicates a lack of reasoning about optimization, as the student fails to engage with the mathematical idea of maximizing area under a fixed perimeter constraint. This suggests that fluency, in this case, is not only limited in quantity (few ideas generated) but also in quality (lack of meaningful variation and generalization). Furthermore, during the review of completion steps, Student 1 did not do so, indicating limited metacognitive monitoring and evaluation during mathematical problem-solving (Susanna et al., 2026). The absence of verification reflects weak metacognitive regulation, particularly in monitoring and error detection. This confirms that the student's difficulty is systemic, spanning across representation, strategy selection, execution, and reflection.

The reason Student 1 had difficulty solving Problem 1 was that they did not fully understand the problem's context, did not understand the rectangular area material, and rarely practiced answering mathematical word problems, which can be interpreted as epistemological and didactical learning obstacles related to weak conceptual grounding and limited exposure to contextual problems (Hendriyanto et al., 2024). More broadly, this case illustrates how low CTS fluency is associated with constrained idea generation, rigid schema use, and limited cognitive flexibility, which collectively hinder the development of meaningful mathematical problem-solving competencies. This shows that Student 1's difficulties align with the research of Yulaichah et al. (2024), which state that students' mathematical CTS on fluency indicators with low category levels tend not to be fluent in getting various solutions from problems in mathematical word problems because students have difficulty understanding problems in math problems, determining various mathematical problem-solving strategies, and implementing these problem-solving strategies. To further deepen the qualitative analysis and identify recurring patterns across students' responses, this study develops a thematic matrix that maps specific types of errors to each student and CTS indicator. This matrix enables a more systematic identification of cognitive and conceptual difficulties beyond individual case descriptions.

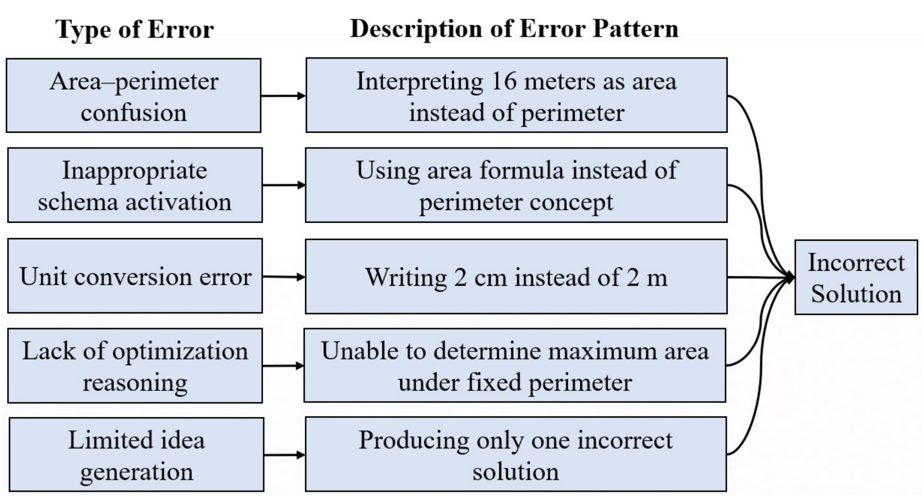


Figure 7. Thematic matrix of student 1's errors in the fluency indicator of mathematical CTS

The thematic matrix in Figure 7 reveals that Student 1's errors are not isolated but form a consistent pattern across multiple dimensions of mathematical cognition, including area–perimeter confusion as a fundamental conceptual misunderstanding, inappropriate schema activation reflecting cognitive rigidity in strategy selection, unit conversion errors indicating weaknesses in mathematical precision, and the absence of optimization reasoning pointing to limited higher-order thinking related to generalization and maximization. Furthermore, the pattern of limited idea generation shows that the student's fluency is constrained both in quantity and quality, reinforcing the interpretation that low CTS fluency is associated with restricted cognitive flexibility and an inability to explore alternative solution pathways; therefore, by systematically mapping these errors, the analysis extends beyond descriptive evaluation toward a more structured understanding of how specific cognitive breakdowns contribute to students' difficulties in mathematical problem-solving.

Flexibility Indicator

Based on the CTS flexibility indicator, students generate a variety of ideas using different approaches to solve a problem. The flexibility indicator is found in Problem 2 of the material on the least common multiple. Of the 15 students who worked on Problem 2 of the CTS test, only 1 student answered it correctly. The other 14 students experienced obstacles and difficulties in answering problems. Student 2's response demonstrating the flexibility indicator is presented below. *Problem 2.* The following is Asep's extracurricular schedule for August 2024.

Figure 8. Asep's extracurricular activity schedule in august 2024 (reproduced from Figure 1)

Mr. Asep participates in futsal extracurriculars every 3 days, scouts every 5 days, and basketball every 6 days. On what day does Asep participate in scouting extracurricular activities as well as basketball?

Student 2's Response

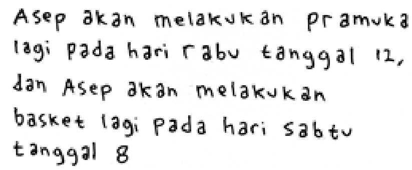


Figure 9. Student 2's response to those who completed the mathematical CTS test on the flexibility indicator

Translate: *Mr. Asep will do scouting again on Wednesday, the 12th, and basketball again on Saturday, the 8th.*

Based on Figure 9 above, Student 2 had difficulty solving Problem 2. Student 2 proposed a strategy to solve the problem, namely:

"*Mr. Asep answers that he will do another scouting on Wednesday, the 12th, because 5 days after the 7th, since Asep did the scouting, namely the 12th, while Asep will do basketball again on Saturday, the 8th, because 6 days after the 2nd, since Asep did basketball, which is the 8th*". (Interview with Student 2).

