JURNAL EDUSCIENCE (JES)
p-ISSN : 2303 - 355X | e-ISSN : 2685 - 2217
PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

Analysis of Student Errors in Computational Thinking Based on Newman's Error Analysis in Statistics

Raden Arsyilia Putri Makin Nabila[1], Rizky Rosjanuardi[2], Siti Fatimah[3]

[1]Department of Mathematics Education, Universitas Pendidikan Indonesia, Jawa Barat, Indonesia
[2,3]Department of Mathematics, Universitas Pendidikan Indonesia, Jawa Barat, Indonesia
*Email: rizky@upi.edu

ARTICLE INFO

Keywords:
Computational thinking
Student errors
Newman's prosedure
Statistics

ABSTRACT

Purpose – Computational thinking is a fundamental skill every individual must possess, alongside reading and writing. Limitations in implementing this skill lead to student errors. This study aims to analyze errors in computational thinking using Newman's error analysis in statistics.

Methodology – The research method was qualitative, using a case study approach, and was conducted with 17 ninth-grade students from a junior high school in Garut Regency who had studied statistics. Three students were selected as subjects, each representing a different category of computational thinking. Data were collected through a computational thinking essay test containing decomposition, pattern recognition, abstraction, and algorithmic thinking in each question, as well as interview results.

Findings – S1, S2, and S3 made errors in the computational thinking components. In decomposition, S1 and S2 made no errors, while S3 made a comprehension error. In pattern recognition, S1 made no errors, while S2 and S3 made understanding errors. In abstraction, S1 also made no errors, whereas S2 and S3 made errors in understanding and transformation. In algorithmic thinking, all three subjects made errors, specifically process skills errors and errors in writing the final answer.

Contribution – This study contributes to educational assessment by showing how Newman Error Analysis evaluates students' cognitive processes in computational thinking within mathematics learning. The findings provide diagnostic information that helps teachers make instructional decisions, develop targeted interventions, and improve evaluation practices in statistics education.

Received 29 Maret 2026; Received in revised form 18 April 2026; Accepted 19 June 2026
Jurnal Eduscience (JES) Volume 13 No. 1 (2026)
Available online 30 June 2026

INTRODUCTION

Computational thinking is a framework that every individual needs. As Wing (2006) noted, computational thinking is a fundamental skill that is just as important for students to master as reading and arithmetic. This ability has become a focal point for educators and educational researchers worldwide, including in the Indonesian education system, where computational thinking is a key component of the curriculum. In the Indonesian curriculum, computational thinking is integrated across various subjects at all levels of education; mathematics is one such subject. This skill is widely recognized as a critical component of problem-solving education. Computational thinking also plays a crucial role in solving real-world mathematical problems and can be applied across various topics in mathematics education, including statistics. This is consistent with research indicating that computational thinking is highly relevant to statistics, as statistics involves collecting, analyzing, and interpreting data. Furthermore, statistics problems are typically presented in a contextual format, requiring students to understand the problem, extract information, perform analysis, and develop solutions following logical steps.

The implementation of computational thinking has not been fully effective in Indonesian education. Several limitations contribute to this, including insufficient teacher training, inadequate infrastructure, and curriculum-related challenges. Research by Irawan et al. yielded similar findings, indicating that the primary barriers to implementing computational thinking are a lack of skills, time, and access to professional development opportunities. Consequently, students' computational thinking abilities in problem-solving remain low (Fitrisyah et al., 2025). This situation shows that students still make various errors when applying computational thinking to solve mathematical problems.

Various studies show that computational thinking errors do not occur in isolation within each component but are interrelated, forming a continuous chain of errors. The findings of Ahmad et al. (2026) indicate that students' mastery of algorithmic thinking components remains low, with some students still making errors in the final stages of calculation. This aligns with the findings of Anggraeni & Nurlaelah (2025), who reported that students make errors across all components of computational thinking; the highest percentage of errors occurs in the algorithmic thinking component, specifically when students design and execute solution steps. However, these errors are also a consequence of errors occurring in the preceding component, namely, abstraction. This finding is supported by Hudzaifah (2023), who states that errors in the abstraction stage often affect the subsequent stage, algorithmic thinking. Thus, students' low ability to formulate solution steps not only indicates a weakness in the algorithmic thinking component but also suggests that conceptual understanding in the preceding stage is not yet optimal.

Patterns of interrelationships among components are also evident in the early stages of computational thinking. Research by Nabila et al. (2025) found that students made errors in the decomposition component, specifically, they incompletely decomposed the information, failing to include the cost information listed in the question. This has the potential to hinder students' ability to recognize the relationships or patterns required in the pattern recognition stage. In the study by Lisa et al. (2024), it was shown that students' errors in pattern recognition stem from their inability to organize information into patterns. This can hinder students at the abstraction stage by making it difficult to identify the relevant information needed to construct a mathematical model. This aligns with the findings of Khoirunnisa et al. (2025), who found that students make errors when creating mathematical models because they do not understand the symbolic meaning of variables, leading to models that lack meaning. These findings indicate that computational thinking errors do not occur in isolation but develop gradually. When viewed holistically, these computational thinking errors can be understood as hierarchical. Errors that arise during the decomposition stage can affect students' success in identifying patterns, thereby impacting their ability to abstract and, ultimately, to formulate solution steps during the algorithmic thinking stage. Thus, students' errors in the components of algorithmic thinking are not always caused solely by procedural weaknesses but can result from the accumulation of errors occurring in previous components.

According to Yarman et al. (2025), error analysis not only identifies the causes of recurring student errors but also serves as a powerful tool for diagnosing learning difficulties and guiding remedial instruction, enabling teachers to provide targeted instruction tailored to students' needs. M. Anne Newman developed a method for analyzing student errors known as Newman's Error Analysis (NEA) or the Newman procedure (Fauzi et al., 2022). The Newman procedure is an analytical method for examining errors in problem-solving in detail (Mubarokah & Amir, 2024) because it provides a framework for identifying the underlying causes of errors students experience when solving math word problems (Fineldi & Jupri, 2026). Unlike Polya, who focuses more on the problem-solving process (Firdausi et al., 2021), Watson, who categorizes errors in general (Nurhayati et al., 2026), and Kastolan, who does not map out the sequence of problem-solving steps (Sumargiyani, 2026), the Newman procedure helps teachers guide the use of effective learning approaches to address students' difficulties (Sundayana & Parani, 2023). According to Newman (1977, in Ellerton & Clements, 1978), solving written math problems requires following a fixed sequence: students go through the stages of reading, comprehension, transforming the problem into a mathematical form, applying process skills, and encoding the final answer. Thus, error analysis aims to identify the types and causes of student errors, in line with the approach outlined in Newman's Error Analysis, making this procedure highly relevant for analyzing student errors in this study.

