Jurnal Pembelajaran Matematika Inovatif
Volume 9, No. 5, September 2026

ISSN 2614-221X (print)
ISSN 2614-2155 (online)

DOI 10.22460/jpmi.v9i5.32607

A SEQUENTIAL ERROR PATTERN IN MATHEMATICAL CREATIVE THINKING: FROM CONCEPT TO REPRESENTATION

B. Widya Melati Patricia[1], Duano Sapta Nusantara*[2], Syamsir Sainuddin[3], Da Tien Nguyen[4]

[1,2,3] Universitas Jambi, Jl. Letjen Soeprapto No. 33, Telanaipura, Indonesia
[4]Hanoi Metropolitan University, No. 98 Duong Quang Ham, Cau Giay, Hanoi, Vietnam.
[1]imel3012@gmail.com, [2]duanosaptanusantara@unja.ac.id, [3]syamsirsainuddin@unja.ac.id, [4]ntda@hnmu.edu.vn

ARTICLE INFO

Article History
Received Jun 23, 2026
Revised Jul 30, 2026
Accepted Sep 25, 2026

Keywords:
Conceptual error;
Education;
Error analysis;
Mathematical creative thinking;
Students

ABSTRACT

This study analyzes the types and patterns of mathematical errors made by low-achieving students in solving mathematical creative thinking ability tasks. A qualitative descriptive approach with an error analysis method was employed. From 54 eighth-grade students at two public junior high schools in Jambi, who were randomly sampled for the MCTA test, 44 students were purposively selected as low-achieving. Data were collected through written tests, semi-structured interviews, and documentation. Only three of six error types were observed, namely Conceptual Error, Strategic Error, and Representation Error. CE was the most frequent type on every item, observed in 61.4% to 90.9% of the students, and SE and RE occurred mostly together with CE. Procedural, Symbolic, and Computational Errors were not observed. This pattern suggests that the work of low-achieving students stalled at the conceptual stage before procedural work began. The study offers a frequency-based account of how error types co-occur on creative tasks, which indicates that conceptual understanding is a foundational prerequisite for MCTA.

Corresponding Author:
Duano Sapta Nusantara,
Universitas Jambi
Jambi, Indonesia
duanosaptanusantara@unja.ac.id

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

Penelitian ini menganalisis jenis dan pola kesalahan matematis siswa berkemampuan rendah dalam menyelesaikan soal kemampuan berpikir kreatif matematis (KBKM). Pendekatan deskriptif kualitatif dengan metode analisis kesalahan digunakan dalam penelitian ini. Sebanyak 54 siswa kelas VIII dari dua SMP Negeri di Jambi dipilih secara acak untuk mengerjakan tes KBKM, kemudian 44 siswa dipilih secara purposif sebagai siswa berkemampuan rendah. Data dikumpulkan melalui tes tertulis, wawancara semi-terstruktur, dan dokumentasi. Hanya tiga dari enam jenis kesalahan yang teramati, yaitu Conceptual Error (CE), Strategic Error (SE), dan Representation Error (RE). CE merupakan jenis yang paling sering pada setiap soal, teramati pada 61,4% sampai 90,9% siswa, dan SE serta RE sebagian besar muncul bersama CE, sedangkan Procedural Error, Symbolic Error, dan Computational Error tidak teramati. Pola ini mengindikasikan bahwa pekerjaan siswa berkemampuan rendah terhenti pada tahap konseptual sebelum tahap prosedural dimulai. Penelitian ini menawarkan gambaran berbasis frekuensi tentang bagaimana jenis kesalahan muncul bersamaan pada soal kreatif, yang menunjukkan bahwa pemahaman konseptual merupakan prasyarat mendasar bagi KBKM.

How to cite:

Patricia, B. W. M., Nusantara, D. S., Sainuddin, S., & Nguyen, D. T. (2026). A sequential error pattern in mathematical creative thinking: From concept to representation. *JPMI – Jurnal Pembelajaran Matematika Inovatif, 9*(5), 1485-1506.

INTRODUCTION

Mathematical creative thinking ability (MCTA) is an important competency that students need to master in order to face the challenges of the 21st century, as it enables them to generate diverse, flexible, original, and detailed ideas when solving mathematical problems (Suherman & Vidákovich, 2022). MCTA not only plays a role in mathematical problem-solving but also serves as a foundation for developing higher-order thinking skills required in real life (Ersoy & Kara, 2026). Without adequate MCTA, students tend to rely on memorized procedures and are unable to cope with problems that require exploring more than one solution approach (Kholid et al., 2024). Read together, these studies describe MCTA both as a goal of mathematics learning and as a gateway to open problems, because the four qualities named in its definition, namely fluency, flexibility, originality, and elaboration, are exactly what a student must show when a problem has no single prescribed route. A weakness in MCTA therefore limits how far a student can engage with such problems at all, and it also limits what an assessment of MCTA can reveal about the student's mathematical thinking.

Although MCTA is recognized as important, the reality in the field shows that this ability remains low, particularly among low-achieving students. Research indicates that the majority of students are only able to respond at the most basic level when faced with tasks requiring creativity, with elaboration being the most difficult component to achieve (Incikabi, 2025). Nufus et al. (2024) also reported that incomplete conceptual understanding is the main barrier to the development of students' mathematical creativity such that even when tasks are designed to facilitate creativity, many students fail to produce even a single response that meets the task demands. These findings describe what students fail to produce, but they do not show where in the solving process a response breaks down. The reported link between incomplete conceptual understanding and absent responses suggests that low MCTA scores may reflect a missing prerequisite rather than a lack of creative ideas, and scores alone cannot settle this possibility.

Leaving this question open is a theoretical problem for research on mathematical creativity and not only a practical one. When low scores are read as low creativity without examining the work behind them, the construct measured by an MCTA task becomes confounded with the conceptual knowledge that the task silently requires. Accounts of how MCTA develops then cannot say whether creative ability or prerequisite understanding limits a student's performance, and instructional responses built on either account risk targeting the wrong cause. Examining the errors students make on MCTA tasks offers a way to separate these explanations, because an error shows which kind of knowledge failed and at which step.

One important indicator of this barrier is the errors students make when solving creative tasks. Mathematical errors are not merely incorrect final answers but rather reflections of cognitive obstacles experienced by students during the thinking process (Benecke & Kaiser, 2023). These obstacles do not only arise in creative tasks but also in tasks requiring deep reasoning such as PISA-type items, where students demonstrate similar patterns of difficulty in constructing valid mathematical arguments (Nusantara et al., 2025a). Delastri and Lolang (2023) explain that conceptual error is the type most difficult to detect and most influential on the overall problem-solving process because it is not always visible from the final answer. If such errors are not accurately identified, teachers cannot design instruction that targets the true root of the problem and the same barriers will continue to recur (Lin et al., 2025). Taken together, these sources imply that final answers alone cannot show where a student's thinking failed. A conceptual obstacle can sit behind a blank or generic response, so identifying it requires both the written work and the student's own explanation of that work. This study follows that logic by pairing written responses with interviews.

Several factors that contribute to the high frequency of errors on MCTA tasks include weak foundational conceptual understanding, inability to select appropriate strategies, and failure to use representations meaningfully (Kenney & Ntow, 2024; Dorner et al., 2025). Low-achieving students in particular tend to rely on the most familiar approach without being able to explore other strategies, which prevents creativity from developing (Ersoy et al., 2025). This situation is further compounded by instructional designs that have not provided sufficient space for strengthening conceptual understanding as a prerequisite for the development of mathematical creativity (Suherman & Vidákovich, 2025). In the sources reviewed here, these factors are discussed separately, and the connection between them within a single solution attempt on a creative task is not examined. The answer matters for teaching, because it determines whether the three factors should be addressed together or in a particular order.

Studies of students' errors have mostly examined conventional tasks in specific topics. Delastri and Lolang (2023) and Kenney and Ntow (2024) analyzed errors in algebraic problems, and Nurhayati et al. (2026) did so for exponent and logarithm items. Only two of the studies reviewed here analyzed errors on creative thinking tasks, and each was limited to one content topic, namely polyhedra in Jumariah et al. (2025) and circles in Siregar (2019).

These studies leave two questions open. They do not show which error types appear when low-achieving students face tasks that demand fluency, flexibility, originality, and elaboration across several content areas within the same instrument. They also do not show how the error types that do appear are related within one solution, which is the information a teacher needs to decide where instruction should begin. Their findings cannot simply be assumed to transfer to MCTA tasks either, because creative tasks demand diversity and depth of response and may therefore give rise to error patterns that differ from those found in conventional mathematical tasks.