Based on Student 2's strategy for solving Problem 2, at the stage of understanding the problem, Student 2 was unable to understand the sentence of the problem, namely, "*On what day does Mr. Asep participate in scouting extracurriculars as well as basketball?*", indicating difficulty in semantic comprehension and problem representation within mathematical word-problem processing (Wong & Yip, 2023).

From a cognitive standpoint, this reflects a failure to construct a relational representation of periodic events, where the problem requires synchronizing multiple cycles rather than isolated counting processes. The student's interpretation remains local and sequential, rather than global and relational. Furthermore, at the stage of planning a problem-solving strategy, Student 2 planned a strategy to determine the date Mr. Asep would participate in scouting extracurriculars, using the logic of counting the next 5 days after August 7, 2024. As for planning a strategy to determine when Mr. Asep will participate in basketball extracurriculars, consider the next 6 days after August 2, 2024, and provide procedural reasoning that is not connected to the conceptual structure of the least common multiple (Setlur et al., 2024). This indicates procedural fixation, in which the student relies on a single linear counting strategy rather than flexibly shifting to a multiplicative or least common multiple framework. Such rigidity demonstrates limited cognitive flexibility, a core component of CTS, particularly in coordinating multiple mathematical representations. Next, during the problem-solving stage, Student 2 calculates 7 + 5 = 12 to determine the date Asep participated in the basketball extracurricular, and then calculates 2 + 6 = 8. So, Mr. Asep will do scouting again on Wednesday, August 12, 2024, and basketball again on Saturday, August 8, 2024, reflecting fragmented numerical processing rather than the integrated relational reasoning required to synchronize periodic events. This fragmented numerical processing shows that the student fails to integrate the two sequences into a unified temporal structure, which is essential for identifying coincidence points in periodic problems. In this sense, flexibility is constrained not only by strategy selection but also by the inability to transform representations across mathematical domains (arithmetic to number theory). Furthermore, during the review of completion steps, Student 2 did not review them, indicating limited metacognitive monitoring and verification during problem-solving (Baºokçu & Güzel, 2022). The absence of reflective comparison between alternative strategies further limits flexibility, as students do not evaluate or revise their approach when inconsistencies arise.

The reason Student 2 has difficulty solving Problem 2 is that they do not understand the full context of the sentence in the problem, do not understand the least common multiple material, and rarely practice answering mathematical word problems, which can be interpreted as epistemological and didactical learning obstacles related to weak conceptual understanding of periodicity and limited exposure to contextual mathematical tasks (Hendriyanto et al., 2024). This aligns with research by Lestari et al. (2024), which found that students in the low category on the flexibility indicator tend to have difficulty generating ideas across various approaches. This occurs because students face many difficulties in understanding math problems, generating ideas, finding alternative problem-solving strategies, and determining which to use. To further deepen the qualitative analysis, a thematic matrix is developed to systematically map Student 2's specific error patterns in the flexibility indicator. This approach enables a more structured identification of cognitive, procedural, and conceptual difficulties underlying the student's problem-solving performance.

The thematic matrix in Figure 10 shows that Student 2's errors form a coherent pattern reflecting limitations in relational and flexible thinking. The misinterpretation of the problem context and the lack of relational representation indicate that the student fails to conceptualize the task as a synchronization problem involving multiple cycles. Instead, the student processes each activity independently, resulting in fragmented reasoning.

Furthermore, the presence of procedural fixation demonstrates that the student relies on a familiar but inappropriate strategy, namely linear counting, rather than shifting toward a multiplicative framework such as the least common multiple. This rigidity reflects limited cognitive flexibility, particularly in transforming representations across mathematical domains. The fragmented numerical processing and failure

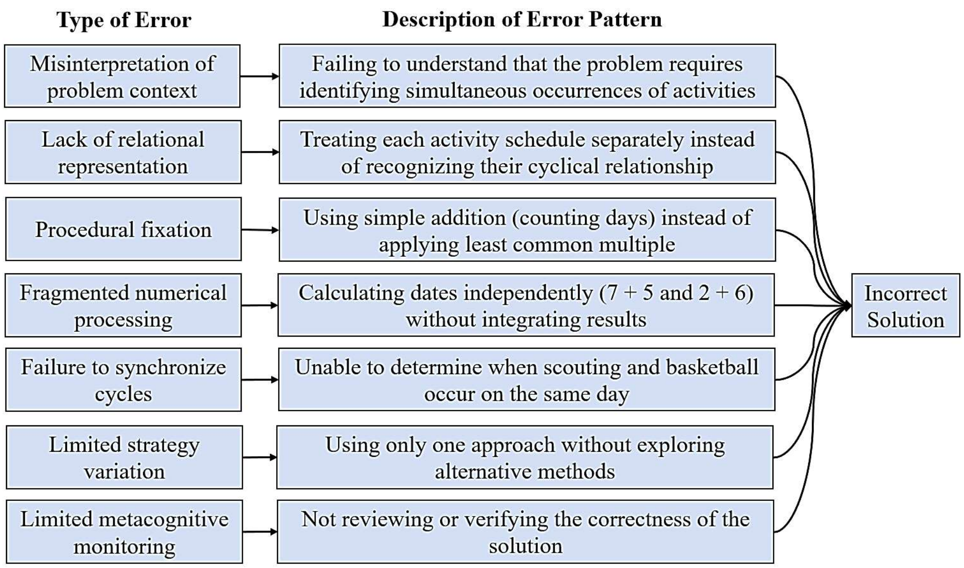


Figure 10. Thematic matrix of student 2's errors in the flexibility indicator of mathematical CTS

to synchronize cycles further confirm that the student is unable to integrate multiple pieces of information into a unified structure.