Although previous studies have examined students' errors in solving mathematical problems, including those involving the Newman procedure, studies that combine the Newman procedure with computational thinking remain limited. Research by Fatmawati & Nasution (2024) has integrated the Newman procedure with computational thinking skills. However, the study's use of computational thinking primarily served to categorize skills as high, moderate, or low. Consequently, the study did not explicitly examine how students' computational thinking processes operated during problem solving, and thus, no mapping of these processes through error analysis based on the Newman procedure was evident. This study is expected to contribute to the field of mathematics education, particularly by presenting an analytical framework that integrates the Newman procedure into each component of computational thinking, thereby enabling the mapping of the specific types of errors students make in each component. The objective of this study is to analyze the types of student errors based on Newman's procedure for each component of computational thinking, including decomposition, pattern recognition, abstraction, and algorithmic thinking in solving statistics problems.

METHODOLOGY

Research Design

This study uses a qualitative case study method. Qualitative research is research that reveals a phenomenon by comprehensively describing data and facts through words regarding the research subject (Fiantika et al., 2022). This aligns with the objective of this study, which is to analyze students' errors in computational thinking—encompassing decomposition, pattern recognition, abstraction, and algorithmic thinking—in statistics material using Newman Error Analysis (NEA) or the Newman procedure

Participant

The study was conducted at one of the MTs in Garut Regency. The study participants consisted of 17 students who took the computational thinking test. Based on their total scores, participants were categorized into three groups according to Sudijono (2013) criteria: high, moderate, and low. From each category, one student was purposively selected as a research subject for an interview. This selection aimed to obtain representation from each computational thinking score category so that differences in the types of errors experienced by students in each computational thinking category when solving statistics problems could be analyzed based on Newman's theory

Data Collection

The data collection technique used in this study was triangulation, which involved both test and non-test methods. The test method was obtained through a computational thinking ability test on statistical material. The non-test method in this study was an interview technique.

Instrument

The research instrument used in this study was an essay-type test comprising computational thinking questions on statistics, consisting of four validated items reviewed by expert validators. Each item was structured into four question points, each representing the components of computational thinking in sequence. Point (a) covers decomposition, point (b) covers pattern recognition, point (c) covers abstraction, and point (d) covers algorithmic thinking. The design of these questions aims to guide students in solving problems step by step, in accordance with the components of computational thinking. Research data were obtained from test results completed by students without the intervention of Artificial Intelligence.

Data Analysis

Data analysis was conducted in several stages. The first stage involved analyzing students' computational thinking abilities using indicators for each component. The indicators for the computational thinking components in this study are based on (Dong et al., 2019)and are presented in Table 1.

Tabel 1. Components and Indicators of Computational Thinking Components

Components	Indicators
Decomposition	Able to identify complex problems as simpler ones by breaking them down into sub-problems and sub-information to solve the problem.
Pattern Recognition	Able to recognize patterns, regularities, similarities, or relationships visible in a problem to aid in the solution process.
Abstraction	Ability to determine relevant information and formulate a simple solution.
Algorithmic Thinking	Can organize solution steps logically and systematically to solve problems.

The next step involves analyzing students' errors in each component of the computational thinking analysis results using Newman Error Analysis (NEA), which includes reading, comprehension, transformation, process skill, and encoding errors. The indicators of the Newman procedure used to identify error analysis, based on the research by Reskina & Kartini (2022), are presented in Table 2.

Tabel 2. Error Type Indicators Based on the Newman Procedure

Error Type	Indicator
Reading	The student misreads terms, symbols, words, or important information in the question.
Comprehension	a. The student does not know what the question is actually asking and misinterprets the information. b. The student misinterprets the information in the question and therefore does not proceed to the next step.
Transformation	a. Students fail to correctly transform the mathematical model b. Students make mistakes in using arithmetic operation symbols to solve problems
Process Skills	a. The student made a mistake in calculation or computation b. Students did not complete the problem-solving procedure
Answer Writing	a. The student is unable to write the final answer required by the question b. Students cannot derive the answer according to the mathematical statement

Based on a review of the computational thinking components proposed by Dong et al (2019)and the stages of Newman's procedure described by Reskina & Kartini (2022), the researchers developed an analytical framework to identify student errors. This framework is presented in a table that illustrates the relevance of computational thinking components to error types, based on Newman's procedure. The framework is organized based on the relevance of cognitive processes within each component. Each stage in Newman's procedure reflects specific thinking activities aligned with the indicators of computational thinking components. The relevance of error types based on Newman's procedure to computational thinking components is described in Table 3.

Tabel 3. Relevance of Error Based on Newman's Procedure and Components of Computational Thinking

Components	Procedure Categories	Description
Decomposition	Reading Errors, Comprehension Errors	In decomposition, students are asked to break down complex problems into simpler ones by identifying sub-problems. Errors may arise when students fail to identify sub-problems due to reading errors or misunderstandings of the problem. Decomposition is not relevant to transformation errors because this stage has not yet reached the formation of a mathematical model, nor is it relevant to process skill errors and errors in writing the final answer because it has not yet entered the stage of solving and writing the answer.
Pattern Recognition	Reading Errors, Comprehension Errors	In pattern recognition, students are asked to recognize and understand symbols, terms, and question formats that exhibit regularities, patterns, similarities, or relationships within the given data or problems. Errors may arise when students fail to recognize the appropriate patterns or representations. Thus, this is highly relevant to reading errors and comprehension errors. Transformation errors, process skills, and final answer writing are not relevant to this component because the process has not yet reached those stages.
Abstraction	Comprehension errors, Transformation Errors	In the abstraction stage, students are asked to identify relevant information for problem-solving and construct it into a simple formula. Errors may occur because students do not understand the relevant information for problem-solving, so they cannot transform it into a simple formula; thus, this is highly relevant to comprehension errors and transformation errors. Errors in process skills and in writing the final answer are not relevant to this component because students have not yet reached the stage of calculation and answer writing.
Algorithmic Thinking	Process Skill Errors, Encoding errors	The algorithmic thinking component requires students to outline the steps of the solution process from the initial stages through to finding the final answer; therefore, the errors relevant to this stage are process skill errors and encoding errors

This study employs the data analysis technique of the Miles and Huberman model. (Miles & Huberman, 2014)state that this qualitative data analysis is conducted interactively and continuously until completion, so that no further information emerges from the data collection process. This technique includes data collection, data reduction, data presentation, and drawing conclusions.

FINDINGS

The results of this study present findings obtained from the computational thinking test instrument and interviews. Based on the computational thinking test results for 17 students, 3 (18%) were in the high computational thinking ability category, 10 (59%) in the moderate category, and 4 (23%) in the low category. These findings indicate that the majority possess moderate computational thinking skills. Students with moderate computational thinking ability tended to make errors when generalizing problems or creating simple formulas, resulting in the problem-solving process not being completed accurately at the algorithmic thinking stage. This indicates student errors, necessitating further analysis to identify their location and type using the Newman procedure. The error analysis process for computational thinking components, based on the Newman procedure, aligns with the mapping between these components and the error types identified by the procedure, as presented in the researcher's Table 3. The selected students are representatives deemed to best reflect the characteristics of their respective categories.