Given this gap, the present study analyzes the types and patterns of mathematical errors made by low-achieving students in solving MCTA tasks. Participants were identified through person measure results from the Rasch model obtained during the initial measurement phase of this research series. This psychometric approach allows the low-achieving group to be defined in a systematic and objective manner rather than based on assumptions or one-sided judgments. Lusiana et al.'s (2025) error classification was then applied to examine what types of errors emerge when low-achieving students face tasks requiring mathematical creativity rather than merely routine tasks. The findings are expected to provide a deeper understanding of the cognitive barriers experienced by low-achieving students and serve as a reference for teachers in designing more targeted instruction. The study also contributes a frequency-based account of how error types co-occur on creative tasks, which extends the use of the classification beyond conventional tasks. To achieve this purpose, the present study is guided by the following research questions. (1) What types of mathematical errors do low-achieving students make in solving MCTA tasks? (2) How do these error types interconnect to form a pattern in low-achieving students' solutions to MCTA tasks?

METHOD

This study employed a qualitative descriptive approach with an error analysis method, aiming to explore the types and patterns of errors made by low-achieving students in solving MCTA tasks in depth rather than measuring or comparing variables (Creswell, 2018). The error analysis method was selected because it enables the systematic identification of sources of mathematical learning difficulties based on patterns in students' responses (Benecke & Kaiser,

2023). Lin et al. (2025) affirm that qualitative error analysis provides deeper insight into the root causes of difficulties compared to purely quantitative analysis. The design is cross-sectional, so the study describes the pattern of errors present in students' responses at one point in time and does not test causal relations between error types.

The study was conducted in 2026 at two public junior high schools in Jambi, selected because they represent the diversity of geographical and demographic characteristics of education in Jambi Province. A total of 54 eighth-grade students participated in the MCTA test, consisting of 29 students in Jambi City and 25 students in Muaro Jambi Regency, selected using a random sampling technique. Random sampling therefore applied to the measurement phase of the research series, in which the MCTA test was administered and scored with the Rasch model.

The error analysis reported in this article used a second, purposive step. Based on the Rasch model measurement conducted as part of this research series, 44 students were identified as low-achieving and became the focus of analysis, while the remaining 10 students were classified as high-achieving and were not analyzed. This criterion-based selection follows from the aim of the study, which concerns the error patterns of low-achieving students. The low-achieving group is also the largest group in the sample, at 44 of 54 students (81.5%), and the problem addressed here is the low MCTA reported for low-achieving students (Incikabi, 2025; Nufus et al., 2024). The analyzed group, which consisted of 24 students from Muaro Jambi Regency and 20 from Jambi City, is therefore a purposively selected subset of a randomly sampled group and not a random sample of low-achieving students. The study was conducted in three stages as shown in Figure 1.

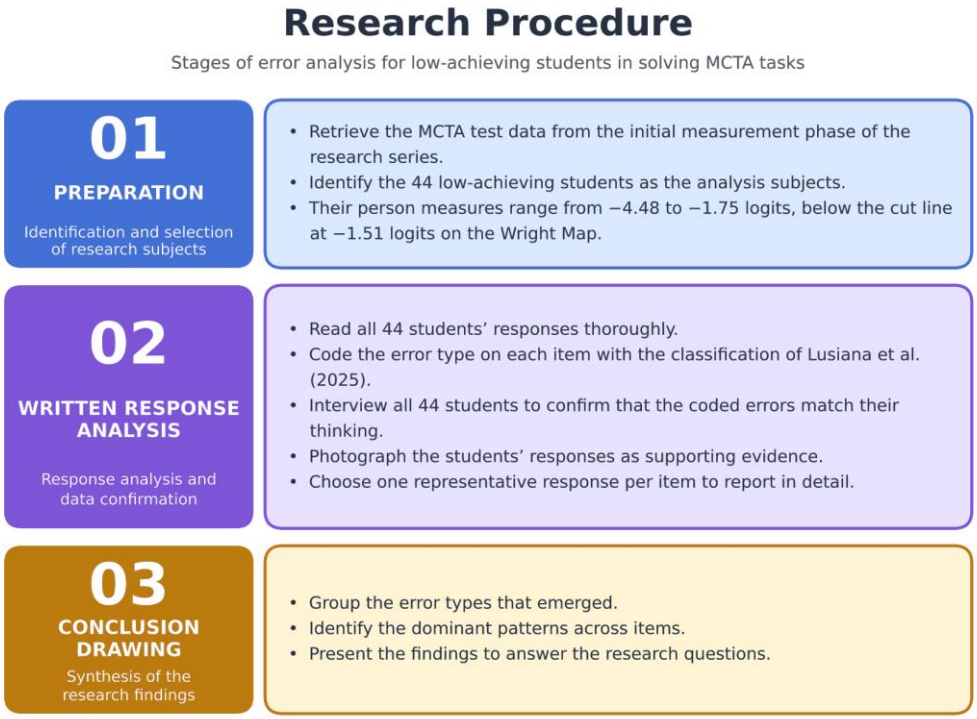


Figure 1. Research Procedure for Error Analysis of Mathematical Creative Thinking Ability (MCTA)

Figure 1 illustrates the research procedure, which consists of three stages namely preparation, written response analysis, and conclusion drawing. The preparation stage involved retrieving MCTA test data from the initial measurement phase of this research series and identifying 44 low-achieving students as the analysis subjects with person measures from −4.48 to −1.75

logits, below a cut line at −1.51 logits on the Wright Map. The written response analysis stage involved reading all 44 students' responses thoroughly to identify the type of error in each item based on Lusiana et al.'s (2025) classification. Data confirmation was carried out through semi-structured interviews with the students to ensure that the identified errors corresponded to the students' actual thought processes, supplemented by photographs of students' responses as supporting evidence. The final stage involved drawing conclusions by grouping the error types that emerged, identifying dominant patterns across items, and systematically presenting the findings to address the research objectives.

For each item, one response was selected from the 44 responses as the representative response to be reported in detail. The selected response illustrated the error types coded for that item, the errors could be read from the written work, and the interview with the student confirmed them. The remaining responses were coded with the same procedure and contributed to Table 3, which shows how common each error type was, so the reported response illustrates the coded errors and does not describe every student.

Data were collected through three instruments used in an integrated manner through triangulation. The first instrument was a written MCTA test consisting of five essay items incorporating mathematical creative thinking indicators with eleven assessment components that had been psychometrically analyzed using the Rasch model with an item reliability of 0.97 (item separation 5.35) and a person reliability of 0.70 (person separation 1.53) within this research series. The second instrument was a semi-structured interview conducted to confirm the types of errors identified. The third instrument was documentation in the form of photographs of students' responses as supporting data for the analysis.

All 44 low-achieving students were interviewed after the written test. The interviews were needed because written work alone often did not show what a student actually understood, so each error could be checked against the student's own explanation and its reason explored. The responses reported as S1 to S5 are therefore not the only interviewed students. They were chosen because, for each item, they illustrated the coded error types and were confirmed in the interview.

Data analysis was conducted in two main stages. The first stage involved classifying students' ability levels based on person measure results from the Rasch model obtained within this research series, whereby 44 students with person measures from −4.48 to −1.75 logits, below a cut line at −1.51 logits, were designated as the low-achieving group and became the focus of analysis. Person measures were estimated with Winsteps and expressed in logits, and among the 54 students they ranged from −4.48 to 0.66 (M = −2.59, SD = 1.21). Because person measures and item difficulties share one scale, students were grouped relative to this sample, so the low-achieving label describes their position among the 54 students and not an absolute level. The 10 students with measures above −1.51, from −1.45 to 0.66 logits, formed the high-achieving group.

In raw scores on the 11 scored components, the 44 low-achieving students had totals of 3 to 10, and the 10 high-achieving students had totals of 11 to 19. Person separation was 1.53, which gives about 2.4 statistically distinct levels of ability (Wright & Masters, 2002), so grouping the students into a low and a high group is consistent with the measurement. The cut line was read from the Wright Map, where the S marker above the person mean shows approximately one standard deviation above the mean, and students at or above that marker were classified as high-achieving. The second stage involved qualitatively analyzing students' responses using Lusiana

et al.'s (2025) error classification, which encompasses six types of errors as presented in Table 1.