In addition, the limited strategy variation indicates that the student does not explore alternative solution pathways, which is a key characteristic of low flexibility in mathematical creative thinking. The absence of metacognitive monitoring reinforces this pattern, as the student neither evaluates nor revises the chosen strategy. Overall, these interconnected error patterns suggest that Student 2's difficulties are rooted in weak conceptual understanding of periodicity, restricted use of strategies, and limited reflective control, all of which constrain the development of flexibility in mathematical problem-solving.

Originality Indicator

Based on the CTS originality indicator, students produced unusual combinations of new ideas or products, making them up to date. The originality indicator was found in Problem 3 of the material on reducing the number of numbers. Of the 15 students who worked on Problem 3 of the CTS test, 9 students answered it correctly. The other 6 students experienced obstacles in answering problems. Student 3's response demonstrating the originality indicator is presented below. *Problem 3.* Several tickets from the game results can be redeemed for the following prizes.

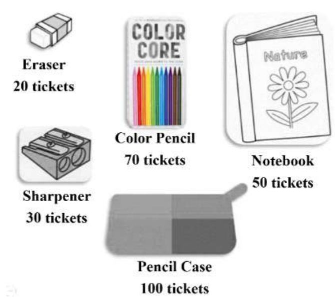


Figure 11. Problem context of ticket-based prize redemption (reproduced from figure 2)

Mr. Budi has 200 tickets. He had exchanged his ticket for a color pencil. What other prizes can Budi redeem to run out his tickets?

Student 3's Response

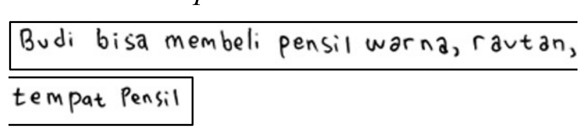


Figure 12. Student 3's response to those who completed the mathematical cts test on the originality indicator

Translate: *Mr. Budi can buy colored pencils, sharpeners, and pencil cases.*

Based on Figure 12 above, Student 3 experienced obstacles in solving Problem 3. Student 3 proposed strategies to solve these problems, namely:

"*Mr. Budi answers that he can buy colored pencils, clothes, and pencil cases because he has 200 tickets. The prizes that Budi can redeem so that his tickets run out are 200 tickets minus 70 tickets (for the prize of color pencil prizes), then minus 30 tickets (for the prize of a sharpener), then minus 100 tickets (for the prize of a pencil case).*" (Interview with Student 3).

Based on Student 3's strategy for solving Problem 3, at the stage of understanding the problem, Student 3 was unable to understand the sentence in the statement, namely, "*He has exchanged his ticket for colored pencils*," indicating difficulty in semantic interpretation and contextual representation of transactional relationships in mathematical word problems (Ntumi et al., 2026). This indicates difficulty in constructing a constraint-based representation, where the problem requires generating multiple valid combinations under a fixed total (200 tickets). The student instead reduces the task to a single deterministic pathway. Furthermore, during the planning stage of problem-solving, Student 3 planned a strategy to choose prizes by reducing 200 tickets to 70 for color pencil prizes, 30 for sharpness prizes, and 100 for pencil case prizes, reflecting procedural trial-and-error reasoning rather than the generative, combinatorial thinking associated with originality (Ario et al., 2025). This reflects convergent rather than divergent thinking, in which the student focuses on arriving at a single correct answer rather than exploring multiple possible combinations. In the context of originality, this suggests a limitation in combinatorial reasoning and idea generation. Next, at the stage of implementing the problem-solving strategy, Student 3 calculated 200 % 70 % 30 % 100 = 0. So, Mr. Budi could buy a colored pencil, a sharpener, and a pencil case, showing reliance on a single solution rather than exploring multiple possibilities (Nilimaa, 2023). Although the result is numerically valid, the solution lacks novelty and variation, which are essential dimensions of originality. The student does not attempt alternative configurations, indicating that correctness is achieved without creative exploration. Furthermore, during the review of completion steps, Student 3 did not review them, indicating limited metacognitive monitoring and evaluative control (Tay et al., 2024). The lack of metacognitive reflection prevents the student from recognizing that multiple solutions are possible, thereby constraining the emergence of original responses.

The reason Student 3 encountered obstacles in solving Problem 3 was that they did not fully understand the context of the sentence and rarely practiced answering mathematical word problems, which may be interpreted as epistemological and experiential learning obstacles that constrain the development of creative idea generation (Kandaga et al., 2022). This aligns with the research of Safaria and Agus (2024), which states that students' CTS on the indicators of originality at a low category level have difficulty producing unusual combinations of new ideas or products because they experience many difficulties in understanding problems, determining new solution strategies, and implementing these problem-solving strategies. To deepen the qualitative analysis of students' originality in mathematical creative thinking, a thematic matrix is constructed to systematically map Student 3's error patterns, enabling a more detailed examination of cognitive processes related to combinatorial reasoning, idea generation, and metacognitive control.