Based on the categorization of computational thinking ability, one student was selected from each of the high, low, and moderate categories. This selection ensured that each category was represented so the analysis could provide an overview of variation in student abilities. The subjects selected for this study were S1 (high), S3 (moderate), and S14 (low). The selected students were interviewed to confirm their understanding of the work they had completed, after which an error analysis was conducted based on the Newman procedure. To facilitate the analysis, this study used the following codes: “S1” for students in the high category, “S2” for students in the moderate category, and “S3” for students in the low category. In the interview excerpts, the code “P” refers to the interviewer. The following discussion presents an analysis of each subject based on the components of computational thinking.

Decomposition

S1 and S2 completed the decomposition stage accurately and systematically for each question, while S3 made decomposition errors on every question except question number 2. S1’s answer to question number 3 is presented in Figure 1.

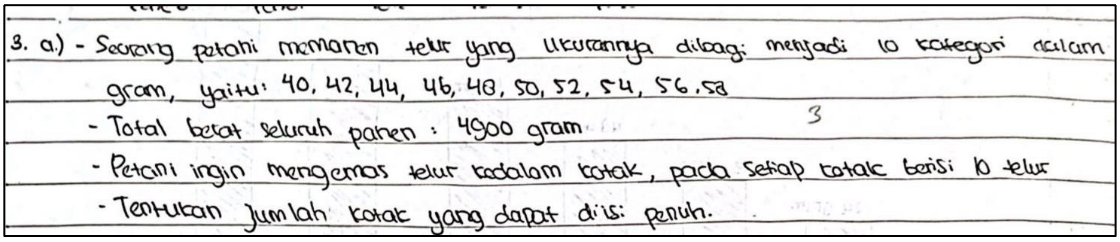


Figure 1. Student 1’s Answer for the Decomposition Component

Based on Figure 1, S1 was able to break down the information into simpler sub-problems and sub-information, meaning S1 could manage and organize the information from the word problem into sub-problems and key information essential for problem-solving. S1 could read and understand the problem accurately and write answers systematically; therefore, it can be concluded that S1 solved problem 3 accurately and systematically, without errors. Figure 2 shows Student 3’s answer to question 3.

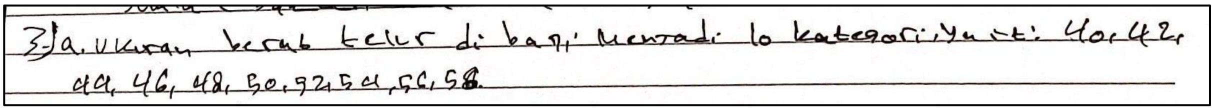


Figure 2. Student 3’s Answer on the Decomposition Component

Based on Figure 1, S3 appears to have misunderstood the problem. The problem given is that a layer chicken farmer is harvesting eggs. Egg weights are divided into 10 categories, namely (in grams): 40, 42, 44, 46, 48, 50, 52, 54, 56, 58. The total weight of the entire egg harvest is 4900 grams. The farmer wants to pack the eggs into boxes, with each box containing 10 eggs. Determine the number of boxes that can be filled. S3 merely restated the information from question three, and even that information was incomplete. The student did not write down the problem to be solved in question three, even though the question was explicitly stated, because the student did not understand what was being asked. The results of the interview with S3 are as follows:

Tabel 4. The Results of The Interview with S3

Question	Answer
Based on this question, what information do you think is given and what is being asked?	Egg weights are divided into 10 categories: 40, 42, 44, 46, 48, 50, 52, 54, 56, and 58 grams. The total weight of the entire egg harvest is 4,900 grams. The farmer wants to pack the eggs into boxes, with each box containing 10 eggs. Determine the number of boxes that can be filled. That's it, Ma'am.
Take it slow, what information do we have?	The egg weights are divided into 10 categories, namely 40, 42, 44, 46, 48, 50, 52, 54, 56, and 58 grams. The total weight of the egg harvest is 4,900 grams. The total weight of the egg harvest is 4,900 grams. Then, the question asked was: 'Determine the number of boxes that can be filled, Ma'am.

Based on the interview response with S3, the written answer was correct according to the question, even though S3's response was incomplete; therefore, the student did not make a reading error. However, S3 only stated the answer based on the presented question without processing or organizing the problem and information into sub-points.

Pattern Recognition

S1 completed the pattern recognition stage correctly and accurately on all questions, while S2 and S3 made mistakes on question three and question four. S1's answer to question 4 is presented in Figure 3.

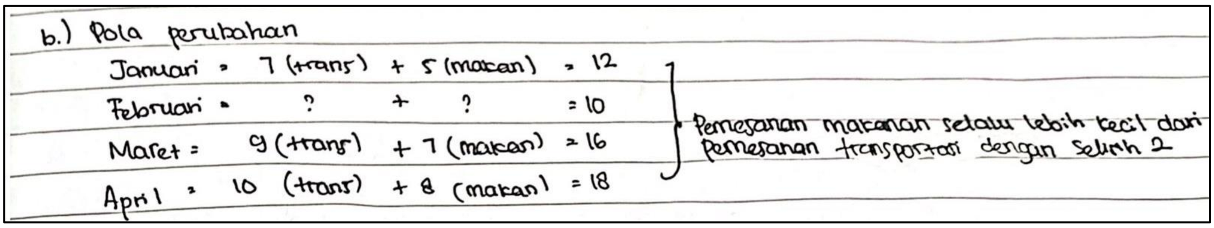


Figure 3. S1's Answer on the Pattern Recognition Component

Based on Figure 3, Student 1 accurately read the table because they could see that the total number of transportation and food orders matched the frequency shown in the graph. Student 2 observed and understood the pattern that the number of food orders was always 2 fewer than the number of transportation orders. Therefore, it can be concluded that Student 2 was able to read and understand the problem. An example of an error on question 4, made by S2, is shown in Figure 4.

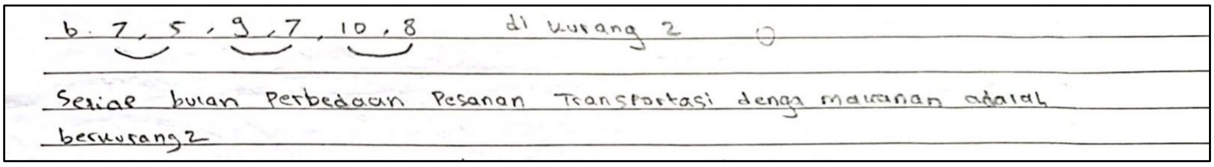
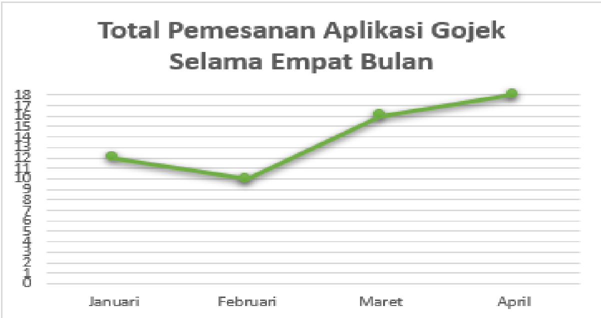


Figure 4. Student S2's Answer on the Pattern Recognition Component

Based on Figure 2, S2 appears to have misunderstood the pattern. The context of question number four is presented in Figure 4.

