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Analysis of Errors Made by Students with Low Computational Thinking Levels Using the Newmann Procedure

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Abstract

Computational thinking plays a crucial role in strengthening strategies for solving complex problems. However, many students are still found to have low computational thinking abilities, which are attributed to errors occurring during the problem-solving process based on computational thinking. This study aims to analyze the errors made by students with low computational thinking abilities when solving rational number problems using the Newmann procedure. The method employed is descriptive analysis of the responses from students with low computational thinking abilities, following the Newmann procedure. The analysis revealed that comprehension errors were the most frequently observed type of error in solving rational number problems based on computational thinking indicators, particularly in problems assessing decomposition, algorithmic thinking, and generalization. Other types of errors were also identified, including reading and transformation errors in problems assessing abstraction, process errors in problems measuring decomposition, and final answer errors in problems evaluating decomposition, abstraction, and generalization. The results of this study indicate that low computational thinking abilities in students can be attributed to errors summarized in the Newmann procedure, and it offers recommendations for enhancing computational thinking by considering interventions that can minimize these types of errors.

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INTRODUCTION

Computational thinking is a crucial skill that plays a significant role in strengthening digital competencies and strategies for solving complex problems (Izquierdo-Álvarez & Pinto-Llorente, 2025). In education, this skill opens opportunities to develop higher-order thinking abilities through algorithmic thinking processes (Angeli & Giannakos, 2020). Additionally, computational thinking is closely related to metacognitive strategies that contribute to students' academic success (Yadav et al., 2022).

The integration of computational thinking in mathematics education can be applied from primary education to higher education. In STEM education, this skill supports problem-solving activities based on real-world contexts, including the use of computational modeling in complex situations (Wang et al., 2021). Rich et al. (2022) emphasize that the application of computational thinking in mathematics can enhance cognitive demands and student engagement. In other words, this approach can shift learning from being purely procedural to fostering a more meaningful and applicable understanding of concepts (Li et al., 2020).

However, various studies suggest that the computational thinking skills of Indonesian students remain underdeveloped. Research by Salwadila and Hapizah (2024) shows that many students are unable to optimally apply computational thinking strategies in solving mathematics problems. The results of the 2024 Bebras Challenge also confirm this trend, with most participants from Indonesia scoring below the national average. This condition highlights the ongoing challenges in developing computational thinking skills in schools.

Rational number problems play a crucial role in fostering computational thinking in mathematics education. Francis and Davis (2021) argue that the context of rational numbers can simultaneously trigger decomposition and generalization processes during problem-solving. This occurs because solving rational number problems requires identifying critical information to simplify the problem and applying it to broader contexts. Moreover, rational number problems necessitate algorithmic thinking that must be executed accurately and systematically, as procedural steps are fundamental to understanding rational number concepts (Vallejo, 2020). Similarly, when rational number problems are presented in a contextualized format, they strongly stimulate abstraction during problem-solving. Consequently, this topic provides an ideal context for integrating and practicing all core components of computational thinking in mathematics.

Compared to other topics, such as algebra or number patterns, which tend to emphasize only abstraction or algorithmic thinking (Chan et al., 2021; Sarmasági et al., 2025), rational numbers offer a systematic thinking process that can be effectively observed and developed across the four primary computational thinking indicators. In a broader context, insufficient understanding of rational numbers has long-term implications for arithmetic skills and success in higher-level mathematics learning (Siegler & Lortie-Forgues, 2017). Solving rational number problems requires conceptual understanding, reasoning, and strategic adaptation according to the problem context, particularly in realistic scenarios (González-Forte et al., 2022). Lemonidis and Pilianidis (2020) found that students tend to rely on a single strategy when performing operations with rational numbers, indicating limitations in both flexibility and conceptual understanding.