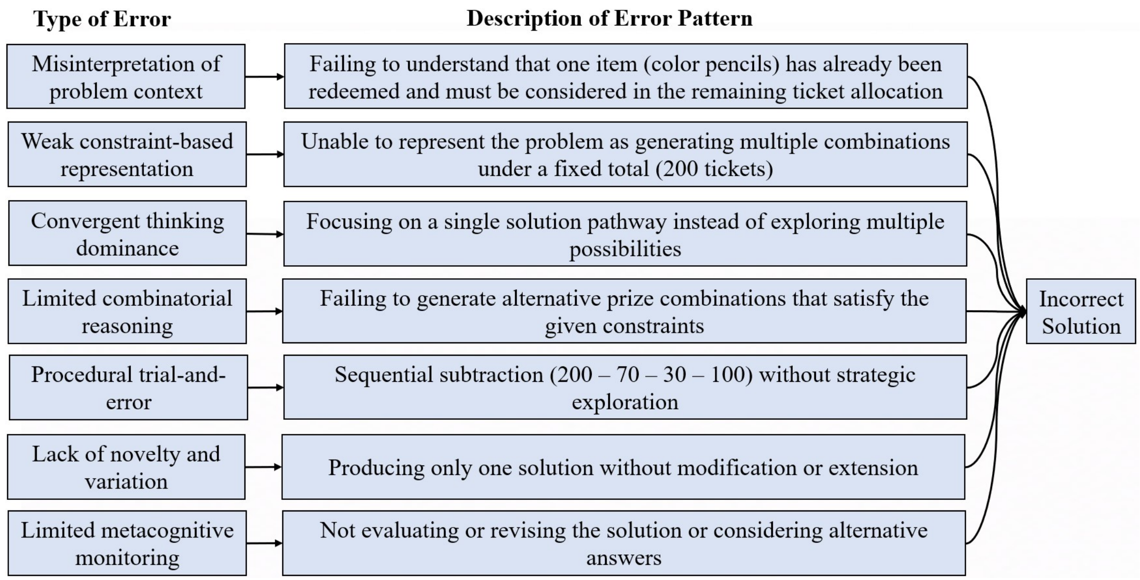


Figure 13. Thematic matrix of student 3's errors in the originality indicator of mathematical CTS

The thematic matrix in Figure 13 indicates that Student 3's errors form a consistent pattern of limited originality, characterized by weak constraint-based representation, convergent thinking dominance, and restricted combinatorial reasoning. The misinterpretation of the problem context prevents the student from accurately framing the task, while the reliance on a single deterministic pathway reflects limited generative thinking. In addition, procedural trial-and-error through sequential subtraction shows a lack of strategic exploration, yielding a numerically correct solution but lacking novelty and variation. The limited metacognitive monitoring further constrains the student's ability to evaluate and extend the solution, reinforcing a pattern of minimal idea generation. Overall, these interconnected error patterns indicate that Student 3's originality is constrained by weak conceptual representation, limited divergent thinking, and insufficient reflective control in mathematical problem-solving.

Awareness Indicator

Based on the CTS for the awareness indicator, it was able to identify and address problems in response to a situation. The awareness indicator was found in Problem 4 of the distance material. Of the 15 students who worked on Problem 4 of the CTS test, 9 students answered it correctly. The other 6 students had difficulty answering problems. Student 1's response demonstrating the awareness indicator is presented below.*Problem 4.* Take a look at the picture below!

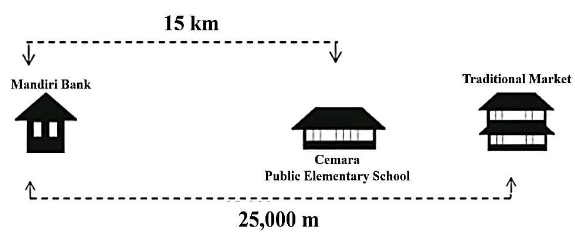


Figure 14. Illustration of the distance between cemara public elementary school and the traditional market (reproduced from figure 3)

What is the distance from Cemara Public Elementary School to the Traditional Market?

Student 1's Response

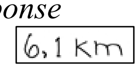


Figure 15. Student 1's response to those who completed the mathematical CTS test on the awareness indicator

Translate: *6.1 kilometers.* Based on Figure 15 above, Student 1 had difficulty solving Problem 4 in mathematics. Student 1 put forward a strategy for solving the problem, namely:

"*The answer is 6.1 kilometers because the distance from Mandiri bank to Cemara public elementary school is 15 kilometers, so the distance from Cemara public elementary school to the traditional market is around 6.1 kilometers*." (Interview with Student 1).

Based on Student 1's strategy for solving Problem 4, at the stage of understanding the problem, Student 1 was unable to understand the problem sentence "*How far is it from Cemara public elementary school to the traditional market?*" and was unable to understand the illustration in the problem picture, indicating difficulty in visual–spatial interpretation and contextual representation within mathematical cognition (Harris, 2023). This suggests a breakdown in visual–spatial reasoning, where the student fails to extract quantitative relationships from graphical representations. Awareness, in this context, requires the ability to recognize relevant information embedded in visual formats, which is not demonstrated here. Furthermore, at the stage of planning a problem-solving strategy, Student 1 did not do so, reflecting a breakdown in strategic formulation and problem-structuring processes (Lai & Lavi, 2025). This absence of strategic formulation indicates weak problem awareness, as the student does not identify what needs to be solved or how to approach it systematically. Next, during the implementation stage of the problem-solving strategy, Student 1 provided an estimate of the distance from Cemara Public Elementary School to the traditional market: 6.1 kilometers, indicating intuitive guessing rather than conceptually grounded measurement reasoning (Fischer et al., 2022). This reflects intuitive guessing rather than analytical reasoning, suggesting that the student relies on informal judgment instead of structured mathematical processes. Such behavior indicates low situational awareness in mathematical contexts. Furthermore, during the review of the solution steps, Student 1 did not engage in metacognitive monitoring and evaluative control, indicating limited metacognitive monitoring and evaluative control (Tay et al., 2024). Without reflective evaluation, the student cannot assess the plausibility of the answer, reinforcing the lack of awareness in both problem interpretation and solution validation.