Dalam empat bulan terakhir, seorang pekerja rutin menggunakan aplikasi Gojek untuk transportasi dan pembelian makanan. Ia rajin mencatat pengeluaran serta jumlah pemesanan setiap bulan, tetapi lupa mencatat data pada bulan Februari. Ketika membuka aplikasi Gojek, ia melihat grafik yang menampilkan total penggunaan dari bulan Januari hingga April (Lihat Gambar 3). Sementara itu, catatan manualnya disajikan dalam Tabel 1 yang memuat jumlah pemesanan transportasi dan makanan.



Gambar 3. Grafik Total Pemesanan Aplikasi Daring

Tabel 1. Banyaknya Pemesanan Transportasi dan Makanan

Bulan	Pemesanan aplikasi Gojek	
	Transportasi	Makanan
Januari	7	5
Februari	A	B
Maret	9	7
April	10	8

Gunakan informasi dari grafik dan tabel untuk memperkirakan jumlah pemesanan transportasi dan makanan pada bulan Februari!

Figure 5. Question Number 4

Based on Figure 2, S2 can read the table but does not make the connection between the table and the graph. This may be because the student does not understand that the two data representations are related. S2 is fixated only on the data from the Table 1, as evidenced by Figure 2, where S2 compares only the number of transportation and food orders without noticing other patterns—such as the total of transportation and food orders each month shown in the graph, or the decline in order volume from January to February as depicted in the graph. To confirm the answer, an interview was conducted with S2. The following is an excerpt from the interview with S2 during the pattern recognition stage:

Tabel 5. The Results of The Interview with S2

Quastion	Answer
Now, take a look at the information in the question. Is there a pattern of relationship in question number four?	Yes, ma'am.
Can you describe the patterns?	In the transportation data, the number goes up by one.
Okay, anything else?	The food data decreases by two.
Is there anything else, or is that it?	That's it, ma'am.
Take a look at the diagram. What was the total number of Gojek orders in January? Is there a connection between the table and the graph?	12, ma'am. No, ma'am.

From this excerpt of the interview with S2, it can be concluded that the student can read the problem, the diagram, and the table. However, S2 does not understand the relationship between the two data representations.

Abstract

At this stage, S1 answered all questions accurately and systematically, while S2 made mistakes on questions three and four, and S3 made mistakes on all questions. S1's answer to question 3 is shown in Figure

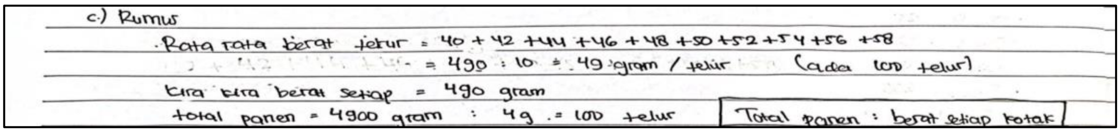


Figure 6. S1's Answer in the Pattern Recognition Component

In the abstraction stage, Student 1 was able to write a simple formula. Additionally, Student 1 understood how to select relevant information to construct a simple formula for the solution process; specifically, Student 1 selected and calculated the average. Student 1 also understood that the total harvest must be divided by the average number of eggs to form the simple formula. At this stage, S1 successfully understands and transforms the problem. An example of an error in question 3 made by S3 is shown in Figure 7.

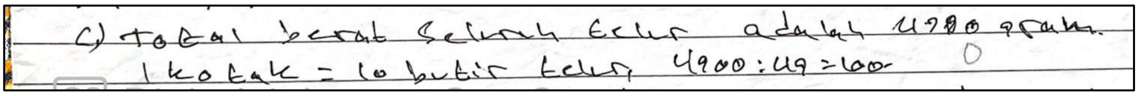


Figure 7. Student S3's Answer in the Abstraction Component

Based on Figure 4, during the abstraction stage, S3 did not write down important information relevant to constructing mathematical symbols or simple formulas. S3 only wrote down some information and proceeded directly to calculating, even though this stage is not related to calculation. Thus, based on Table 3 regarding the relevance of error types in computational thinking, S2 made errors in understanding and transformation. Additionally, as seen in S3's response in Figure 2, the error occurred because S3 did not understand question number 3 from the start. Consequently, the student struggled to identify the relevant key information needed to construct or transform it into mathematical symbols or simple formulas. The following is an excerpt from the interview with S3 during the abstraction stage:

Tabel 6. The Results of The Interview with S3

Question	Answer
For question 3, do you know what the important information is?	No, ma'am.
Try reading it again. What is the task in this problem?	Determine the number of boxes that can be completely filled, Ma'am.
How do you do that? What do you need to know first?	I don't know, ma'am.

Based on the interview results, Student 3 did not understand the problem in question number three; Student 3 only read the text of the question and was therefore unable to construct the key information into a mathematical symbol or a simple formula.

Algoritgmic Thinking

Student 1 was able to complete the algorithmic thinking stage for all questions correctly, but not systematically, while Students 2 and 3 made algorithmic thinking errors on all questions. Student 1's answer to question number 1 is presented in Figure 8.

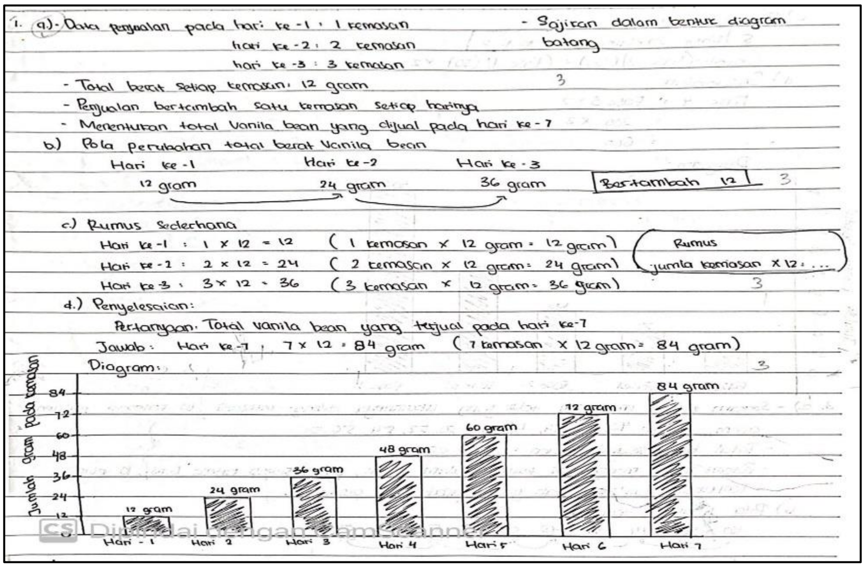


Figure 8. Student S1's Answer for the Algorithmic Thinking Component

Based on Figure 8, Student 1 demonstrates an excellent ability to structure the solution and calculate the solution process accurately. Additionally, Student 1 includes a bar chart showing the weight of the vanilla bean each day from the first to the seventh day, making the procedure flow not only logical but also traceable through visual representation. However, S1 only wrote down the calculations; S1 was not yet able to systematically write down the steps leading to the final answer. This indicates that S1 is capable of constructing and executing algorithms, but not yet fully. Unlike S1, S2 was not yet able to demonstrate the algorithmic process in its entirety. Figure 5 shows S2's answer in the algorithmic thinking section for question number 1.