Several studies also emphasize that rational numbers are a challenging topic, so students' errors in this area require in-depth analysis (Gilmore et al., 2024; Siegler & Lortie-Forgues, 2017). Moreover, rational number material can be designed in line with higher-order thinking indicators, including within the framework of computational thinking (Chan et al., 2021). Therefore, this topic is considered suitable for analyzing students' computational thinking abilities while simultaneously identifying errors that occur in the problem-solving process.

Student errors in solving mathematical problems can serve as valuable sources of information. For students, errors help reinforce conceptual understanding, while for teachers, identifying these errors forms the basis for planning, implementing, and evaluating learning (Khasawneh et al., 2023). One approach that can be used to examine these errors is the Newmann procedure, which identifies in reading, problem comprehension, transformation, calculation, and final answer stages (Alghadari et al., 2022; Obeng et al., 2024; Rohmah & Sutiarso, 2017).

Student errors in solving mathematical problems can serve as valuable sources of information. For students, errors help reinforce conceptual understanding, whereas for teachers, identifying these errors provides a basis for planning, implementing, and evaluating the learning process (Khasawneh et al., 2023). One approach to examining these errors is the Newman procedure, which identifies errors in the stages of reading, comprehension, transformation, calculation processes, and writing the final answer (Obeng et al., 2024; Rohmah & Sutiarso, 2017). In the context of problem-solving based on computational thinking, Maharani et al. (2019) demonstrated that students still make errors at the abstraction stage due to difficulties in understanding the given mathematical problems. Similarly, Fitrisyah et al. (2024) reported frequent student errors in decomposition and algorithmic thinking, especially in calculations and final answers. Furthermore, Anggraeni and Nurlaelah (2025) specifically identified forms of errors consistent with the Newman procedure across all stages of computational thinking.

The importance of analyzing errors in mathematical problem-solving related to computational thinking indicators has been previously highlighted by Anggraeni and Nurlaelah (2025), who identified student errors in solving systems of linear equations through the stages of computational thinking. Their study focused on a descriptive analysis of errors in student responses that reflected computational thinking indicators. However, the study did not integrate a specific error analysis method, such as the Newman procedure, which categorizes errors systematically in mathematical problem-solving. Furthermore, their findings did not focus on students with low computational thinking abilities. Meanwhile, Suseelan et al. (2022) demonstrated that errors in the problem-solving process are more frequently observed among low-performing students. Based on these findings, the present study emphasizes the urgency of analyzing errors among students with low computational thinking abilities by applying a widely used error analysis method in mathematical problem-solving, namely the Newman procedure.

Based on the background, the purpose of this study is to analyze the errors made by students with low computational thinking abilities when solving rational number problems using the Newmann procedure. Specifically, this study addresses the following research questions: (1) What types of errors arise among students with low computational thinking abilities in solving rational number problems? (2) How are these errors related to the stages of computational thinking, such as decomposition, abstraction, algorithmic thinking, and generalization? The findings of this study can provide valuable insights into mathematics education, particularly in enhancing computational thinking in students on the topic of rational numbers.

RESEARCH METHODS

This research utilizes a descriptive qualitative design. It was conducted to analyze and describe the types of errors made by seventh-grade students with low computational thinking skills when solving problems based on the indicators of computational thinking, referring to the Newmann procedure. The instruments used in this study were a test instrument and documentation. The test instrument included contextual problems to measure the decomposition and abstraction indicators, as well as procedural and complex problems to assess the algorithmic thinking and generalization indicators, as detailed in the Appendix A. The instrument underwent validation by three experts experts in mathematics education and reliability testing. The results of the validation conducted are presented in Table 1.

Table 1. Results of Validity Test

Item Number	V1	V2	V3	Decision
Q1	1	1	1	Valid
Q2	0	1	1	Valid
Q3	1	1	0	Valid
Q4	1	1	1	Valid

The conclusion from the expert validation of the test instrument is that all four test items were deemed valid with minor revisions. Following expert validation and subsequent revisions, the instrument was pilot-tested on 23 seventh-grade students outside the research sample, with the results shown in Table 2.