Table 1. Classification of Mathematical Error Types (Lusiana et al., 2025)

Error Type	Indicator	Code
Conceptual Error	Misunderstanding the definition, properties, or meaning of a mathematical concept	CE
Procedural Error	Following steps mechanically without understanding or performing steps in the wrong order	PE
Strategic Error	Selecting an inappropriate solution method or attempting approaches randomly	SE
Representation Error	Misinterpreting or misusing visual representations such as models	RE
Symbolic Error	Misunderstanding the meaning or use of mathematical symbols	SY
Computational Error	Making basic calculation errors or sign errors	CO

The error types and indicators in Table 1 follow Lusiana et al. (2025), and the researcher coded the responses following the same source. Each response was read item by item, and a response was coded with an error type when its written work, checked against the interview, matched the indicator for that type. The codes were then compared across items to identify the order in which they appeared within a solution.

Credibility was supported first through triangulation of three data sources, namely the written test, the semi-structured interviews, and the photographs of students' responses, so that each coded error could be checked against more than one source. The interviews also served as a check on interpretation. Because every student was interviewed, follow-up questions allowed each coded error to be confirmed or revised against the student's own explanation, as the interview excerpts in the Results show. The interviews also worked as member checking, because the researcher's reading of each response was put to the student, who could confirm or correct it. The coding was also checked by another author of this article.

RESULTS AND DISCUSSION

Results

This study involved 54 students, 44 of whom were identified as low-achieving through Rasch model measurement and became the focus of analysis. The data analyzed encompass the score distribution per MCTA component and the types of mathematical errors found in students' responses. The score distribution is presented in Table 2.

Table 2. MCTA Score Distribution for Low-Achieving Students (n = 44)

Indicator	Item	Score 0	Score 1	Score 2	Score 3	Mean
Fluency	Item 1	9 (20.5%)	23 (52.3%)	10 (22.7%)	2 (4.5%)	1.11
Fluency	Item 2	2 (4.5%)	31 (70.5%)	11 (25.0%)	0	1.20
Flexibility	Item 2	29 (65.9%)	11 (25.0%)	4 (9.1%)	0	0.43
Flexibility	Item 5	32 (72.7%)	12 (27.3%)	0	0	0.27
Originality	Item 3	1 (2.3%)	34 (77.3%)	8 (18.2%)	1 (2.3%)	1.20
Originality	Item 5	39 (88.6%)	5 (11.4%)	0	0	0.11
Elaboration	Item 2	35 (79.5%)	9 (20.5%)	0	0	0.20
Elaboration	Item 3b	13 (29.5%)	28 (63.6%)	2 (4.5%)	1 (2.3%)	0.80
Elaboration	Item 3c	12 (27.3%)	28 (63.6%)	4 (9.1%)	0	0.82
Elaboration	Item 4	33 (75.0%)	10 (22.7%)	1 (2.3%)	0	0.27
Elaboration	Item 5	41 (93.2%)	3 (6.8%)	0	0	0.07

Table 2 shows that almost all MCTA components are dominated by scores of 0 and 1. The highest item means were 1.20, found in fluency on item 2 and in originality on item 3, while the lowest was 0.07, found in elaboration on item 5. Averaging the item means within each component gives 1.16 for fluency, 0.66 for originality, 0.43 for elaboration, and 0.35 for flexibility, so fluency stands well above the other three components. The Winsteps item measures agree with this pattern. The hardest components were elaboration (3.30 logits) and originality (2.58 logits) on item 5, and the easiest were originality on item 3 (−2.22), fluency on item 2 (−2.16), and fluency on item 1 (−2.06). This pattern indicates that low-achieving students are only able to respond at the most basic level without being able to develop ideas mathematically.

Of the six error types examined based on Lusiana et al.'s (2025) classification, only three were identified, namely Conceptual Error (CE), Strategic Error (SE), and Representation Error (RE). The remaining three, namely Procedural Error (PE), Symbolic Error (SY), and Computational Error (CO), were not observed in students' responses. This does not by itself show that students could not make such errors, because some responses left calculation sub-items blank, so no procedural or symbolic work was available to code. The representative responses to items four and five, for example, contained no calculations. A summary is presented in Table 3.

Table 3. Number and Percentage of Low-Achieving Students (n = 44) Showing CE, SE, and RE per Item

No.	Item	CE	SE	RE
1	Number patterns	27 (61.4%)	6 (13.6%)	—
2	Arrangement of 12 cookies	38 (86.4%)	28 (63.6%)	21 (47.7%)
3	Flat shape creation	28 (63.6%)	19 (43.2%)	13 (29.5%)
4	Sierpinski triangle	40 (90.9%)	30 (68.2%)	11 (25.0%)
5	44 cm wire	39 (88.6%)	5 (11.4%)	5 (11.4%)

Table 3 shows that CE was the most frequent error type on every item, observed in 27 to 40 of the 44 students (61.4% to 90.9%). SE was observed in 5 to 30 students per item, and RE in 5 to 21 students on items 2 to 5. SE and RE occurred mostly together with CE. Across the five items, SE appeared without CE in 12 of 88 cases, and on items 2 to 5, RE appeared without CE in 9 of 50 cases. The reverse did not hold, because CE appeared without SE in 96 of its 172 occurrences (55.8%). SE and RE were less closely tied to each other, because RE appeared without SE in 26 of the 50 cases on items 2 to 5. All three types together in one response were uncommon, at 13, 2, 4, and 2 students on items 2, 3, 4, and 5. Among the responses on items 1 to 5 that contained at least one error, 152 of 190 (80.0%) fitted an order in which RE appeared only with SE and SE only with CE, so this order is a tendency and not a rule. An in-depth analysis per item is presented below.

Item one required students to create as many number patterns as possible with different rules, starting from the number 2. A representative student response is presented in Figure 2.

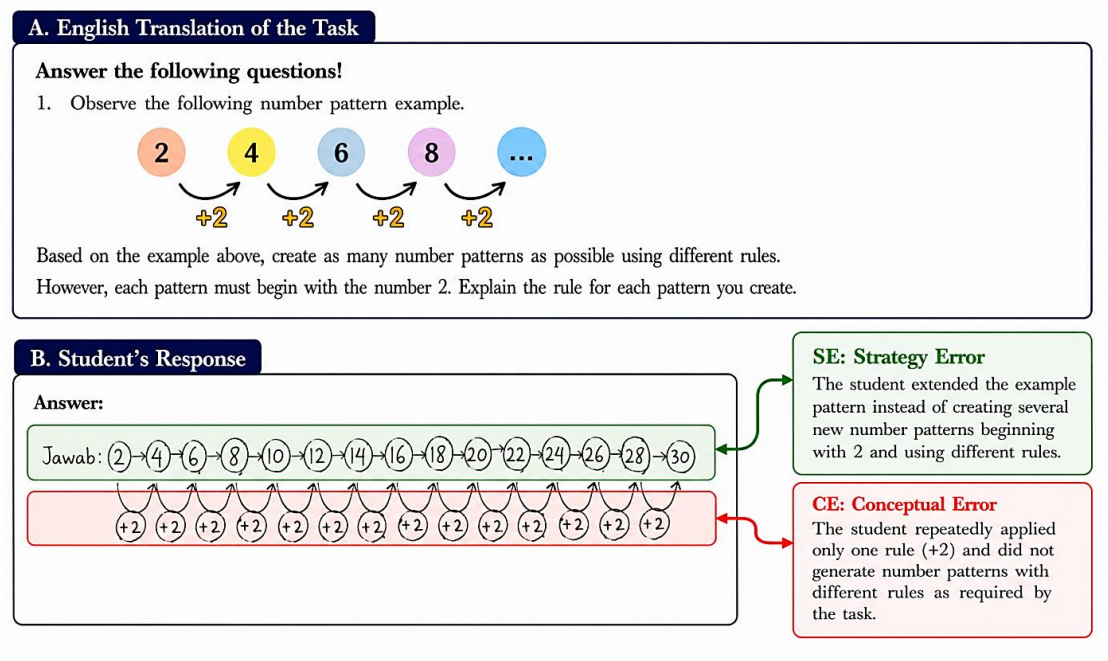


Figure 2. Response of S1 Showing CE and SE on the Number Sequence Item

In Figure 2, the student only wrote one pattern using the add-two rule from the example then extended it to more than ten terms. CE was identified because the student did not understand that different rules mean using different types of operations such as multiplication or subtraction. This was confirmed through an interview with S1 below.

P : Based on the pattern you made, do you think it already matches what the question asked? The rules are all the same though. Do you know what different rules means?

S1 : Yes, it already matches because it asked us to make different patterns.