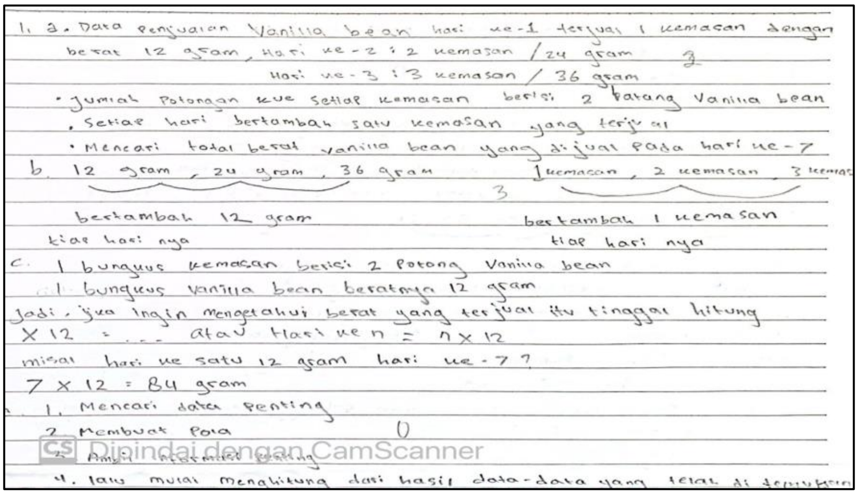


Figure 9. Student S2's Answer in the Algorithmic Thinking Component

Based on Figure 5, it is evident that S2 solved the problem correctly up to the stages of decomposition, pattern recognition, and abstraction. However, during the algorithmic thinking stage, S2 did not implement the solution steps operationally; instead, they merely wrote a description that did not support the calculation process. This indicates that the algorithmic thinking stage was not carried out correctly. Consequently, Student S2 made a process skill error by failing to follow the solution procedure sequentially, which led to an error in the final answer. This error occurs because the calculation is performed at the abstraction stage rather than the algorithmic stage, as it should be. Additionally, S2 did not present a diagram to represent the final answer, indicating an error in the encoding indicator within Newman's analytical framework. The following is an excerpt from the interview with S2 during the abstraction stage:

Tabel 7. The Results of The Interview with S2

Question	Answer
What are the steps to solve for the vanilla bean?	How, ma'am?
So you got 84 grams as the result. Now, try to explain the steps you took to arrive at that result.	Well, first I had to figure out what information was needed and what was being asked, then determine the pattern. From the pattern, I could derive a formula; when I plugged the values into the formula, I got 84 grams, Ma'am.

Based on the answer sheet and the interview, S2 demonstrated an understanding of algorithmic thinking that is not yet fully developed. S2 was able to describe the problem-solving process, but still mixed the stages of decomposition, pattern recognition, and abstraction within the solution. In the algorithmic thinking stage, S2 was not yet able to write down procedural steps clearly and in a structured manner; S2 only wrote down steps describing the process of substitution into the formula. S2 also performed calculations during the abstraction process.

Students' computational thinking abilities, categorized as high, moderate, and low, showed significant differences in problem-solving performance. Students with low computational thinking abilities tended to make errors across nearly every component analyzed. These difficulties are primarily caused by students' inability to understand problem contexts that differ from the problems they typically encounter. This situation results in students' inaccuracies in identifying key information, formulating problems, and determining appropriate solution steps. A summary of the types of errors students experienced based on Newman's procedure is presented in Table 8.

Table 8. Summary of errors in computational thinking based on Newman's procedure

Component	S1	S2	S3
Decomposition	-	-	√
Pattern Recognition	-	√	√
Abstraction	-	√	√
Algorithmic thinking	√	√	√

Based on Table 8, S1, who falls into the high computational thinking ability category, only made errors in the algorithmic thinking component; S2, who has abilities in the Moderate category, was able to complete the decomposition component but did not yet demonstrate adequate ability in the pattern recognition, abstraction, and algorithmic thinking components. Meanwhile, S3, who falls into the Low computational thinking ability category, was not yet able to solve computational thinking-based problems well across all measured components.

DISCUSSION

The analysis results show that students' ability to perform decomposition varies across each category of computational thinking. S1, representing the high category, accurately and systematically breaks down the problem's information into simpler parts. Student S1 not only restated the information but also organized it into sub-problems relevant to the solution, consistent with Dong et al.'s (2019) definition of decomposition, which involves breaking down data, processes, or problems into meaningful, manageable parts. This is evident in their answers, which consistently present information in a complete, structured manner, allowing the problem-solving process to proceed without hindrance. In contrast to S1, S2, representing the moderate category, still demonstrates fairly good decomposition skills but is not yet fully consistent. In some questions, S2 correctly broke down the information, but in others, inaccuracies were found in identifying key information, particularly in question 2. This indicates that S2 has not yet fully mastered problem identification, leading to errors.

Meanwhile, S3, in the low category, exhibits the most dominant errors during the decomposition stage. Based on their answers, S3 tends to merely copy information from the question without breaking it down into the sub-information needed to grasp the problem's core. Furthermore, some of the information provided is incomplete and does not lead to efforts to solve the problem. This error aligns with the interview results, in which S3 admitted confusion about what the question was actually asking. This condition aligns with Solehudin et al. (2024), who found that students often fail to decompose problems because they are not accustomed to breaking them down into smaller, more easily understood units. According to Senita & Kartini (2021), misunderstandings occur because students are unable to fully articulate what is being asked and what is known in the problem. Errors in understanding significantly influence the solution steps taken (Reskina & Kartini, 2022). This is because students must first understand the meaning of a math problem before proceeding to the problem-solving stage in order to arrive at the correct answer (Epran et al., 2025). Consequently, S3 was unable to solve problem number 3. Thus, S3's error can be categorized as a problem-understanding error based on Newman's procedure.

In the pattern recognition component, S1, representing the high category, demonstrated strong performance. S1 was able to read tables and graphs accurately and to identify relationships in the data precisely. Through the answers provided, S1 could recognize that the number of food and transportation orders followed a consistent pattern. This ability indicates that S1 understands the data not only numerically but also relationally, allowing them to accurately identify patterns of change. This aligns with Dong et al.'s (2019) definition of pattern recognition: the process of observing and identifying patterns, trends, and regularities in data, processes, or problems.

