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Student errors in solving exponent problems: A qualitative Newman's procedure analysis among Indonesian senior high school students

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Abstract
Exponents constitute a fundamental concept essential for understanding advanced mathematical topics such as logarithms, geometric sequences, and compound interest. However, many students continue to experience difficulties in solving exponent-related problems. This qualitative descriptive study aims to analyze the types of errors made by tenth-grade students when solving exponent problems using Newman's procedure and to investigate the factors contributing to these errors. The participants were 23 students from *Madrasah Aliyah Negeri* (MAN) Insan Cendekia Siak in the 2024/2025 academic year. Data were collected through written tests and interviews, then analyzed by organizing and categorizing students' errors according to Newman's five stages. The results show that 12% of students committed reading errors due to inaccuracies in interpreting the questions, while no comprehension errors were identified. Transformation errors were the most common (49%), primarily due to students' difficulties in constructing appropriate mathematical models. Process skill errors accounted for 21%, primarily due to computational mistakes, and encoding errors represented 18%, arising from students' inability to use the provided information effectively. These findings deepen the understanding of students' patterns of error in exponent problems and imply the need for more targeted instructional strategies, especially those that strengthen mathematical modeling and procedural accuracy.

Keywords: error analysis; Newman procedure; exponent; mathematics education; problem solving

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I. Introduction

Exponents play a significant role in everyday life and across various fields, such as the natural sciences, technology, economics, and calculations involving growth or decay (Susanti, 2024; Şenay, 2024). Understanding exponents is essential for mastering advanced mathematical topics, including logarithms, geometric sequences, and compound interest (BSKAP, 2024; Rosyadi, Kafifah, Cholily, & Inganah, 2024). Research globally shows that many students face challenges in grasping exponent concepts, which affects their ability to solve complex problems (Benecke & Kaiser, 2023). In the Indonesian curriculum, exponents are introduced gradually from elementary to senior high school levels, starting with simple powers, moving on to exponent operations in junior high, and then to fractional exponents and contextual problem-solving in senior high school (Rahma & Khabibah, 2022).

Despite this structured progression, both local and international studies indicate that many students still experience substantial difficulties when working with exponent-related problems. Students commonly misapply exponent laws, struggle to translate contextual information into correct mathematical expressions, and commit procedural mistakes that lead to incorrect solutions (Jitendra, George, & Sood, 2019; Stacey & Vincent, 2009). Similar patterns have also been observed based on the researcher's experience in teaching mathematics at the senior high school level, where students often make errors in essay-type exponent problems due to conceptual misunderstandings, misinterpretation of question statements, and computational inaccuracies.

Errors in solving exponent problems are not unique to Indonesian students but form part of a global pattern documented in mathematics education research. International studies reveal that students frequently encounter difficulties in transforming contextual information into appropriate mathematical models (Kazemi & Rafiepour, 2015), misinterpret mathematical relationships in exponential functions (Ron, Kafifah, Cholily, & Inganah, 2020), and demonstrate limited procedural fluency when manipulating algebraic expressions with exponents (Star & Stylianides, 2013). Indonesian research echoes these issues, showing that students often make reading, comprehension, transformation, procedural, and encoding errors (Anggraini & Siregar, 2020; Gunawan & Fitra, 2021). These insights collectively highlight the importance of conducting systematic error analysis to identify the specific stages where students' thinking breaks down.

A substantial body of literature has examined student errors in exponents. Rahmawati & Permata (2018) reported high rates of comprehension and procedural errors, while Murtiyasa & Wulandari (2020) found recurring transformation and final-answer errors. International findings similarly suggest that exponent errors vary widely across tasks' cognitive demands, instructional contexts, and students' prior knowledge (Clarke & Roche, 2018). However, existing studies (both Indonesian and global) tend to emphasize error classification without adequately integrating the underlying cognitive or affective factors that contribute to such errors. Furthermore, there is limited synthesis across studies, which results in inconsistent explanations regarding why certain error types dominate. For example, some studies point to conceptual misunderstanding as the primary cause, while others attribute errors to weak algebraic manipulation or misreading problem statements.

Student errors may be influenced by a combination of internal and external factors. Internal factors include motivation, prior conceptual understanding, metacognitive strategies, and individual problem-solving tendencies (Kramarski & Mevarech, 2003), while external factors relate to learning environment, instructional methods, and classroom social interactions (Nurianti & Ijudin, 2015). However, most Indonesian studies applying Newman's procedure have focused primarily on describing error frequencies without incorporating students' internal explanations or thought processes, leaving a gap in fully understanding the cognitive reasons underlying each error stage.