P : Are the patterns you made actually different?

S1 : Yes, in the example the pattern only goes up to 8 but I made it go up to 30.

S1's statement shows that the student interpreted the instruction as many as possible as referring to the quantity of terms rather than the diversity of rules. This is a semantic misreading of the instruction. S1 linked the phrase as many as possible to the feature of the example that could

be counted, which is the number of terms, and did not link the phrase different rules to the operation that generates the terms. Extending the pattern from eight to thirty therefore satisfied the instruction as S1 understood it, and this explains why S1 judged the response to match the task even after the interviewer pointed out that all rules were the same.

A second mechanism concerns the conceptual schema that S1 appears to hold for number patterns. In this schema a pattern is a list that grows by repeated addition, as in the given example, so a different rule has no place to be imagined, because a rule is equated with the addition already shown. This is an interpretation drawn from S1's written work and interview, and it was not tested with further tasks.

SE emerged because the student merely extended the example pattern without employing any strategy to create new patterns. The mean fluency score on this item was only 1.11, and RE was not identified since this item did not require a connection to visual representation.

Item two required students to arrange 12 cookies in various rectangular configurations while explaining the connection to factorization. A representative student response is presented in Figure 3.

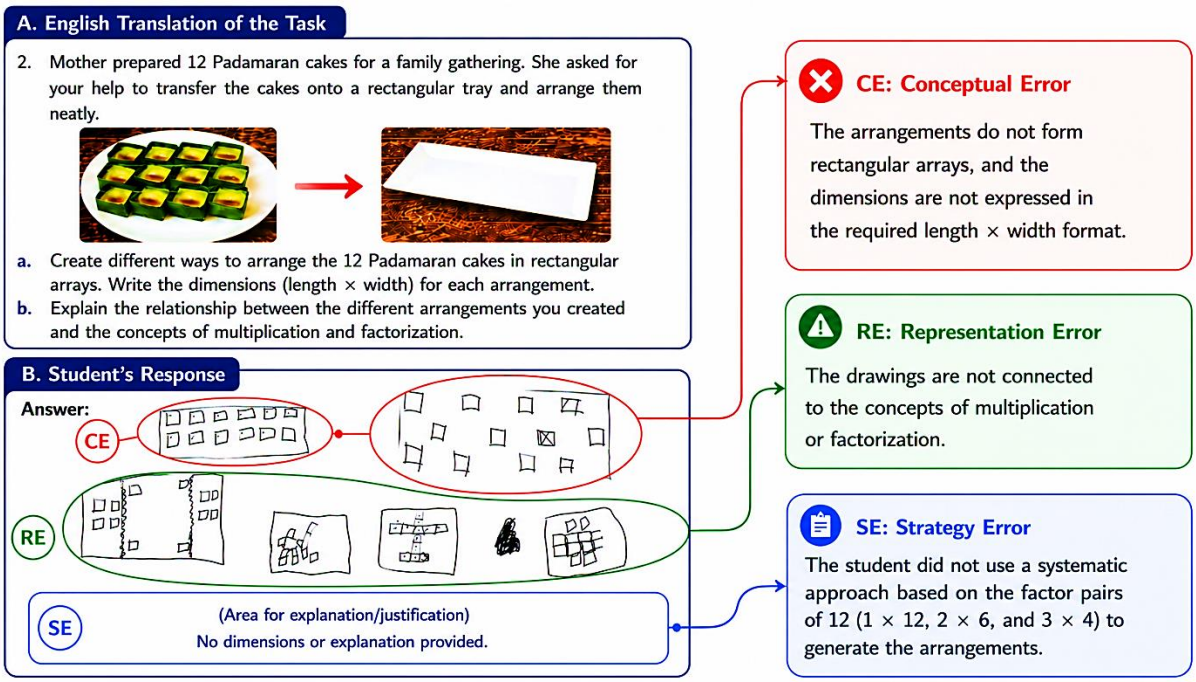


Figure 3. Response of S2 Showing CE, SE, and RE on the Multiplication and Factorization Item

Figure 3 shows a cookie arrangement that is not rectangular with no dimensions provided and no answer to the factorization section. CE was identified because the student did not understand that arranging 12 cookies in a rectangular form means determining pairs of rows and columns whose product is exactly 12. This was confirmed through an interview with S2 below.

P : Can you explain what you have drawn here?

S2 : This is the arrangement of cookies on the tray. There are 12 on each tray.

P : Have you arranged the cookies in a rectangular shape that has a defined length and width?

S2 : I was confused about how to arrange them in a rectangle.

P : Your first drawing was actually correct. How did you draw it?

S2 : I copied it from my friend's work then I tried to make other shapes on my own.

P : In your first drawing how many cookies are in each row?

S2 : There are 6 in a total of 2 rows.

P : What do you think is the connection to the topic of factorization?

S2 : Is factorization the one about dividing things? I do not know how they are related.

S2's statements reveal that the student was confused about how to arrange the cookies in a rectangular form. Although the first drawing was correct it had been copied from a classmate, and S2 could not state how the drawing related to factorization. The correct drawing therefore did not indicate understanding, which shows why written work alone can hide a conceptual error. The concept of multiplication as a row-and-column relationship had not been established. SE emerged because factorization was not used as a strategy for finding valid dimension pairs. The mean flexibility score on this item was only 0.43 with 29 students scoring 0.

RE was identified because the visual representation was not connected to the concept of factorization. The drawing showed a quantity of twelve but gave no dimensions, so it could not serve as a tool for reasoning about row and column pairs. The mean elaboration score was only 0.20 with 35 students scoring 0.

Item three required students to create an original drawing from a combination of flat shapes and describe it using a mathematical narrative. A representative student response is presented in Figure 4.

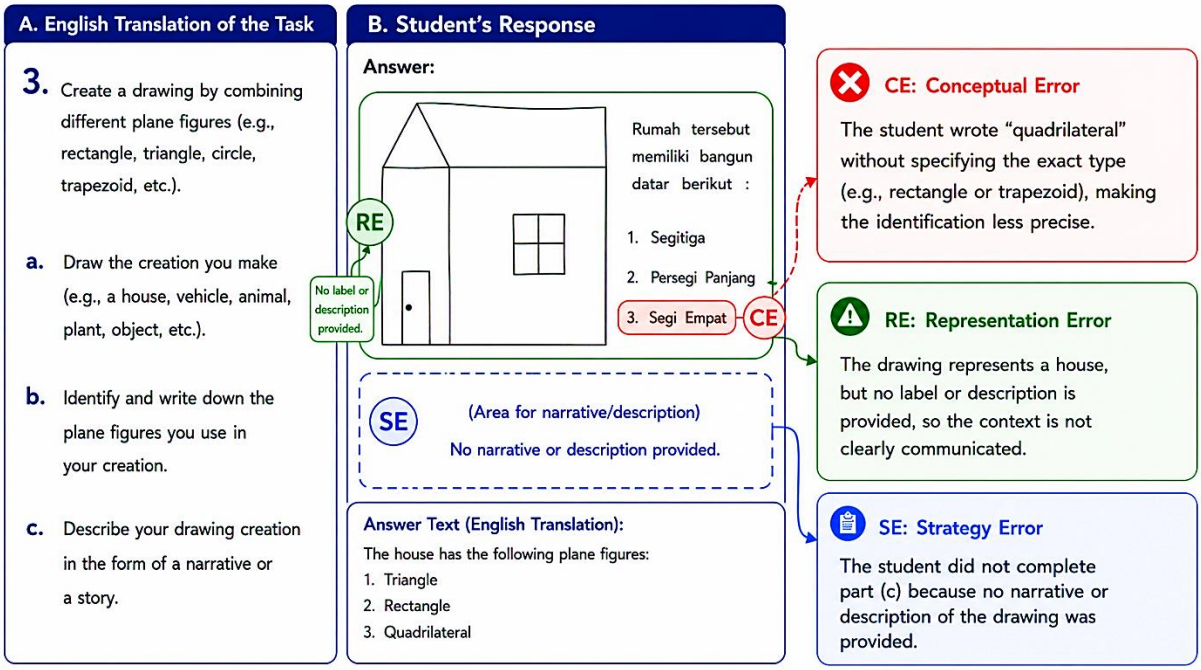


Figure 4. Response of S3 Showing CE, SE, and RE on the Flat Shapes Item

Figure 4 shows a student drawing a house with three shape names written alongside it. CE was identified from the written work, because the student named the third shape as a quadrilateral without specifying its type, such as a rectangle or a trapezoid, which shows incomplete knowledge of how quadrilaterals are classified. The choice of a house, which was already given as an example in the item, is treated below as evidence of SE. The interview with S3 below bears on the choice of drawing and on the narrative, so the coding of the quadrilateral rests on the written work.