Table 2. Results of the Reliability Test

Reliability Test	Number of Students	Cronbach's Alpha Value
Cronbach Alpha	23	0.63

The results in Table 2 show that the Cronbach's Alpha value is 0.63>0.05, indicating that the instrument is reliable for use in the research. The research was carried out at SMP Negeri in Yogyakarta, with the research subjects consisting of 48 seventh-grade students who had studied rational number material. The students included 26 females and 22 males with heterogeneous academic abilities. Data collection was conducted using a random sampling technique, which is a sampling method in which every member of the population has an equal and measurable chance of being selected (Bhardwaj, 2019). The data collected in this study consisted of the students' answers, which will be used to determine their computational thinking skills. The indicators and scoring guidelines for the computational thinking test are presented in Table 3.

Table 3. Scoring Guidelines for the Computational Thinking Test

Aspect	Indicator	Score	Explanation
Decomposition	The student is able to break down the problem into smaller, more manageable components.	3	The student can group information according to the specified aspect and provide a correct answer.
		2	The student can group information according to the specified aspect but provides an incorrect answer.
		1	The student does not group information according to the specified aspect.

(*continued on next page*)

Table 3. (*continued*)

Abstraction	The student can create a model or representation of relevant aspects of the given problem.	3	The student can model a contextual problem into a mathematical operation with a correct result.
		2	The student can model a contextual problem into a mathematical operation, but the result is incorrect.
		1	The student does not model the contextual problem into the correct mathematical operation.
Algorithmic Thinking	The student can determine the correct procedure for solving the problem.	3	The student is able to identify the correct procedure and provide the accurate solution.
		2	The student is able to identify the correct procedure but provides an incorrect answer.
		1	The student is unable to identify the correct procedure for solving the problem.
Generalization	The student can identify a solution pattern and apply it to other contexts.	3	The student is able to identify the common difference between terms in a sequence and generate a new sequence with the same common difference.
		2	The student can identify the common difference between terms in a sequence but fails to create a new sequence with the same common difference.
		1	The student is unable to identify the common difference between terms in a sequence and does not apply it to solve the problem.

The data from the computational thinking assessment were analyzed descriptively, following the data analysis steps outlined by Widoyoko (2009), in order to determine the criteria for students' computational thinking levels as shown in Table 4.

Table 4. Criteria for Computational Thinking

Interval	Criteria
$X + M_i + 1.8Sbi$	Very High
$M_i + 0.6Sbi < X < M_i + 1.8Sbi$	High
$M_i - 0.6Sbi < X < M_i + 0.6Sbi$	Middle
$M_i - 1.8Sbi < X < M_i - 0.6Sbi$	Low
$X < M_i - 1.8Sbi$	Very Low

Students who obtained computational thinking scores in the low and very low categories were subsequently analyzed for errors using the Newmann procedure. The students' errors were analyzed according to the five aspects of errors in the Newmann procedure, namely reading errors, understanding errors, transformation errors, process errors, and final answer writing errors (Obeng et al., 2024), as detailed in several indicators in Table 5.

Table 5. Types of Errors and Indicators Based on the Newmann Procedure

Error Indicator	Type of Error	Code
a. The student writes information that differs from the information given in the problem.	Reading Error	A
b. The student does not use the given information correctly.	Understanding Error	B
c. The student does not use the requested information correctly.	Understanding Error	B
d. The student incorrectly applies a symbol or mathematical operation to the given data.	Transformation Error	C
e. The student incorrectly applies a mathematical rule or principle.	Process Error	D
f. The student makes a calculation error.	Process Error	D
g. The student writes the final conclusion incorrectly.	Final Answer Writing Error	E

RESEARCH RESULTS

Summary of data analysis and research results are presented in the following subsections.

Overview of Computational Thinking Levels

The results of the computational thinking test, which includes key indicators: decomposition, abstraction, algorithmic thinking, and generalization with using rational number material, show that the ideal maximum score is 12, the ideal minimum score is 4, the ideal mean score (Mi) is 8, and the ideal standard deviation (Sbi) is 2. Therefore, the general overview of students' computational thinking levels can be identified as shown in Table 6.