Student S2, representing the intermediate category, and Student S3, representing the low category, made errors on questions 3 and 4. S2's error was evident in their inability to identify the regularity of the difference pattern. S2 understands some of the information but is not yet able to identify regularities, similarities, or relational patterns in a problem when it is new; for instance, S2 can solve questions 1 and 2 but is unable to do so for questions 3 and 4. S2's error can be categorized as a comprehension error in Newman's procedure because the student misinterprets the relationships among data points. In S3, the errors are more pronounced. S3 is unable to identify patterns, regularities, similarities, or relational patterns and focuses only on the visible data values, without conducting further analysis to discover the underlying regularity. This indicates that S3 struggled with both understanding the data and connecting it to one another. Thus, S3's errors reflect a misunderstanding within the Newman procedure. This aligns with the research by Senita & Kartini (2021), which found that many students wrote the correct answer format but made mistakes in applying the patterns of relationships between data; this is because students often recognize patterns superficially. Errors in understanding patterns impact subsequent problem-solving steps (Supiarmo et al., 2021). Consequently, students cannot solve problems completely because the identified patterns are incorrect, preventing them from engaging in abstraction and algorithmic thinking.

Regarding the abstraction component, S1, who represents the high category, solved each problem well, including problem 3. S1 identified relevant key information to construct a mathematical form or simple formula using average calculations, with the resulting average then used as the divisor for the total harvest. From this process, a simple formula was derived to determine the number of egg cartons: dividing the total weight of the egg harvest by the weight of eggs per carton. This aligns with Dong et al.'s (2019) definition of abstraction, which involves identifying important and relevant information within a problem. One example of applying abstraction in a mathematical context is found in verbal and story-based problems, where students are expected to identify relevant data and express their solutions in symbolic language (Irawan, 2024). Thus, it can be concluded that S1 understands the problem and is able to transform it into a mathematical form or a simple formula.

S2, representing the moderate category, made errors at the abstraction stage on questions 3 and 4, while S3, representing the low category, made errors at that stage on every question. S2 and S3 were not yet able to transform information into a mathematical model or a simple formula. S2 tends to jump straight into calculations, even though that stage is part of the algorithmic thinking process. Tampubolon et al. (2025) also found that errors in abstraction occur due to students' inability to connect symbolic representations. Meanwhile, S3 cannot understand the problem from the very beginning of the decomposition stage; thus, by the abstraction stage, S3 is unable to filter out the relevant key information needed to construct a mathematical form. This aligns with Firdaus' (2021) findings that most students remain at the low-abstraction stage because they cannot connect the key information in the problem to a mathematical form. This is because students struggle to connect key elements of the problem to general principles (Muthi'ah et al., 2025). Nevertheless, when examined in terms of process skill errors, S2 performed correct calculations and thus did not commit any. However, both S2 and S3 made errors in the Newman procedure, specifically in understanding and transformation.

At the algorithmic thinking stage (S1), representing the high category, one could solve each problem accurately but not systematically. In problems 1 through 3, S1 did not write down systematic steps as defined by algorithmic thinking—namely, the logical and systematic arrangement of solution steps to solve a problem (Dong et al., 2019). At this stage, Student 1 only performed calculations. This is inconsistent with Irawan's (2024) research, which found that algorithmic thinking skills enable students to systematically formulate problems and identify the steps required to solve them. Thus, it can be concluded that in the Newman procedure, Student 1 made errors in process skills and in writing the final answer.

S2, representing the moderate category, was unable to complete the algorithmic thinking stage for all questions. S2 documented only general steps from previous components, failing to specify solution steps; S2 also performed calculations during the abstraction stage, even though the abstraction stage should not yet involve calculations. This aligns with the research by Supiarmo et al. (2021), which found that students had not reached the algorithmic thinking stage due to incomplete and unsystematic problem-solving steps. Students did not implement the solution steps operationally; they merely wrote meaningless descriptions. This condition indicates that the algorithmic thinking stage was not carried out correctly. Students do not outline logical steps in finding solutions (Junaedi et al., 2024). This aligns with the findings of Puad & Wijaya (2025), which show that algorithmic thinking skills are not yet evident because students are unable to solve problems thoroughly. Thus, it can be concluded that errors S2 and S3 in process skills and final answers stem from students' abilities not yet having reached the stage of algorithmic thinking. The results of the computational thinking error analysis summary, based on the Newman procedure, are presented in Table 9.

Table 9. Summary of Computational Thinking Error Analysis Based on the Newman Procedure

Components of Computational Thinking	Subject		
	S1	S2	S3
Decomposition	-	-	Misunderstanding
Pattern Recognition	-	Misunderstanding	Misunderstanding
Abstract	-	Misunderstanding, Transformation errors	Misunderstanding, Transformation errors
Algorithmic thinking	Process skill errors, Final answer errors	Process skill errors, Final answer errors	Process skill errors, Final answer errors

Table 9 shows that students' errors tend to increase in the more difficult components of computational thinking. Students in the high category (S1) can solve problems from the decomposition stage through to the abstraction stage. At the algorithmic thinking stage, students made process-skill errors by failing to organize the solution steps systematically and final-answer errors by failing to draw a final conclusion. In relation to the computational thinking component abilities according to Dong et al. (2019), S1's abilities in decomposition, pattern recognition, and abstraction are very good; however, its algorithmic thinking ability needs improvement. Students in the moderate and low categories exhibit differences in the types of errors they make. At the decomposition stage, the student in the moderate category (S2) made no errors, whereas the student in the low category (S3) made errors in this component. The error made by S3 was a comprehension issue: it did not understand the problem context and could not break it down into smaller parts. This aligns with the findings of Solehudin et al. (2024), who showed that, in the decomposition component, students merely copied information from the problem and were unable to break it down into smaller parts.

However, both S2 and S3 students made comprehension errors in the pattern recognition and abstraction components, as well as transformation errors in the abstraction stage and errors in algorithmic thinking. These findings align with Supiarmo et al. (2021), who stated that students often recognize patterns but do not understand the patterns they form, thus failing to connect those patterns to the next step in the solution process—abstraction—when the problem is sequential. At the abstraction stage, students still struggle to filter relevant information and to transform it into a mathematical model, which, in turn, affects subsequent components. This also aligns with Anggraeni & Nurlaelah (2025), who noted that errors in algorithmic thinking stem from mistakes made during the abstraction stage. Viewed through the computational thinking components outlined by Dong et al. (2019), students in categories S2 and S3 still need improvement in their computational thinking abilities. Thus, it can be concluded that, in general, students' error patterns indicate a hierarchical structure among the components of computational thinking. Students in the low category (S3) experience errors at the decomposition stage because they cannot understand the problem, which then carries over to the pattern recognition component, where their incomplete understanding prevents them from identifying the correct pattern. This subsequently impacts the abstraction stage because the understanding of the problem and the identified pattern is incorrect, leading to errors in the abstraction and algorithmic thinking components.