The reason Student 1 experienced obstacles in solving Problem 4 was that he did not fully understand the context of the sentence, did not understand the distance material, and rarely practiced answering mathematical word problems, which can be interpreted as epistemological and experiential learning obstacles related to weak conceptual understanding and limited exposure to spatially contextualized problems. This aligns with research by Lu and Kaiser (2022), which explains that students' CTS in the awareness indicator, at a low category level, have difficulty capturing and generating problems in response to a situation because they have difficulty understanding problems, determining new problem-solving strategies, and implementing these strategies. To deepen qualitative analysis of the awareness indicator, a thematic matrix is developed to systematically identify Student 1's error patterns, particularly regarding visual–spatial reasoning, situational interpretation, and metacognitive monitoring in mathematical problem-solving.

The thematic matrix in Figure 16 indicates that Student 1's errors form a coherent pattern of limited awareness, characterized by weaknesses in visual–spatial reasoning, situational interpretation, and metacognitive monitoring. The misinterpretation of the visual context and weak visual–spatial reasoning show that the student fails to construct an accurate representation of the

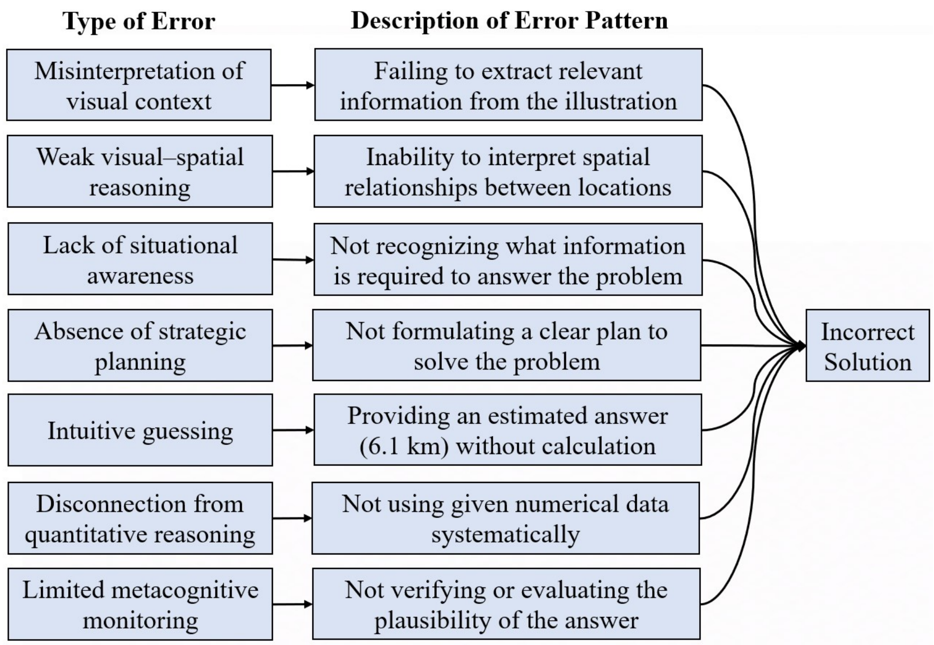


Figure 16. Thematic matrix of student 1's errors in the awareness indicator of mathematical CTS

problem from the given diagram, resulting in an inability to extract relevant quantitative relationships. This reflects a breakdown in situational awareness, in which the student does not clearly identify what needs to be solved or how to use the available information.

Furthermore, the absence of strategic planning and the reliance on intuitive guessing indicate that the student bypasses structured mathematical reasoning, instead providing an answer without a clear procedural basis. This suggests a disconnection from quantitative reasoning, as the student does not engage with the numerical data presented in the problem. The lack of metacognitive monitoring further reinforces this pattern, as the student neither evaluates nor verifies the plausibility of the response. Overall, these interconnected error patterns demonstrate that a weak visual–spatial representation constrains Student 1's awareness, limited situational understanding, and insufficient reflective control in mathematical problem solving.

Elaboration Indicator

Based on the CTS for the elaboration indicator, the idea could be improved and fleshed out to make it more interesting. The elaboration indicator was in Problem 5, which concerned the combined area of a square and a rectangle. Of the 15 students who worked on Problem 5 of the CTS test, 3 students answered it correctly. The other 12 students experienced obstacles and difficulties in answering the problem. Student 2's response, demonstrating the elaboration indicator, is presented below. *Problem 5.* Look at the picture below!

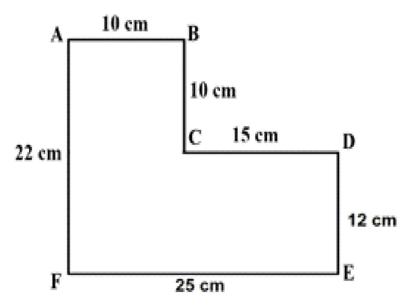


Figure 17. Composite plane figure for area calculation (reproduced from figure 4)

Calculate the total area of the plane geometry above! *Student 2's Response*

Translate: *A + B + C + D + E + F = 10 + 10 + 15 + 12 +25 + 22 = 94. So, the total area of the plane geometry above is 94 cm.*

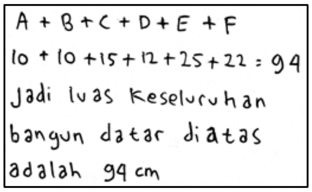


Figure 18. Student 2's response to those who completed the mathematical CTS test on the elaboration indicator

Based on Figure 18 above, Student 2 had difficulty solving Problem 5. Student 2 proposed a strategy to solve the problem, namely:

"*The answer A + B + C + D + E + F = 10 + 10 + 15 + 12 +25 + 22 = 94 is obtained from the sum of the lengths of each side in figure no. 5. That is what is called the overall area of the plane geometry*." (Interview with Student 2).