P : Why did you draw a house when a house was already given in the question as an example?

S3 : I did not know what else to draw. A house was the easiest thing I could think of.

P : Then why did you not continue with the mathematical narrative?

S3 : I thought it was enough to just write the names of the shapes since the drawing was already there.

S3's statements show that the student recognized the narrative requirement but lacked a strategy to fulfill it mathematically, which constitutes SE. S3 also chose a house because it was the easiest thing to think of, so the choice reflects no search for alternatives even though a house was already given as an example.

RE emerged because there was no connection between the drawing and an adequate mathematical explanation. The mean elaboration score was 0.80 for shape identification and 0.82 for the narrative.

Item four presented the Sierpinski Triangle pattern with triangle counts of 1, 3, 9, and 27 then asked students to draw the fifth pattern, calculate the tenth, and derive the general formula. A representative student response is presented in Figure 5.

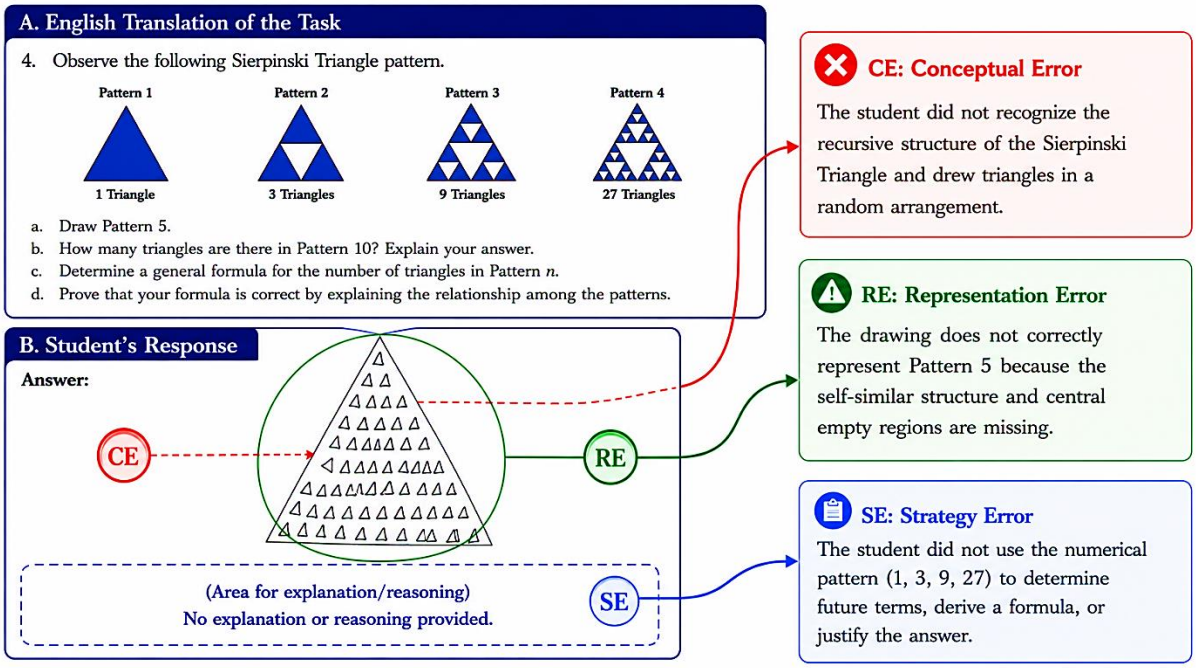


Figure 5. Response of S4 Showing CE, SE, and RE on the Geometric Sequence Item

Figure 5 shows small triangles drawn randomly without following the Sierpinski Triangle structure while all calculation sub-items were left blank. CE was identified because the student did not recognize the multiplicative relationship in the sequence 1, 3, 9, 27, which was already provided. This was confirmed through an interview with S4 below.

P : Take a look at the pattern from 1 to 3 and from 3 to 9. What is the pattern?

S4 : It increases by 2 then increases by 6. The differences are all different.

S4's statement shows that the student interpreted the multiplicative sequence using additive logic. The student compared each term with the one before it only through differences, and because the differences were all different, no regularity could be seen.

SE emerged because the given sequence was not utilized as the basis for pattern analysis, leaving the student with no starting point to answer the subsequent sub-items. The student therefore could not go beyond the drawing, and all calculation sub-items were left blank.

RE was identified because the drawing did not represent the self-similar structure of the fifth pattern and because the available numerical data were not recognized as a representation to be interpreted. The mean elaboration score was only 0.27 with 33 students scoring 0.

Item five presented the context of creating a wall decoration from a 44 cm wire and asked students to create several different shapes, calculate their areas, and determine the best shape with justification. A representative student response is presented in Figure 6.

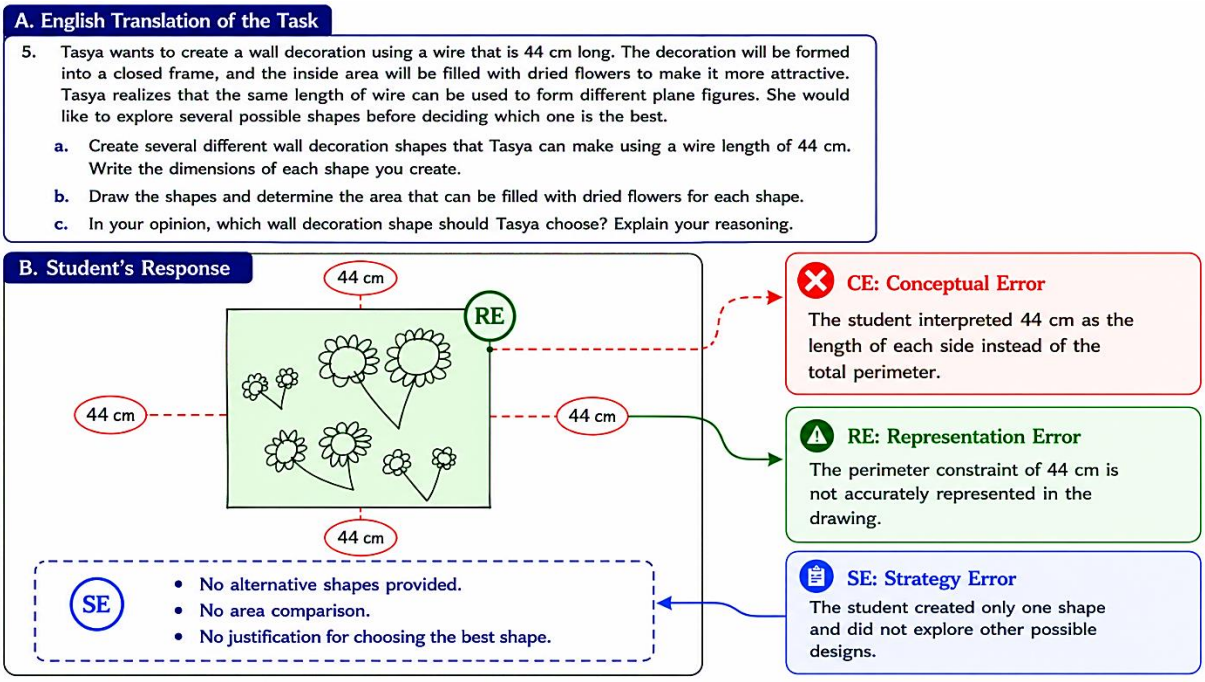


Figure 6. Response of S5 Showing CE, SE, and RE on the Perimeter of Flat Shapes Item

In Figure 6, the student drew a single square with 44 cm written as the side length along its sides with no other shapes and no area calculations. A fundamental CE was identified in that the student equated the length of the wire with the side length rather than the perimeter. The item stated that 44 cm was the total length of the wire, which equals the perimeter of the shape, but the student treated it as the length of one side. This was confirmed through an interview with S5 below.

P : What shape is the decoration you drew and what are its measurements?

S5 : It is a square with a side length of 44 cm.

P : Why did you choose this shape?

S5 : I did not know what else to draw.

P : If the side length is 44 cm what would the perimeter be?

S5 : Four times 44. Oh that means the wire would not be enough right?

S5's statements reveal that the misconception was only recognized after a follow-up question was posed. Once the student computed four times 44, the student saw that the wire would not be enough, which suggests that the idea of perimeter was available but was not applied to the task.