Unlike previous studies that used computational thinking merely as a basis for grouping students' abilities Fatmawati & Nasution, 2024), this study explicitly mapped error types for each component of computational thinking using Newman's procedure. The results of this mapping indicate that each component of computational thinking exhibits distinct error characteristics. In the decomposition and pattern recognition components, students tended to make comprehension errors; in the abstraction component, students made comprehension and transformation errors; while in the algorithmic thinking component, all students made errors in process skills and writing the final answer. These findings indicate that integrating Newman's procedure into each component of computational thinking can yield a more detailed and systematic mapping of errors than simply grouping students by computational thinking ability.

CONCLUSION

Based on the research findings, students made errors in decomposition, pattern recognition, abstraction, and algorithmic thinking. The errors included misunderstandings, transformations, process skills, and the final answer. Errors in one component can affect subsequent components, showing that students' errors are interconnected within the problem-solving process. The implications of this study suggest that mathematics instruction should strengthen each component of computational thinking. Teachers should pay attention not only to students' final answers but also to the underlying thought processes that lead to errors at each stage of problem-solving. Future research could involve a larger sample and additional mathematical content to provide a more comprehensive understanding of computational thinking and errors, following Newman's procedure.

ACKNOWLEDGMENT

The authors thank the ninth-grade students for their participation in this study, as well as the school principal and mathematics teacher for granting permission to conduct the study. Gratitude is also due to the experts for their assistance in instrument validation and to the supervisors for their valuable feedback, which significantly improved the quality of this study.

REFERENCES

Ahmad, F. A., Nurlaelah, E., & Mulyaning, E. C. (2026). Kemampuan Computational Thinking Siswa SMP dalam Pemecahan Masalah Deret Aritmatika. *Jurnal Ilmiah Pendidikan Matematika)*, *14*(2), 208–218. https://doi.org/10.25273/jipm.v14i2.22722

Anggraeni, R., & Nurlaelah, E. (2025). Analisis Kesalahan Siswa dalam Menyelesaikan Soal Cerita SPLDV Berdasarkan Tahapan Computational Thinking. *Research and Development Journal of Education*, *11*(2), 808. https://doi.org/10.30998/rdje.v11i2.12335

Astuti, A., Syahza, A., & Putra, Z. H. (2023). Penelitian Computational Thinking Dalam Pembelajaran Matematika. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(1), 363. https://doi.org/10.24127/ajpm.v12i1.5860

Difani, A. F., Kurniawan, A. P., & Istiqomah, N. R. (2025). Analisis Kemampuan Berpikir Komputasi Siswa dalam Menyelesaikan Masalah Statistika Berdasarkan Pola Pikir Divergen dan Konvergen. *POLINOMIAL: Jurnal Pendidikan Matematika*, *4*(4).

Dong, Y., Cateté, V., Jocius, R., Lytle, N., Barnes, T., Albert, J., Joshi, D., Robinson, R., & Andrews, A. (2019). Prada: A practical model for integrating computational thinking in K-12 education. *SIGCSE 2019 - Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, 906–912. https://doi.org/10.1145/3287324.3287431

Ellerton, N. F., & Clements, K. (1978). Newman Error Analysis: A Comparative Study Involving Year 7 Students in Malaysia and Australia. *Teoh Sooi Kim*.

Epran, Kusumah, Y. S., & Jupri, A. (2025). *Analisis Numerasi Dan Kesalahan Siswa Dalam Menyelesaikan Soal-Soal Aljabar Ditinjau Dari Adversity Quotient* [Thesis Magister, Universitas Pendidikan Indonesia]. https://repository.upi.edu/136884/

Fatmawati, D. P., & Nasution, N. B. (2024). Kesalahan dalam Menyelesaikan Soal Cerita Berdasarkan Teori Newman Ditinjau Dari Computational Thinking. *ProsidingDiskusi Panel Nasional Pendidikan Matematika*, 239–250.

Fauzi, N. I., Sagita, L., Setiyani, & Wicaksono, B. (2022). Analysis Of Student Errors in Solving Trigonometry Problems Based on The Newman Procedure. *Kalamatika: Jurnal Pendidikan Matematika*, *7*(1), 1–14. https://doi.org/10.22236/kalamatika.vol7no1.2022pp1-14

Fiantika, F. R., Wasil, M., Jumiyati, S., Honesti, L., Wahyuni, S., Mouw, E., Jonata, Mashudi, I., Hasnah, N., Maharani, A., Ambarwati, K., Noflidaputri, R., Nuryami, & Waris, N. (2022). *Metodologi Penelitian Kualitatif* (Pertama). Global Eksekutif Teknologi.

Fineldi, R. J., & Jupri, A. (2026). Examining Potential Teachers' Capabilities for Creative Thinking in Geometry Problems Using Analytical Framework NEA. *Range: Jurnal Pendidikan Matematika*, *7*(2), 404–418. https://doi.org/https://doi.org/10.32938/jpm.v7i2.10007

Firdaus. (2021). Analisis Kesalahan Berdasarkan Teori Newman dalam Menyelesaikan Masalah Luas dan Keliling Bidang Datar. *Jurnal Publikasi Pendidikan*, *11*(3), 2021. https://doi.org/https://doi.org/10.70713/publikan.v11i3.23756

Firdausi Rahman, R., Rosita Dewi Nur, I., Singaperbangsa Karawang, U., Ronggo Waluyo, J. H., Telukjambe Timur, K., & Barat, J. (2021). Analisis Kesalahan Siswa Menyelesaikan Soal Pemecahan Masalah Polya. *Jurnal Pembelajaran Matematika Inovatif*, *4*(6). https://doi.org/10.22460/jpmi.v4i6.1413-1422

Fitrisyah, M. A., Hapizah, & Mulyono, B. (2025). Computational Thinking Ability of Students in Exponential Material Using Problem-Based Learning. *Jurnal Riset Pendidikan Matematika*, *12*(2), 148–162. https://doi.org/10.21831/jrpm.v12i2.75787

Hudzaifah, H. (2023). *Analisis Kesulitan Siswa dalam Menyelesaikan Masalah Kontekstual Berdasarkan Tahapan Computational Thinking* [Skripsi, Universitas Pendidikan Indonesia]. https://repository.upi.edu/100306/

Irawan, E. (2024). *Keterampilan Computational Thinking Mahasiswa Melalui Penerapan Desain DIidaktis Dengan Memanfaatkan Perangkat Lunak-R Pada Mata Kuliah Statistika* [Disertasi Doktoral, Universitas Pendidikan Matematika]. https://repository.upi.edu/117915/

Irawan, E., Rosjanuardi, R., & Prabawanto, S. (2024a). Promoting Computational Thinking through Programming Trends, Tools, and Educational Approaches: a Systematic Review. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *8*(4), 1327. https://doi.org/10.31764/jtam.v8i4.26407