Based on Student 2's strategy of solving the Problem 5, at the stage of understanding the problem, Student 2 was unable to understand the sentence of the problem "*Calculate the total area of the flat shape above!*" and was unable to understand the illustration in the problem picture, indicating difficulty in visual–spatial comprehension and conceptual interpretation of composite geometric structures (Dorel, 2023). This indicates difficulty in decomposing composite figures into meaningful substructures, a key requirement for elaborative reasoning in geometry. Next, during the planning stage of the problem-solving strategy, Student 2 summed all side lengths in the flat-shape composite image, reflecting procedural misapplication and confusion between perimeter and area concepts (Luqman et al., 2025). This reflects a fundamental conceptual confusion between perimeter and area, showing that the student relies on superficial visual cues rather than underlying geometric principles. From a cognitive perspective, this demonstrates weak conceptual integration. This error demonstrates a well-documented misconception in elementary geometry: students conflate linear measurement (perimeter) with two-dimensional measurement (area) by relying on surface features of figures rather than their underlying spatial structure (Nadzeri et al., 2022; Rabab'ah, 2025).

Next, at the stage of implementing the problem-solving strategy, Student 2 calculated 10 + 10 + 15 + 12 + 25 + 22 = 94. So, the total number of plane geometries above was 94 cm, indicating reliance on surface numerical manipulation rather than area-decomposition reasoning (Israel et al., 2023). This procedure highlights surface-level numerical manipulation without engaging in area decomposition or spatial structuring, which are essential for elaboration. The student does not expand or refine the idea; instead, they apply a simplistic aggregation strategy. Such reasoning reflects difficulties in coordinating unit iteration and spatial covering, which are fundamental cognitive processes for understanding area measurement in school mathematics (Idrus et al., 2022). Furthermore, during the completion steps review, Student 2 did not review them, indicating limited metacognitive monitoring and evaluative regulation. The reason Student 2 has difficulty solving Problem 5 is that they do not fully understand the sentence's context, do not understand the material on combined square and rectangular areas, and rarely practice answering mathematical word problems, which may be interpreted as epistemological and experiential learning obstacles that hinder conceptual integration and detailed reasoning (Hendriyanto et al., 2024). The absence of verification prevents the student from refining or extending their reasoning, which is a critical component of elaboration as a higher-order thinking process. More broadly, the inability to distinguish between area and perimeter constrains elaboration, as students cannot build on incorrect foundational concepts to produce detailed, coherent solutions. Prior research has similarly shown that students frequently misinterpret area problems as perimeter calculations when instruction emphasizes procedural formulas without sufficient conceptual grounding in spatial measurement (Andini & Cahyaningsih, 2024; Asil Güzel & Yeºildere Ýmre, 2024). This supports the research of Kholid et al. (2024), which indicated that students' CTS on elaboration indicators at a low category level have difficulty forming an idea and providing more details because they struggle to understand problems, determine new solution strategies, and implement problem-solving strategies. From a cognitive perspective, the inability to distinguish between area and perimeter further constrains elaboration processes, as students cannot refine or extend their solution representations based on correct geometric concepts. Their skills indicated a CTS of 5 for 5th-grade students, with high CTS in achieving indicators of flexibility, originality, awareness, and elaboration. Of the 15 students, one achieved a high CTS score in mathematics. Students with high mathematical CTS demonstrate problem-solving skills, including the ability to understand problems, plan problem-solving, carry out problem-solving, and draw conclusions, as indicated by indicators of flexibility, originality, awareness, and elaboration, suggesting well-developed cognitive regulation, flexible schema coordination, and reflective reasoning.

The mathematical CTS of 5th-grade students is reflected in students' skills in demonstrating originality, awareness, and elaboration. Of 15 students, 1 achieved a moderate CTS score in mathematics. Students whose mathematical CTS have problem-solving skills in stages of being able to understand problems, plan problem-solving, carry out problem-solving, and make conclusions on indicators of originality, awareness, and elaboration, indicating partial development of conceptual understanding and metacognitive control.

The mathematical CTS of 5th-grade students whose mathematical CTS was low is indicated by the student's inability to achieve the indicators of fluency, flexibility, originality, awareness, and elaboration, or by the student's inability to achieve the indicators of originality and awareness. Of the 15 students, 13 were categorized as having low CTS scores in mathematics. Students who have low mathematical CTS have problem-solving skills with the stages of being able to understand problems, plan problem-solving, carry out problem-solving, and make conclusions about indicators of fluency or originality or awareness or originality and awareness, or without achieving indicators of fluency, flexibility, originality, awareness, and elaboration, reflecting pervasive constraints in problem representation, cognitive flexibility, divergent thinking, and metacognitive regulation that collectively limit the development of mathematical CTS. To further deepen the qualitative analysis of students' elaborations in mathematical creative thinking, a thematic matrix is constructed to systematically map Student 2's error patterns, particularly with respect to conceptual integration, spatial structuring, and metacognitive monitoring in solving composite geometry problems.

The thematic matrix in Figure 19 indicates that Student 2's errors form a coherent pattern of limited elaboration, characterized by weak visual–spatial structuring, area–perimeter confusion, surface-level numerical processing, and the absence of metacognitive monitoring. The misinterpretation of the problem context and the inability to decompose the composite figure demonstrate that the student fails to construct a structured representation of the geometric task, which is essential for elaborative reasoning. Instead of breaking down the figure into meaningful components, the student applies a simplistic aggregation strategy by summing all numerical values, reflecting procedural misapplication and reliance on superficial cues.