Table 6. Students' Computational Thinking Levels

Computational Thinking Levels	Number of Students	Percentage
Very High	5	10.41%
High	15	31.25%
Middle	21	43.75%
Low	5	10.41%
Very Low	2	4.17%

Based on the results shown in Table 4, the average student has a moderate level of computational thinking. However, there are still seven students who fall into the categories of low and very low computational thinking. Therefore, the final answers of these seven students will be analyzed for errors using the Newmann Procedure.

Overview of Errors Made by Students with Low Computational Thinking

According to the Newmann procedure, the types of errors made by students in solving problems can be analyzed using five main aspects: reading errors (code A), understanding errors (code B), transformation errors (code C), process errors (code D), and final answer writing errors (code E). Students who did not provide an answer are assigned code F. An overview of the types of errors made by students with low computational thinking levels on rational number problems based on computational thinking indicators is shown in Table 7.

Table 7. Types of Errors Made by Students with Low Computational Thinking Levels Based on the Newmann Procedure

Student Number	Type of Error			
	Q1	Q2	Q3	Q4
S1	A	-	B	B
S2	D	C	-	E
S3	F	C, E	-	B
S4	B, D	C	B	B
S5	B, D	F	B	B
S6	F	F	B	B
S7	D	C	B	F

Table 5 shows that the types of errors made by students with low computational thinking levels on rational number problems, based on computational thinking indicators, vary when analyzed using the Newmann Procedure. A summary of the types of errors made by the students is presented in Figure 1.

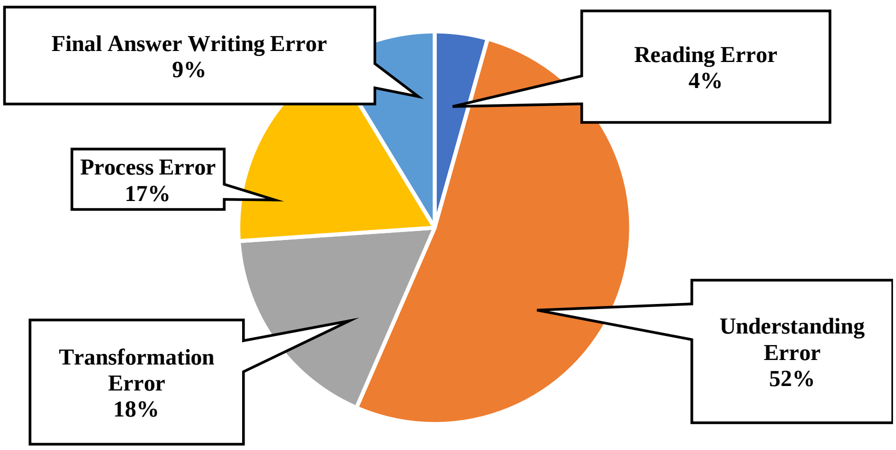


Figure 1. Summary of the Types of Errors Made by Students

Reading Errors

Only one student made a reading error on Question 1, which measures the decomposition indicator of computational thinking. According to Monika et al. (2025), reading errors arise when students fail to interpret the sentences they read accurately. In this study, such reading errors were observed when the student recorded information that differed from the details provided in the problem, as illustrated in Figure 2.