SE emerged because exploration stopped immediately at one shape without attempting other forms. The mean flexibility score on this item was only 0.27 and the mean originality score only 0.11.

RE arose because the square labelled 44 cm on its sides did not represent a wire of that length, which would give a side of 11 cm, and because without more than one valid shape a comparison of areas could not be performed. The mean elaboration score was only 0.07 with 41 students scoring 0, making it the lowest score across all items.

Across the five items, CE was the most frequent error and the first error visible in each representative response. In the representative responses, SE appeared next, in that no workable approach was chosen, and RE appeared whenever the item required a drawing or a data set to be linked to a concept. These responses show the three types together, but Table 3 shows that this full pattern was uncommon in the whole group, so the order is described as a tendency observed within responses and is not treated as evidence of causation. PE, SY, and CO were not observed, which is consistent with students stopping before the procedural stage, although the open-ended design of the items could also have limited the chance for such errors to appear.

Discussion

The results show that the MCTA of low-achieving students is at a very low level. The dominance of scores 0 and 1 across all MCTA components indicates that the majority of students can only respond at the most basic level. This is consistent with the finding of Suherman and Vidákovich (2025) that students' MCTA often fails to develop because instruction has not provided sufficient support for the factors that facilitate creativity. The present finding reinforces that report and shows the shortfall in all four components of MCTA.

Fluency was the strongest component, with an average item mean of 1.16, while the other components averaged 0.66 for originality, 0.43 for elaboration, and 0.35 for flexibility. Fluency requires only a quantity of responses, so a student can score on it without a secure concept. The other components require responses that are valid, different from one another, or developed in detail. Flexibility had the lowest component average, and elaboration on item five had the lowest single mean at 0.07. Both results fit the view that components needing valid and varied responses depend more on conceptual understanding than fluency does.

The findings both reinforce and expand the report of Incikabi (2025). Incikabi (2025) found that students with low creativity tend to produce non-varied responses, and low elaboration scores appear in the present study as well, which reinforces that report. The findings expand it because many students in the present study did not produce a single response meeting the task demands, whereas the low-creativity students in that study still produced mathematically valid responses. A likely reason for this difference is that the tasks used here combine creative demands with conceptual demands. The two studies also differ in tasks and participants, so the comparison remains tentative.

This difference may be related to students' prior conceptual understanding. Ersoy and Kara (2026) found that university students were able to improve elaboration after participating in creative problem-solving instruction because they already possessed a sufficient conceptual foundation. The students analyzed here lacked this foundation on all five items, which is consistent with conceptual understanding acting as a prerequisite for creative responses. Because the two studies differ in age group and design, this reading is an interpretation and not a test of the prerequisite.

This weak conceptual understanding is directly reflected in the main finding of the study, namely CE, which was the most frequent type on every item and was observed in 27 to 40 of the 44 students. The form of CE changed with the content of each item. Students read rule variation as the number of terms in item one, did not treat multiplication as a row-and-column relationship in item two, and wrote quadrilateral without naming the type in item three. In item four the multiplicative relationship in the geometric sequence went unrecognized, and in item five the wire length was equated with the side length instead of the perimeter. Because these misconceptions differ in content yet appear on every item, they are not confined to a single topic and point to a general gap in the concepts that the tasks build on.

A second characteristic of CE is that it was often hidden in the written work. S2's first drawing was correct but had been copied, and S5 recognized the problem with the 44 cm square only after a follow-up question. These cases match the observation of Delastri and Lolang (2023) that CE is the type most difficult to detect and most important to address, and they show the value of interviews for locating it.

These results reinforce earlier work. Kenney and Ntow (2024) explain that low-achieving students consistently struggle to understand the context and demands of tasks from the outset, meaning that failure occurs before creative thinking can even begin. Nufus et al. (2024) reported that incomplete conceptual understanding is the main barrier to the development of students' mathematical creativity. Siregar (2019) also found that creative thinking errors are dominated by failures to understand concepts and difficulties in generating more than one solution approach. Jumariah et al. (2025) found that in creative geometry tasks, students produced many responses but most were mathematically incorrect due to a lack of understanding of the underlying concepts. The results differ from Kholid et al. (2024), who found that students at the lowest creative level were still able to produce at least one valid solution, whereas many students in the present study did not produce a single adequate response. This suggests that MCTA tasks can impose heavier conceptual demands than creative tasks in general, but the tasks and the classification of creative levels differ across the two studies, so the suggestion needs further testing.

Several factors reported in the literature may underlie CE. Weak foundational conceptual understanding is one (Kenney & Ntow, 2024), and instruction that leaves little room for

strengthening concepts before creative demands are introduced is another (Suherman & Vidákovich, 2025). The present data do not isolate these factors, so they are offered as plausible explanations and not as findings.

SE was observed on all five items, in 5 to 30 students per item, and it mostly appeared together with CE, since SE occurred without CE in only 12 of 88 cases. SE occurs when students cannot select an appropriate solution approach because they lack sufficient conceptual understanding. Where SE occurred, students relied on the most familiar and straightforward approach. In item one, students merely extended the example pattern without a strategy for creating new patterns. In item two, factorization was not used as a strategy for finding dimension pairs. In item three, students chose an object already present in the item without exploring other ideas. In item four, the given sequence was not used as the basis for pattern analysis. In item five, students immediately drew one shape without attempting others. SE was less common on items 1 and 5, at 6 and 5 students, than on items 2 to 4.

The interviews show how a missing concept limited the choice of strategy. S1 believed that lengthening the example met the requirement for different rules, so no new strategy seemed necessary. S4 saw only additive differences in the sequence 1, 3, 9, 27, which left no starting point for the later sub-items. S3 said a house was the easiest thing to think of, which shows no search for alternatives. S5 treated 44 cm as the side of a square and did not know what else to draw. In each case the strategy that was missing depended on a concept that the student did not hold.

This pattern fits the report of Ersoy et al. (2025) that low-achieving students tend to rely on the most familiar approach, which prevents creative exploration from developing. It also agrees with Rosyana et al. (2026), who found that low-achieving students depend more on procedural approaches than on creative conceptual exploration in mathematical problem-solving. Benecke and Kaiser (2023) found that in general mathematical task contexts, conceptual, procedural, and factual errors are distributed relatively evenly. The present study differs, since CE was observed on every item, and the contrast suggests that creative tasks require conceptual understanding before any strategy can be chosen. This aligns with findings on PISA-type tasks, where students without adequate conceptual understanding also failed to explore diverse solution strategies even when the task context was meaningfully designed (Nusantara et al., 2026).

RE was observed on items 2 to 5, the items that required a connection between visual representation and mathematical concepts, and it was less frequent than CE, at 5 to 21 students on items 2 to 5. RE mostly appeared together with CE, since it occurred without CE in 9 of 50 cases on items 2 to 5, but it often appeared without SE, in 26 of 50 cases. RE occurs when the drawings or symbols produced by students do not function as mathematical thinking tools because there is no link between the representation and the concept that should underlie it. The cookie arrangement in item two had no dimensions and no connection to factorization. The drawing in item three was not accompanied by an adequate mathematical narrative, the triangles in item four did not follow the recursive structure of the Sierpinski pattern, and the square labelled 44 cm in item five did not represent a wire of that length. In each case the representation existed on the page but did not work as a thinking tool, because the student could not connect it to the concept that should underlie it.

Suherman and Vidákovich (2022) affirm that representation in MCTA assessment directly reflects the depth of students' conceptual understanding, while Lin et al. (2025) found that

students with mathematical difficulties frequently exhibit visual-spatial errors closely linked to the failure to connect representations with mathematical concepts. Kenney and Ntow (2024) add that the failure to use representations meaningfully is one of the most consistent characteristics of low-achieving students. The present study agrees with these reports and adds that, in creative tasks, RE mostly appeared together with CE in the same responses.

Table 4 brings together the characteristics, evidence, possible underlying factors, and relation to earlier studies for each error type.