Newman's error analysis framework widely used internationally (Newman, 1977; Clarkson, 1991), systematically identifies errors across five cognitive stages: reading, comprehension, transformation, process skills, and encoding. While numerous previous studies in Indonesia have used Newman's framework to categorize student mistakes, they have not thoroughly examined why particular errors occur at specific stages of Newman's framework or how students' thought processes contribute to these patterns. This study extends prior research by combining Newman's error analysis with an exploration of internal contributing factors derived from student interviews, thereby providing a more comprehensive, cognitively grounded explanation of students' error patterns.

Therefore, this study aims to (1) analyze the types of student errors in solving exponent problems based on Newman's procedure and (2) identify internal factors that contribute to these errors. The findings are expected to offer teachers clearer insights into the stages at which students struggle and to support the development of targeted instructional strategies that can minimize common error patterns and enhance students' understanding of exponent concepts.

II. Research Method

This study employed a qualitative descriptive design to analyze the types of errors students make when solving exponent problems. A qualitative approach was chosen because it allows for an in-depth examination of students' thinking processes and provides richer insights into the cognitive stages where errors occur, which quantitative scoring alone cannot fully capture. This aligns with the study's goal of understanding not only *what* errors occur but also *why* they emerge, as outlined by Newman's procedure.

The research was conducted with 23 tenth-grade students from *Madrasah Aliyah Negeri* (MAN) Insan Cendekia Siak in the 2024/2025 academic year. Participants were selected through purposive sampling based on the three criteria: (1) students had completed the exponent topic, (2) students were present during the assessment session, and (3) students were willing to participate in both the written test and follow-up interviews. These criteria ensured that all participants had comparable learning exposure and could provide valid data for error analysis.

Data were collected through a written test comprising three essay items and semi-structured interviews. The test instrument was developed based on essential competencies related to exponent concepts, including exponential growth, evaluating exponential functions, and simplifying algebraic expressions involving exponents. A brief blueprint of the test is presented in Table 1.

Table 1. Blueprint of exponent problem-solving test items

Indicator Measured	Cognitive Focus	Newman Stages Targeted
Apply exponent rules in contextual population growth	Conceptual & procedural	Transformation, process skills
Determine the exponential function and evaluate values	Modeling & computation	Comprehension, transformation, encoding
Simplify algebraic expressions with exponents	Procedural fluency	Reading, process skills, encoding

The instruments were validated through expert judgment from two mathematics education lecturers to ensure content validity and were piloted with a small group of students to ensure clarity and reliability. The collected data were analyzed using Newman's procedure. Indicators for each type of error were developed to facilitate the classification of student errors. A reading error was categorized if the student misread the problem. A comprehension error occurred when the student failed to fully understand the information provided in the problem, leading to the incorrect identification of known elements. Transformation errors were classified when students incorrectly converted the problem into an appropriate mathematical model. Process skill errors referred to mistakes in performing arithmetic operations. Finally, encoding errors were noted when students produced incorrect final answers or failed to provide one altogether (Annisa, Prayitno, Kurniati, & Amrullah, 2021).

Data analysis followed the stages proposed by Creswell, which include preparing and organizing data, coding data to build descriptions and themes, presenting and reporting findings, interpreting results, and validating accuracy (Yodiatmana & Kartini, 2022). Students' written responses were first compiled and coded according to Newman's five error categories. Each student's answer was examined line by line to identify the specific cognitive stage where an error occurred.

Interview data were analyzed using thematic coding aligned with the same Newman categories. Students' verbal explanations were transcribed and coded to identify reasons underlying each error, such as misconceptions, misinterpretation, lack of strategy, or computational confusion. These interview themes were then compared with the coded written-test errors to confirm whether the verbal explanations supported, contradicted, or clarified the observed mistakes.

Triangulation was conducted by matching (1) the error type detected from the test response, (2) the student's explanation during the interview, and (3) the researcher's interpretation. When discrepancies appeared between written answers and interview statements, the researcher reviewed both sources again to determine the most plausible interpretation of the student's thinking. This process ensured analytical rigor and strengthened the validity of the findings.

III. Results and Discussion

The researchers analyzed students' test responses to determine the types of errors made, using Newman's procedure as the analytical framework. The results of the error analysis of students' work on exponent problems, based on Newman's procedure, are presented in Table 2.

Table 2. Percentage of student errors based on Newman's procedure

Question Number	**Error Type**				
	X_1	X_2	X_3	X_4	X_5
1	0	0	10	4	0
2	0	0	2	2	3
3	4	0	4	1	3
Sum	4	0	16	7	6
%	12	0	49	21	18

Note:
X_1 = reading error
X_2 = comprehension error
X_3 = transformation error
X_4 = process skill error
X_5 = encoding (answer writing) error

Table 2 indicates that the most frequent type of error committed by students is the transformation error, accounting for nearly half of all errors. A more detailed description of each error type for each question will be provided based on students' incorrect responses according to's procedure.