Subject 1's Answer to question 1:

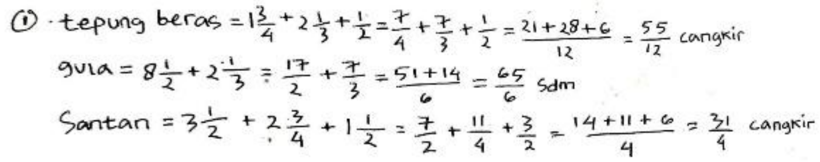


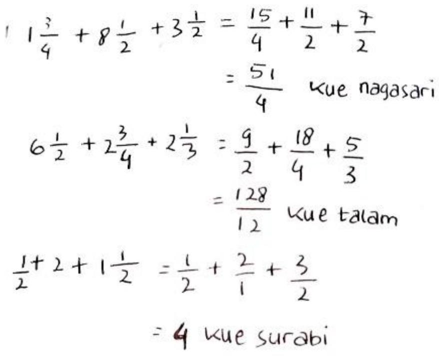
Figure 2. Reading Errors in the Student's Answer

In Figure 2, Student 1 recorded the amount of sugar needed as 17/2 tablespoons and 7/3 tablespoons. However, based on the information provided in the problem, the correct amount of sugar required is 1/2 tablespoon, 13/2 tablespoons, and 2 tablespoons.

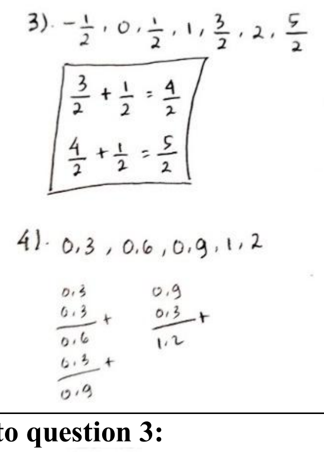
Understanding Error

Understanding error occurs when a student is capable of reading the problem but fails to understand what is being asked or required, leading to the failure to solve the problem (Singh et al., 2010). In this study, understanding errors were observed when students did not use the given or required information correctly. Two students, specifically Student 4 and Student 5, made understanding errors in Question 1. Meanwhile, in Questions 3 and 4, most students experienced errors in understanding the information provided or asked in the questions. Therefore, understanding errors were the most prevalent type of error in this analysis, accounting for 52%. An example of the errors made by students is shown in Figure 3.

Subject 4's answer to question 1:



Subject 3's answer to question 3 and 4:



Subject 7's answer to question 3:

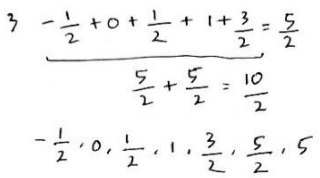


Figure 3. Understanding Errors in the Student's Answer

Figure 3 shows that Subject 4 made an error in Question 1, specifically in their inability to use the requested information correctly. The student failed to classify the requirements for rice flour, sugar, and coconut milk separately. Similarly, Student 3 made an error in Question 4. Although Student 3 essentially identified the pattern in Question 3, they failed to comprehend the information asked in Question 4, which involved using the difference between terms found in Question 3 to form a new sequence for Question 4. This indicates that Student 3 did not understand the information requested in Question 4.

Figure 3 also illustrates that Subject 7 did not utilize the information provided in the problem accurately. The instructions in the question directed students to find the number in the subsequent term of the sequence. However, Subject 7 summed all terms to find those numbers.

Transformation Error

Transformation errors occurred when four students worked on Question 2, which assesses students' abstraction abilities within computational thinking. Suratih and Pujiastuti (2020) define transformation errors as a type of mistake based on Newmann's procedure, which can be identified when students incorrectly choose the operation needed to solve the problem. In this research, transformation errors were made by Subjects 2, 3, 4, and 7. An example of the error made by one of the students is shown in Figure 4.

Subject 7's answer to question 2:

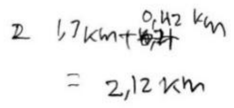


Figure 4. Transformation Errors in the Student's Answer

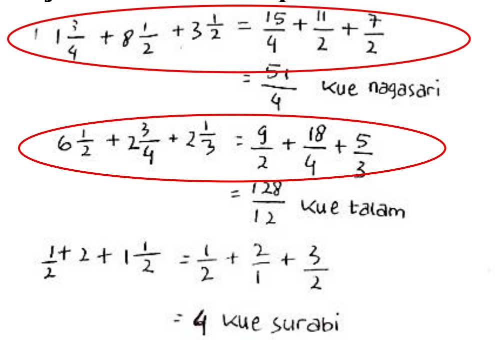
Figure 4 shows that Subject 7 made an error in transforming the context of the problem into a mathematical operation. The student selected the addition symbol in the context of the problem, whereas subtraction should have been used.