Irawan, E., Rosjanuardi, R., & Prabawanto, S. (2024b). Research trends of computational thinking in mathematics learning: A bibliometric analysis from 2009 to 2023. In *Eurasia Journal of Mathematics, Science and Technology Education* (Vol. 20, Number 3). Modestum LTD. https://doi.org/10.29333/ejmste/14343

Junaedi, Y., Umami, M. R., Anwar, S., Juniawan, E. A., & Yulianto, D. (2024). *Analisis Computational Thinking Skills Siswa Sma Melalui Pembelajaran Berdiferensiasi*. *5*(4). http://www.jurnal.untirta.ac.id/index.php/wilangan

Khoirunnisa, M., Hakim, L. El, & Aziz, T. A. (2025). Media Pendidikan Matematika Profil Kesulitan Siswa dalam Menyelesaikan Masalah SPLDV ditinjau dari Computational Thinking Skill dan Self-Confidence. *Desember*, *13*(2). https://e-journal.undikma.ac.id/index.php/jmpm

Lisa, L., Hasratuddin, H., Sinaga, B., Napitupulu, E. E., & Panjaitan, A. (2024). Computational Thinking Skills in Understanding the Limit of Algebraic Functions. *Mathline: Jurnal Matematika Dan Pendidikan Matematika*, *9*(2), 365–380. https://doi.org/10.31943/mathline.v9i2.549

Miles, M. B., & Huberman, A. M. (2014). *Qualitative Data Analysis, A Methods*. Sage Publications.

Mubarokah, A. A. L., & Amir, M. F. (2024). Primary Students' Errors in Solving Mathematical Literacy Problems Based on Newman Analysis. *Mathematics Education Journal*, *18*(2), 217–230. https://doi.org/10.22342/jpm.v18i2.pp217-230

Muthi'ah, D., Nurlaelah, E., & Usdiyana, D. (2025). Analisis Kemampuan Computational Thinking Berdasarkan Gaya Kognitif melalui Problem-Based Learning pada Siswa SMA. *SIGMA DIDAKTIKA: Jurnal Pendidikan Matematika*, *13*(1). https://doi.org/10.17509/sigmadidaktika.v%vi%i.89610

Nabila, R. A. P. M., & Rosjanuardi, R. (2025, June). Computational Thinking in Mathematics Education: A Systematic Review of Trends and Innovation in The Digital Era. *The Fifth International Conference on Innovations Social Sciences Education and Engineering*.

Nabila, S., Fatra, M., & Diwidian, F. (2025). Implementasi RME Untuk Kemampuan Berpikir Komputasional Matematis Berdasarkan Kemandirian Belajar Siswa. *Fibonacci: Jurnal Pendidikan Matematika Dan Matematika*, *11*(1). https://doi.org/https://doi.org/10.24853/fbc.11.1.13-26

Natali, V. (2022). *Computational Thinking Mata Kuliah Pilihan Pendidikan Profesi PraJabatan* (1st ed.). Kementerian Pendidikan, Kebudayaan, Riset dan Teknologi.

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), 11. https://doi.org/10.22460/infinity.v6i1.p11-20

OECD. (2018). *PISA 2022 Mathematics Framework Draft*. https://pisa2022-maths.oecd.org/ca/index.html

Pramesti, S. L. D. P., Mariani, S., Hendikawati, P., Wardono, Waluya, S. B., Pujiastuti, E., & Dewi, H. L. (2025). A Systematic Literature Review of: Computational Thinking in Mathematics Classrooms. *RANGE: Jurnal Pendidikan Matematika*, *7*(1), 172–186. https://doi.org/10.32938/jpm.v7i1.9440

Puad, N. F., & Wijaya, A. (2025). Analisis Kemampuan Computational Thinking dan Curiosity Matematis Siswa Sekolah Menengah Kejuruan di Kota Tasikmalaya. *Jurnal Pendidikan Matematika Dan Sains*, *13*(Special_issue), 326–337. https://doi.org/10.21831/jpms.v13ispecial_issue.90038

Reskina, & Kartini. (2022). Analisis Kesalahan Siswa Dalam Menyelesaikan Soal Aritmetika Sosial Berdasarkan Teori Newman. *Edumatica: Jurnal Pendidikan Matematika*, *12*(3). https://doi.org/https://doi.org/10.22437/edumatica.v12i03.19589

Salehudin, M. (2023). Menggunakan Model Pembelajaran Untuk Implementasi Computational Thinking Bagi Guru Madrasah. *Edusaintek: Jurnal Pendidikan, Sains Dan Teknologi*, *10*(2), 407–425. https://doi.org/10.47668/edusaintek.v10i2.780

Senita, A., & Kartini, K. (2021). Analisis Kesalahan Siswa dalam Menyelesaikan Soal Dimensi Tiga Kelas XI MIPA SMAN 1 Gunung Toar Berdasarkan Teori Newman. *Juring (Journal for Research in Mathematics Learning) p*, *4*(3), 197–204. https://doi.org/http://dx.doi.org/10.24014/juring.v4i3.13529

Solehudin, S., Darhim, D., & Herman, T. (2024). Analisis Kemampuan Dekomposisi Computational Thinking Siswa Pada Materi Sistem Persamaan Linear Dua Variabel. *Jurnal Perspektif*, *8*(2), 218. https://doi.org/10.15575/jp.v8i2.304

Sudijono, A. (2013). *Pengantar Evaluasi Pendidikan*. PT. Raja Grafindo Persada.

Sumargiyani, S. (2026). Analisis Kesalahan Kastolan: Studi pada Materi Turunan Fungsi Trigonometri, Implisit, dan Eksponensial. *Jurnal Pendidikan MIPA*, *16*(2), 364–371. https://doi.org/10.37630/jpm.v16i2.4149

Sundayana, R., & Parani, C. E. (2023). Analyzing Students' Errors in Solving Trigonometric Problems Using Newman's Procedure Based on Students' Cognitive Style. *Mosharafa: Jurnal Pendidikan Matematika*, *12*(1), 135–144. https://doi.org/10.31980/mosharafa.v12i1.762

Supiarmo, M. G., Turmudi, & Elly Susanti. (2021). Proses Berpikir Komputasional Siswa Dalam Menyelesaikan Soal Pisa Konten Change and Relationship Berdasarkan Self-Regulated Learning. *Jurnal Numeracy*, *8*(1). https://doi.org/https://doi.org/10.46244/numeracy.v8i1.1378

Tampubolon, A., Hutagalung, C. F., & Kembaren, N. S. B. (2025). Analisis Kemampuan Berpikir Komputasional Matematis Siswa Sma Pada Materi Fungsi. *Pedagogy*, *10*(4). https://doi.org/https://doi.org/10.30605/pedagogy.v10i4.7713

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35. https://doi.org/10.1145/1118178.1118215

Yarman, Murni, D., & Tasman, F. (2025). Implementation of SOLO taxonomy and Newman error analysis in first-order differential equation. *Infinity Journal*, *14*(3), 695–710. https://doi.org/10.22460/infinity.v14i3.p695-710