Furthermore, the presence of area–perimeter confusion highlights a fundamental conceptual breakdown, in which the student

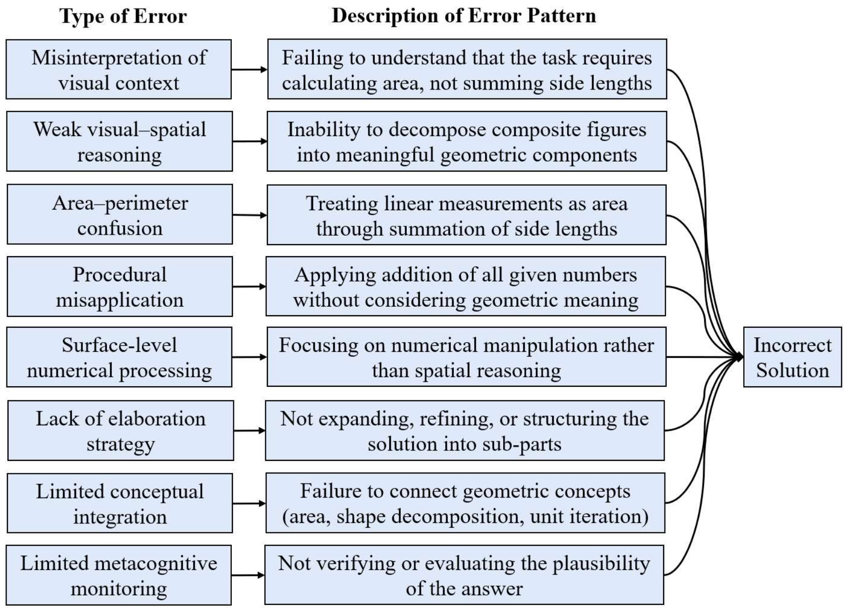


Table 19. Thematic matrix of student 2's errors in the elaboration indicator of mathematical CTS

conflates linear and two-dimensional measurements, limiting the ability to elaborate meaningfully on the solution. The surface-level numerical processing and lack-of-elaboration strategy indicate that the student does not refine or extend the solution but instead produces a minimal, undeveloped response. The absence of metacognitive monitoring further constrains this process, as the student neither evaluates nor revises their reasoning. Overall, these interconnected error patterns suggest that Student 2's elaboration is constrained by weak conceptual integration, limited spatial reasoning, and insufficient reflective control, collectively hindering the development of detailed, structured mathematical problem-solving.

An Analysis of the Causes of Students' Low Mathematical CTS

After reviewing students' CTS analyze, including problem-solving from the acquisition of mathematical CTS, and interviews with students, the researcher conducted an interview with a 5th-grade teacher regarding the teaching strategy and the mathematics textbook used as a guidebook. A teacher said:

"*I often use direct instruction teaching strategies in mathematics learning. The media used is the whiteboard. Even though Infocus media is available in class, mothers have difficulty using the media. When students are given routine problems, such as calculating the square root of 16, they can answer them. However, when the mother gives non-routine tests in the form of mathematical word problems about the circumference of a square, students have difficulty understanding them. Understanding the difficulties students face is also difficult. The availability of this book is also limited; only 4 books are available for students in one class*". (Interview with a Grade 5 Teacher).

Based on the interviews with teachers above, teachers often use direct instruction strategies. However, the math exercises given to students have not supported the development of mathematical CTS. Direct Instruction is a teacher-centered learning strategy (Jong et al., 2023). Direct instruction can make it difficult for students to understand complex mathematical material when delivered by teachers (Sweller et al., 2024). However, students' low mathematical

CTS cannot be attributed solely to direct instruction, as multiple learning factors shape the development of creative thinking.

The mathematics textbook used by teachers is Fitrianawati et al. (2022). The author has analyzed the book using praxeological theory, focusing on tasks, techniques, technology, and theory. The researcher analyzed one chapter, namely Chapter 4, on plane geometry. Other contextual factors, including curriculum structure, learning resources, and prior student experience, may also contribute to the observed low CTS (Avcý & Yildiz Durak, 2023; Dilekçi & Karatay, 2023). Thus, students' low mathematical CTS reflects the interaction of pedagogical practice, textbook design, resource availability, and learner background rather than a single causal factor.

In the task aspect, there were indicators of task types in the praxeology element, namely point praxeology, which contained a single type of task, then local praxeology, which contained a series of tasks with limited application to technology, and regional praxeology, which contained the type of task in the point praxeology and local praxeology indicators (Yunianta et al., 2023). In addition to the task type, the knowledge structure ranged from domains, sectors, and themes to questions. In the mathematics textbook by Fitrianawati et al. (2022), the researcher analyzed Chapter 4 on plane geometry. Plane geometry materials were domains with geometry-related themes. As for the questions, the question types were described in the presentation on plane geometry. The task types observed in the book consisted of six variations. The first task was to determine the name of the triangular plane geometry and to calculate its circumference. The second type was to identify the names of the parallelogram and the kite and calculate their circumferences. The third type involved determining the name of the irregular rectangular plane geometry and calculating its circumference. The fourth type focused on identifying the name of the regular pentagonal plane geometry and calculating its circumference. The fifth type required calculating the circumference of a combined flat shape formed by a square and a rectangle. Lastly, the sixth task was to calculate the circumference from a drawing showing various combinations of plane figures, including an equilateral triangle, a kite, an octagon, a combination of triangles and parallelograms, and a combination of squares and rectangles. Tasks 1 to 6 were categorized as point praxeology, each containing a single task. Based on the theory of praxeology, some tasks remained limited to a single element: point praxeology (Utami et al., 2025). There has not been a single assignment that includes the task types point praxeology, local praxeology, and regional praxeology. Thus, there is no contextual story test practice that can develop students' mathematical CTS. This limitation helps explain why many students failed to generate multiple solution strategies and showed weak fluency and flexibility, as observed in the student error analysis.