Process Error

Process errors refer to mistakes made by students when they do not apply the correct mathematical principles or make errors during the calculation process (Suratih & Pujiastuti, 2020). Similarly, in this study, process errors were observed when students incorrectly applied mathematical rules or made errors in their calculations. Process errors occurred in the solution to Question 1, which measures the decomposition indicator in computational thinking. Four students made process errors, and an example of such an error is shown in Figure 5.

Figure 5 shows that Subject 4 made a process error in Question 1, specifically by incorrectly applying the correct mathematical rules or principles. Subject 4 made a mistake in converting a mixed fraction into an improper fraction. A similar error is shown in Subject 2's response, who made a calculation process error.

Subject 4's answer to question 1:



Subject 2's answer to question 1:

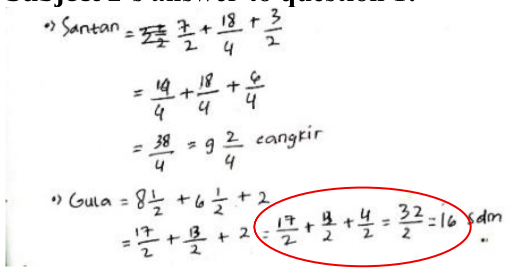
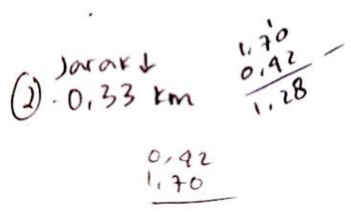


Figure 5. Process errors in the student's answer

Final Answer Writing Error

Final answer errors (encoding errors) occur even when students correctly solve the mathematical problem, but due to carelessness, they write the final answer incorrectly (Singh et al., 2010). In this study, final answer errors were also observed when students correctly performed the calculation process but made a mistake in writing the final conclusion. Two students made final answer errors: Subject 5 in Question 2, and Subject 7 in Question 4, as shown in Figure 6.

Student 5's answer to question 2:



Student 7's answer to question 4:

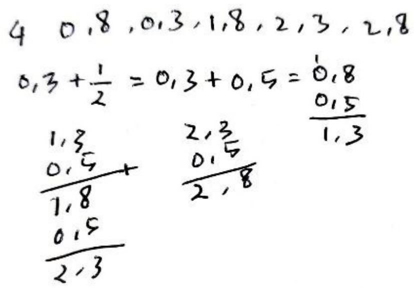


Figure 6. Final answer writing errors in the student's answer

Based on Figure 6, it can be observed that Subjects 5 and 7 performed the correct calculation processes in Question 2 and Question 4, respectively. However, their final answers differ from the actual calculated results. Therefore, these students made final answer errors.

DISCUSSION

The results of the study indicate that students' computational thinking abilities vary. A total of 10.41% of students demonstrate very high computational thinking skills; 31.25% possess high skills; and the majority, 43.75%, exhibit moderate computational thinking skills. However, this study focuses on students with low and very low abilities, which represent 10.41% and 4.17%, respectively. These findings support previous research showing that computational thinking skills among Indonesian students have not developed uniformly, particularly when students face complex mathematical problems that require decomposition, abstraction, and generalization (Fitrisyah et al., 2024; Nurwita et al., 2022).