Reading Errors

According to Table 2, 12% of students made reading errors, with four errors occurring on question number 3. A detailed description of students' reading errors is presented in Table 3.

Table 3. Description of students' reading errors

Question Number	**Description**	**f**	**%**
3	Incorrectly copying the problem at the beginning of the solution process	3	75
	Incorrectly copying the problem during the solution process	1	25

Table 3 shows that students' reading errors occurred both at the beginning of the problem-solving process and during the solution process. Below is the response from subject S08, who incorrectly copied the problem at the beginning of the solution.

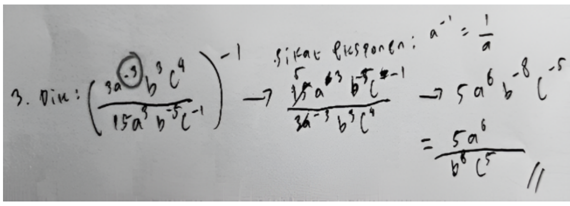

Figure 1. Response of subject s08 to question number 3

Based on Figure 1, the correct problem is a^{-2}, but subject S08 wrote a^{-3}. Reading errors are not only found at the beginning of the problem-solving process; some students also make reading errors during the solution process. Below is the response from subject S17, who incorrectly wrote the exponent during the problem-solving process.

Based on Figure 2, initially, subject S17 correctly copied the problem, but during the process, S17 misread their own writing, changing c^{-2} to c^{-5}. Interviews with subjects S08 and S17 revealed that the cause of their errors was a lack of carefulness and rushing, as they had limited time left to complete question number 3.

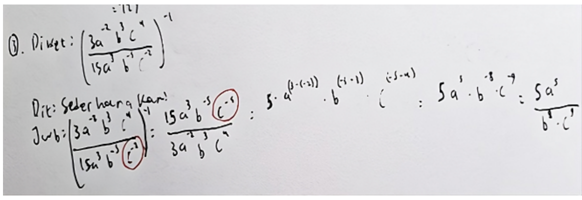

Figure 2. Response of subject s17 to question number 3

While interviews attributed these reading errors to haste and carelessness, a deeper analysis using cognitive theories reveals more nuanced explanations. According to Cognitive Load Theory (Sweller, Ayres, & Kalyuga, 2011), working memory has a strictly limited capacity to process information simultaneously. When students face time constraints during problem-solving, their working memory becomes overloaded, reducing the cognitive resources available for maintaining careful attention to detail in transcription tasks. The concentration required to accurately read and copy complex mathematical notation (particularly multi-digit exponents and variable symbols) may exceed students' available cognitive capacity, especially in essay-type problems where multiple operations must be tracked.

This interpretation aligns with empirical findings by Geary (2004) on numerical cognition, which propose that apparent procedural "errors" in mathematics often stem from temporary failures in working memory capacity rather than from inherent ability deficits or a lack of effort. Furthermore, the pattern observed aligns with Hattie's (2009) description of the impact of time pressure on metacognitive regulation. Students under temporal stress often fail to employ self-monitoring and error-checking strategies for routine tasks such as accurate reading and transcription, despite being able to do so under normal conditions.

The relatively low reading error rate (12%) compared to the transformation error rate (49%) is particularly informative. This disparity suggests that when time pressure is reduced or eliminated, students' reading accuracy improves substantially, providing empirical support for the Cognitive Load Theory explanation rather than attributing these errors to fundamental deficits in student ability.

Comprehension Errors

According to Table 2, no students made comprehension errors (0%). All students demonstrated the ability to understand the problems presented, as reflected in their ability to correctly state what is known and what is being asked in the problems.

However, an interview with subject S11, who made errors on all three questions, revealed a nuanced finding. While the student understood the information provided and identified the questions, there were significant difficulties in applying the appropriate exponent formulas and conceptual frameworks. For question 1, subject S11 did not know which exponent rule to use despite understanding that population growth was involved. For question 2, the student understood the question and identified the exponent of the given function, but did not know how to proceed with the solution. For question 3, subject S11 understood the general approach to simplify the given exponent expression but made operational errors during the calculation process, leading to an incorrect final answer.

The absence of comprehension errors is noteworthy and suggests that students in this cohort have developed adequate language comprehension and problem interpretation skills. This finding aligns with Clarkson (1991) and Nofrianto (2022), who noted that comprehension errors are often linked to linguistic barriers or unfamiliarity with mathematical terminology. Nofrianto's research, demonstrated that when students overcome linguistic hurdles, they can progress to diagnosing deeper cognitive difficulties at transformation and process skill stages. The present cohort has overcome these barriers, at least at the surface level of understanding what information is provided and what is being requested. However, the case of subject S11 illustrates an important distinction: comprehension of what the problem asks does not automatically translate to conceptual understanding of how to solve it. This distinction underscores the importance of attending to the transformation and process skill stages, where students' difficulties become apparent despite their ability to comprehend problem statements.