In the engineering aspect, students had the opportunity to actively engage in understanding concepts, and there were multiple ways to complete assignments (Zakiah et al., 2025). According to praxeology, there were four different types of techniques, namely the perceptual technique which broadly depends on the shape of the image presented; the physical technique, which was a finishing technique using tools to draw or measure; the operational technique which was a finishing technique using small squares or coordinate axes, and the algebraic technique which was notations in the form of algebra. The task techniques 1 to 6 in chapter 4 on flat shapes included perceptual and algebraic techniques for calculating the circumference of an equilateral triangle, a kite, and an octagon, as well as for combinations of triangles and parallelograms, squares and rectangles, based on the size descriptions in the figure. Results of the analysis of technical characteristics in the presentation of students' mathematics textbook Material showed that some tasks still relied on only two techniques: perceptual and algebraic. According to the theory of praxeology, no task has been found to employ all four techniques: perceptual, physical, operational, and algebraic. This restricted diversity of techniques is consistent with students' procedural errors, surface-level reasoning, and confusion between perimeter and area concepts identified in the CTS problem-solving analysis.

In the technological aspect, mathematics textbooks must present space to justify tasks and techniques. The technical description in type 1 stated that the circumference of a triangle could be calculated by summing its side lengths. The description of technology in the type 2 task, namely the circumference of the parallelogram and the kite alignment, could be calculated by summing the sides. The technical description for type 3 states that the circumference of an irregular rectangle can be calculated by adding its sides. The technical description in task type 5, namely the circumference of a combined image of a square and a rectangle, can be calculated by finding the length of an unknown side and adding the side lengths. The technical description for type 6 stated that the circumference of regular triangles, kites, and 8-sided polygons could be calculated by summing their side lengths. In contrast, the circumference of the combination of triangles and parallelograms, and of squares and rectangles, can be calculated by finding the lengths of the unknown sides and adding them. From the perspective of praxeology, there were several types of tasks involving technology, and some tasks contained interrelated technologies. Tasks 1 to 4 used the same problem-solving techniques, task 5 used its own, and task 6 used both. Such repetitive technological justification limits conceptual generalization, which may contribute to students' weak metacognitive verification and fragmented reasoning patterns.

The theoretical aspect was clearly and straightforwardly described (Agustito et al., 2025). The material in Chapter 4 was plane geometry, describing only the circumferences of triangles, parallelograms, kites, irregular rectangles, pentagons, and combinations of squares and line segments. The same technique is used to calculate the circumference: add the lengths of the sides. Based on the theory of praxeology, the theoretical explanation in Chapter 4 of the plane geometry material was unclear and not straightforward. Because there should be other ways to calculate the circumference of a plane geometry, such as the circumference of a square, can use the formula circumference = 4 × sides, circumference of a rectangle = 2 × (length + width), half circumference of a rectangle = length + width, circumference of a parallelogram = 2 × (length of side 1 + length of side 2) with the condition that the length of side 1 is the length of the parallel side and the length of side 2 is the length of the parallel oblique side. The absence of diverse theoretical representations directly relates to students' misconceptions, inappropriate schema activation, and limited conceptual understanding, as observed across CTS indicators. These findings indicate that instructional practices, textbook praxeological limitations, and weak conceptual–theoretical variation constitute the primary causes of students' low mathematical CTS.

Strategies to Foster the Growth and Development of Mathematical CTS

To develop students' mathematical CTS, teachers should choose books that present clear, straightforward mathematical material, with examples of problems that include contextual problem-solving elements, open-ended problem types, and problem practice. In addition, teachers can participate in training on using technology-based media to learn how to leverage interactive media to support learning. Research results from Behnamnia et al. (2025), Deslis et al. (2025), Hidajat (2024), Tang et al. (2022), Wang and Li (2024), and Wulan et al. (2025) show that

PowerPoint media, animation, video, music, digital puzzles, digital modules, and digital comics are proven to foster mathematical CTS. The selection of learning models can also be recommended to develop mathematical CTS. Results from the studies by Ates and Aktamis (2024), Fajri et al. (2025), and Fauzi et al. (2025) show that realistic mathematics education, problem-based learning, and project-based learning can improve students' mathematical CTS.

CONCLUSION

This study concludes that one student has a high level of CTS, achieving indicators of flexibility, originality, awareness, and elaboration. Another student has a moderate level of CTS, achieving indicators of originality, awareness, and elaboration. Meanwhile, 13 students have low levels of CTS, achieving only a limited range of indicators, such as fluency, originality, awareness, or elaboration, and some have not achieved all CTS indicators. The analysis of students' responses further reveals fundamental misconceptions, particularly confusion between area and perimeter, fragmented procedural reasoning, and weak metacognitive verification during problem-solving. To improve students' CTS, learning activities should focus on problem- and project-based, realistic mathematics approaches, supported by mathematics textbooks that emphasize problem-solving processes. In addition, targeted instructional interventions that explicitly address area–perimeter misconceptions, strengthen conceptual representation, and incorporate reflective verification activities are necessary to remediate the cognitive difficulties identified in the data directly.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used the Scopus AI feature to assist with literature search and information summarization. The authors reviewed the outputs and take full responsibility for the final content of the published article.

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