Table 4. Characteristics, Evidence, Possible Underlying Factors, and Relation to Earlier Studies for Each Error Type

Error type	Characteristics in this study	Evidence across items	Possible underlying factors	Relation to earlier studies
CE	A concept the task builds on is misread or not held. It is often hidden in the written work and revealed through interview.	Item 1, rule variation read as number of terms. Item 2, multiplication not seen as rows and columns. Item 3, quadrilateral not specified. Item 4, multiplicative relationship missed. Item 5, wire length equated with side length.	Weak foundational understanding (Kenney & Ntow, 2024). Instruction with little room for concept building (Suherman & Vidákovich, 2025).	Reinforces Nufus et al. (2024), Siregar (2019), and Jumariah et al. (2025). Differs from Kholid et al. (2024) and Benecke and Kaiser (2023).
SE	No workable approach is chosen. Students rely on the familiar route or a single attempt.	Item 1, example extended. Item 2, factorization unused. Item 3, given object reused. Item 4, given sequence unused. Item 5, one shape drawn.	A concept that is not secure leads to the most familiar approach (Ersoy et al., 2025).	Reinforces Ersoy et al. (2025) and Rosyana et al. (2026).
RE	Drawings, symbols, or data do not work as thinking tools because they are not linked to the underlying concept.	Item 2, no dimensions. Item 3, no mathematical narrative. Item 4, triangles not recursive. Item 5, square did not represent a 44 cm wire.	Failure to use representations meaningfully (Kenney & Ntow, 2024; Lin et al., 2025).	Reinforces Suherman and Vidákovich (2022), Lin et al. (2025), and Kenney and Ntow (2024).

Taken together, the frequencies show CE as the common base of the error patterns. CE was the most frequent type on every item, and SE and RE mostly appeared together with it, since SE occurred without CE in 12 of 88 cases and RE without CE in 9 of 50. The link runs mainly in one direction, because CE appeared without SE in 96 of its 172 occurrences. SE and RE were less closely tied to each other, so the pattern is better described as CE at the base with SE and RE as two further types that tend to accompany it. Figure 7 summarizes this pattern as a framework, and the error types that were not observed, namely PE, SY, and CO, are shown separately.

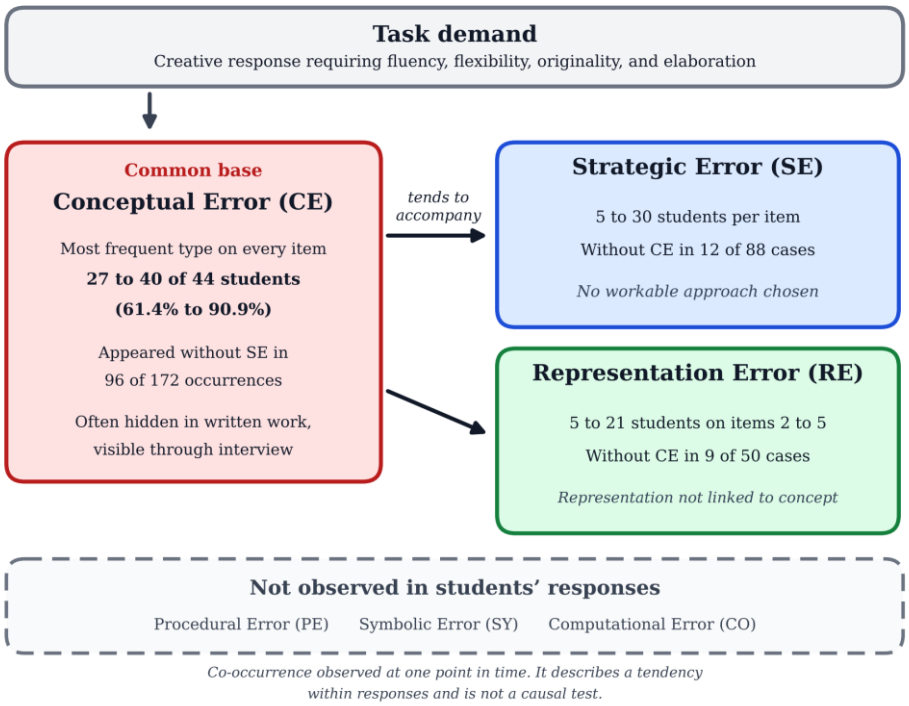


Figure 7. Conceptual Framework of Error Co-occurrence in MCTA Tasks Among Low-Achieving Students

The links in the framework describe tendencies within responses. A strategy is hard to choose when the concept it rests on is misunderstood, and a representation is hard to build meaningfully when the underlying concept is missing. The evidence is the co-occurrence counts in Table 3 and the interview excerpts that tie a missing strategy or representation to a concept the student did not hold. Because the design is cross-sectional, the framework is a proposal for later testing and not a causal model.

The absence of PE, SY, and CO is consistent with CE having constrained students' thinking before calculation or symbolic work was reached. This finding differs from Dorner et al. (2025), who found procedural errors among high school students who already possessed a conceptual foundation. It also differs from Nurhayati et al. (2026), who found procedural error to be the most dominant error type in exponent and logarithm tasks. The differences suggest that creative tasks may place the barrier earlier in the problem-solving sequence than conventional tasks do. An alternative reading is that the open-ended items gave fewer chances for procedural errors to show, a possibility taken up in the limitations.

The main theoretical contribution is a frequency-based account of how error types co-occur on creative tasks. The classification of Lusiana et al. (2025) presents six error types as separate categories, and the present data suggest that on MCTA tasks CE forms the common base, with SE and RE tending to accompany it, so the presence of CE indicates where support is needed first. This extends error analysis to mathematical creative thinking, where the studies reviewed here report error findings within single topics, and it gives researchers a hypothesis to test with other topics and ability groups.

This pattern also bears on assessment. Sainuddin et al. (2022) affirm that sound assessment must accurately identify the location of barriers so that instruction can be directed toward the

root of the problem rather than merely its symptoms. The pattern found here locates that barrier at the conceptual stage for the low-achieving students in this sample.

The instructional implications below are drawn from the literature and from the pattern found here. They are theoretical implications, and this study did not test project-based learning or local contexts. Because CE was the most frequent error and accompanied most SE and RE, improving MCTA would need to begin with strengthening conceptual understanding. Kwon and Lee (2025) found that project-based learning exerts a very large effect on students' creativity because students construct knowledge through real projects that require direct exploration and decision-making. That evidence concerns creativity outcomes and not conceptual understanding among low-achieving students, so it makes project-based learning a candidate approach and not a demonstrated remedy for CE.

A pedagogical mechanism can link local contexts to the formation of concepts. A familiar context lets students use what they already know to give meaning to the terms of a task. A student who has arranged objects in rows and columns or measured a length of wire can tie the words of a task to an action, and a concept built from that action has a concrete referent that a drawing or symbol can later point to. This mechanism would act first on CE, the most frequent error, and could then reduce the chance that SE and RE accompany it. It remains a proposal and not a finding of this study.

Earlier reports support the proposal without confirming it. Nusantara et al. (2025b) showed that locally based cultural contexts effectively help students understand abstract mathematical concepts through authentic experience, while Lusinda et al. (2025) found that local historical object contexts increased student engagement and deepened conceptual understanding. Johar et al. (2025) affirm that the integration of ethnomathematics based on local contexts can build deeper conceptual understanding compared to conventional instruction. These reports did not examine MCTA errors, so they motivate the proposal for low-achieving students and do not establish it.

For project-based learning to support all MCTA components progressively, instructional design would need to encourage deep conceptual exploration and not procedural mastery alone. Nguyen (2025) reviews the growing emphasis on technology integration in project-based learning, and Nusantara et al. (2025c) showed that integrating the PjBL model with innovative media improved fluency, flexibility, originality, and elaboration among pre-service mathematics teachers. That group differs from the junior high school students studied here, so whether the same design would help low-achieving students with severe conceptual barriers is a question for future research.

For teachers, the pattern suggests checking conceptual readiness before assigning tasks that demand creativity, for instance by asking students to explain in their own words what a task asks. A single follow-up question was enough to reveal CE in the interview with S5. Creative tasks that progress gradually from simple to complex demands may also let low-achieving students enter the creative process in a scaffolded way. These are suggestions drawn from the pattern and the literature and have not been tested here.

This study has limits that bound the findings. The analyzed group is 44 low-achieving eighth-grade students from two schools in one province, so the pattern may not hold for other ability levels, grades, or regions. The five items covered number patterns, factorization, flat shapes, geometric sequences, and perimeter, and other topics may give different patterns.

The data were collected at one point in time, so the co-occurrence of CE, SE, and RE is a pattern observed within responses and not evidence of causation. The open-ended items also gave limited chance for PE, SY, and CO to appear, so their absence should not be read as evidence that low-achieving students never make them.

The representative responses were selected by the researchers, which leaves room for subjectivity even with stated indicators, and only five of the 44 students' responses are reported in detail. The coding was done by one researcher and checked by another author.