Seven students' responses were analyzed using Newmann's procedure. The most frequent error type identified in this study was comprehension errors, which accounted for 52% of the students analyzed. These comprehension errors were observed in problem-solving involving decomposition (2 students), abstraction (5 students), and generalization (5 students). This finding is consistent with the theory by Singh et al. (2010), which explains that comprehension errors typically arise when students fail to link the information in the problem to the relevant mathematical representation. In the context of computational thinking, weak decomposition and abstraction skills hinder students from identifying critical information (Abidi et al., 2023; Qian & Choi, 2023). Consequently, subsequent steps such as determining operations, selecting procedures, and formulating final answers become inaccurate. Similar errors were found by Chan et al. (2021), who observed that students with low computational thinking abilities tend to fail in constructing the correct mathematical model from the given context.

In addition to comprehension errors, 18% of transformation errors were found in student responses, particularly in problems involving abstraction, with 4 students making errors. Students who selected the wrong mathematical operations demonstrated their inability to translate contextual information into the correct mathematical expression. This finding aligns with González-Forte et al. (2022), who emphasize that selecting operations in rational numbers is a particular challenge for students, especially those who are not accustomed to associating real-world situations with mathematical symbols.

The third most frequent error, accounting for 17%, was process errors, found in problems containing decomposition indicators, affecting 4 students. These errors indicate that students with low computational thinking abilities tend to lack a sound computational process. According to Li et al. (2020), the ability to determine step-by-step procedures is a crucial component of computational thinking and significantly affects success in solving mathematical problems. Furthermore, only one instance of final answer writing errors was found, meaning the student was able to perform the calculations correctly but was inconsistent in writing their conclusions in alignment with the calculations, leading to an answer that diverged from the procedure they followed. This finding supports the concept of coding errors in Newmann's procedure and shows that some students have not yet developed the habit of reviewing their work (Syarnubi et al., 2024).

The data obtained from the students' responses confirms that low computational thinking skills directly influence the emergence of various types of errors based on Newmann's procedure. As stated by Suseelan et al. (2022), errors in the math problem-solving process are more frequently observed among low-performing students. The findings of this study strengthen the view that computational thinking is closely related to the quality of mathematical problem-solving. Rich et al. (2022) note that computational thinking is not just about using computers but also involves systematic and reflective thinking skills. When these skills are low, students' tendency to make errors increases. This study also complements the findings of Suratih and Pujiastuti (2020), offering new insights by integrating error analysis using Newmann's procedure for students with low computational thinking skills in the context of rational numbers.

The contribution of this study lies in the more detailed mapping of errors related to the indicators of computational thinking. Through this mapping, teachers or other researchers can minimize the most frequent errors and their causes by applying appropriate treatments to improve computational thinking through the development of its indicators. However, this study has limitations. In-depth analysis was conducted on only seven students, so the findings do not represent the entire population. This study also relied solely on written data without interviews, meaning that the students' thought processes were not fully explored. These limitations provide opportunities for future research using triangulation methods or developing computational thinking-based learning interventions to examine changes in students' error patterns more comprehensively.

CONCLUSION

The findings of this study indicate that the majority of students demonstrated computational thinking skills at a moderate level. However, seven students fell into the low and very low categories and were analyzed further using the Newman procedure. The analysis revealed that comprehension errors were the most frequently observed type of error in solving rational number problems based on computational thinking indicators, particularly in problems measuring decomposition, algorithmic thinking, and generalization. Other types of errors were also identified, including reading and transformation errors in problems assessing abstraction, process errors in problems measuring decomposition, and final answer errors in problems assessing decomposition, abstraction, and generalization. These findings suggest that low computational thinking abilities may be associated with errors in reading, comprehension, transformation, process execution, and final answer writing. However, this study has limitations, as the data collection focused solely on the students' answer sheets without including interviews. This limitation provides a recommendation for similar studies to implement data triangulation in qualitative research. Additionally, the results provide recommendations for future research aimed at enhancing students' computational thinking, particularly in the topic of rational numbers, by considering interventions that can minimize these types of errors.

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APPENDIX

Computational Thinking questions on the topic of rational numbers can be accessed through this link: https://bit.ly/RationalNumberCTQuestions.