CONCLUSION

In answer to the first research question, low-achieving students made three of the six error types on MCTA tasks: Conceptual Error (CE), such as reading different rules as more terms; Strategic Error (SE), such as relying on the most familiar approach by extending the given example; and Representation Error (RE), such as a drawing that does not work as a tool for reasoning. Procedural, Symbolic, and Computational Errors were not observed, which is consistent with students' work stopping at the conceptual stage. In answer to the second research question, the error types were interconnected as a pattern of co-occurrence in which CE forms the base. CE was the most frequent type on every item (61.4% to 90.9% of students), and SE and RE mostly appeared together with CE but were less closely tied to each other, so the pattern is not a strict chain. These findings contribute to error analysis in mathematical creative thinking by suggesting that CE is the common base of the error pattern on MCTA tasks, so its presence indicates where support is needed first. Strengthening conceptual understanding, for instance through project-based learning with locally meaningful contexts, is a theoretical implication drawn from the literature that this study did not test. The findings are bounded by the small purposive group from two schools, the five items, the cross-sectional design, and the researchers' selection of representative responses. Future research may examine other topics, ability levels, and larger samples, and may test project-based learning directly.

REFERENCES

Benecke, K., & Kaiser, G. (2023). Teachers' approaches to handling student errors in mathematics classes. *Asian Journal for Mathematics Education, 2*(2), 161–182. https://doi.org/10.1177/27527263231184642

Creswell, J. W. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Delastri, L., & Lolang, E. (2023). Students' conceptual error and procedural error in solving algebraic problems. *Multicultural Education, 9*(1), 18–24. https://doi.org/10.5281/zenodo.7508092

Dorner, C., Ableitinger, C., & Krammer, G. (2025). Revealing the nature of mathematical procedural knowledge by analysing students' deficiencies and errors. *International Journal of Mathematical Education in Science and Technology*, 1–22. https://doi.org/10.1080/0020739X.2024.2445666

Ersoy, E., & Kara, D. O. (2026). The effect of the creative problem solving approach on creative thinking skills. *Frontiers in Psychology, 17*, Article 1734855. https://doi.org/10.3389/fpsyg.2026.1734855

Ersoy, E., Kara, D. O., & Yucel, E. (2025). Unraveling the creative mathematical thinking of primary school children: A qualitative exploration. *The Journal of Educational Research, 119*(2), 174–191. https://doi.org/10.1080/00220671.2025.2525247

Incikabi, S. (2025). Investigating middle school students' creative problem solving in numerical and spatial domains. *Frontiers in Psychology, 16*, Article 1686498. https://doi.org/10.3389/fpsyg.2025.1686498

Johar, R., Fauzan, A., Sugiman, S., Anwar, L., Sa'dijah, C., & Khairunnisak, C. (2025). Developing local instruction theory through ethnomathematics and technological based realistic mathematics education to support students' spatial ability. *Asian Journal for Mathematics Education, 4*(4), 553–587. https://doi.org/10.1177/27527263251383572

Jumariah, E., Sabil, H., & Junita, R. (2025). An analysis of students' creative thinking errors in solving polyhedra problems. *Jurnal Pendidikan Matematika (JPM), 11*(2), 202–211. https://doi.org/10.33474/jpm.v11i2.24683

Kenney, R., & Ntow, F. D. (2024). Unveiling the errors learners make when solving word problems involving algebraic task. *SAGE Open, 14*(4), Article 21582440241299245. https://doi.org/10.1177/21582440241299245

Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education, 11*(1), Article 2394738. https://doi.org/10.1080/2331186X.2024.2394738

Kwon, H., & Lee, Y. (2025). A meta analysis of STEM project based learning on creativity. *STEM Education, 5*(2), 275–290. https://doi.org/10.3934/steme.2025014

Lin, X., Riccomini, P. J., & Liang, X. (2025). Mathematical error patterns of students with mathematics difficulty: A systematic review. *Learning Disability Quarterly, 48*(2), 115–128. https://doi.org/10.1177/07319487241310873

Lusiana, R., Andari, T., Elvierayani, R. R., & Huda, S. (2025). Patterns of pre-service mathematics teachers' scaffolding shaped by students' error diagnosis. *Journal on Mathematics Education, 16*(4), 1167–1192. https://doi.org/10.22342/jme.v16i4.pp1167-1192

Lusinda, U., Pasaribu, F. T., Gustiningsi, T., & Nusantara, D. S. (2025). Pengembangan soal matematika tipe PISA konten uncertainty and data menggunakan konteks Museum Siginjai Jambi. *Numeracy, 12*(1), 99–117. https://doi.org/10.46244/numeracy.v12i1.3128

Nguyen, D. T. (2025). Project-based learning (PjBL) as an experiential pedagogical methodology in interdisciplinary education: A review of the literature. *International Journal of Education in Mathematics, Science and Technology, 13*(4), 1016–1039. https://doi.org/10.46328/ijemst.4869

Nufus, H., Muhandaz, R., Hasanuddin, Nurdin, E., Ariawan, R., Fineldi, R. J., Hayati, I. R., & Situmorang, D. D. B. (2024). Analyzing the students' mathematical creative thinking ability in terms of self-regulated learning. *Heliyon, 10*(3), Article e24871. https://doi.org/10.1016/j.heliyon.2024.e24871

Nurhayati, A., Prabawanto, S., & Novianingsih, K. (2026). Eksplorasi kesalahan siswa kelas X dalam menyelesaikan soal eksponen dan logaritma berdasarkan kategori Watson. *JPMI (Jurnal Pembelajaran Matematika Inovatif), 9*(1), 201–212. https://doi.org/10.22460/jpmi.v9i1.29615

Nusantara, D. S., Zulkardi, Z., & Putri, R. I. I. (2025a). Investigating students' mathematical argumentation ability in solving PISA like mathematics on change and relationships. *Mathematics Education Journal, 19*(4), 807–826. https://doi.org/10.22342/mej.v19i4.pp807-826

Nusantara, D. S., Ibarra, F. P., Pasaribu, F. T., & Lusinda, U. (2025b). Designing JUMPISA: A PISA based jumping task to support students' statistical literacy using Jambi context. *Journal of Instructional Mathematics, 6*(2), 96–116. https://doi.org/10.37640/jim.v6i2.2518

Nusantara, D. S., Pasaribu, F. T., Gustiningsi, T., & Abdullah, A. H. (2025c). Developing mind

mapping based pocketbook with augmented reality to support creative thinking skills in pre service mathematics teachers. *SJME (Supremum Journal of Mathematics Education), 9*(2), 297–317. https://doi.org/10.35706/sjme.v9i2.204

Nusantara, D. S., Herlambang, S. B., Pasaribu, F. T., & Maphutha, K. (2026). Developing PISA-like task using climate change contexts to enhance students' statistical literacy. *JRAMathEdu (Journal of Research and Advances in Mathematics Education), 11*(2), 155–176. https://doi.org/10.23917/jramathedu.v11i2.15181

Rosyana, T., Juniati, D., & Khabibah, S. (2026). Eksplorasi berpikir kreatif siswa dalam pemecahan masalah matematika berbasis computational thinking. *JPMI (Jurnal Pembelajaran Matematika Inovatif), 9*(1), 75–84. https://doi.org/10.22460/jpmi.v9i1.30720

Sainuddin, S., Subali, B., Jailani, & Elvira, M. (2022). The development and validation prospective mathematics teachers holistic assessment tools. *Ingenierie Des Systemes d'Information, 27*(2), 171–184. https://doi.org/10.18280/isi.270201

Siregar, H. M. (2019). Analisis kesalahan siswa dalam menyelesaikan soal tes kemampuan berpikir kreatif matematis materi lingkaran. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 8*(3), 497–507. https://doi.org/10.24127/ajpm.v8i3.2379

Suherman, S., & Vidákovich, T. (2022). Assessment of mathematical creative thinking: A systematic review. *Thinking Skills and Creativity, 44*, Article 101019. https://doi.org/10.1016/j.tsc.2022.101019

Suherman, S., & Vidákovich, T. (2025). Creative self efficacy, attitudes, creative style, and environmental literacy: Promoting mathematical creative thinking. *The Journal of Educational Research, 118*(5), 475–485. https://doi.org/10.1080/00220671.2025.2495329

Wright, B. D., & Masters, G. N. (2002). Number of person or item strata: (4*separation + 1)/3. *Rasch Measurement Transactions, 16*(3), 888. https://www.rasch.org/rmt/rmt163f.htm.