Transformation Errors

Based on Table 2, the most frequent errors made by students were transformation errors, accounting for 49% with 16 instances. This finding places transformation errors as the dominant error category, substantially exceeding other error types. A detailed description of students' transformation errors is presented in Table 4 below.

Table 4. Description of students' transformation errors

Question Number	Description	f	%
1	Incorrect formulation of the mathematical model for population growth	10	100
2	Incorrect transformation of given data into the specified function	1	50
	Failure to transform the given data into the specified function	1	50
3	Incorrect application of properties in exponent operations	4	100

The transformation error made by students on question 1 was the incorrect formulation of the mathematical model for population growth. Below is the response of subject S14 to question number 1.

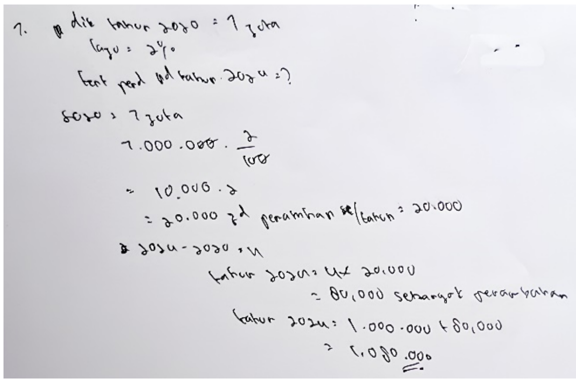

Figure 3. Response of Subject S14 to Question Number 1

As shown in Figure 3, subject S14 calculated the population increase for one year (multiply the initial population by 1.02), then multiplied this yearly increase by four and added it to the initial population. However, the actual population growth each year is not constant but depends multiplicatively on the population of the previous year. Therefore, the mathematical model used by subject S14 was fundamentally incorrect for solving question number 1. Based on the interview with subject S14, the misconception arose because the subject assumed the population growth to be linear (constant additive growth) rather than exponential (multiplicative growth).

This error pattern reflects fundamental challenges in the representation of mathematical problems, as described in Mathematical Modeling Theory (Blum & Leiss, 2007). Successful mathematical modeling requires students to (1) mentally represent the real-world context accurately, (2) identify the underlying mathematical structure, and (3) construct a mathematical representation that captures that structure. Subject S14's linear model reveals a break at step 2 (the student did not recognize that exponential growth involves multiplicative relationships at each time step).

From the perspective of Schema Theory (Baroody, Feil, & Johnson, 2007), this error exemplifies schema interference. Students activate familiar linear growth schemas when encountering unfamiliar exponential contexts. Because linear relationships (constant additions) are cognitively more accessible and learned earlier in students' mathematical experience, they become default interpretive frameworks. When encountering population growth contexts, students often apply linear schemas before progressively learning to recognize and apply exponential schemas. This interference effect is predictable and well documented in mathematics education research and aligns with findings reported by Dwinata & Febrian (2018), who found that transformation errors accounted for 59.1% of student errors in counting problems, reflecting students' limited cognitive ability to understand mathematical concepts and to construct appropriate solution strategies.

For question number 2, the student error involved incorrectly transforming the given data into the exponential function specified in the problem. Below is the response of subject S12 to question number 2.

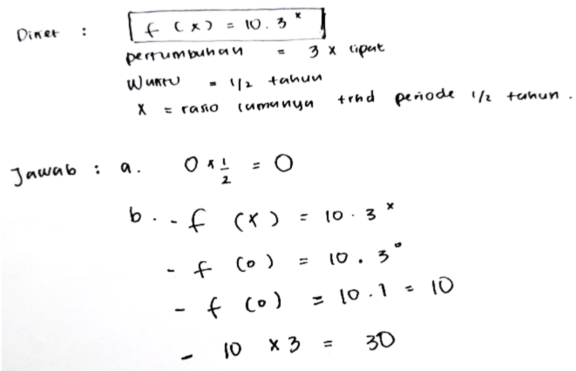

Figure 4. Response of subject s12 to question number 2

In Figure 4, it can be seen that subject S12 correctly determined the exponent to find the initial number of rabbits; however, the subject did not correctly substitute the data into the given function. In part (b) of the question, subject S12 wrote the rabbit growth function but incorrectly substituted the exponent. Although subject S12 identified $f(0)$ as the answer to part (a), they misunderstood its meaning and instead multiplied $f(0)$ by three to find the number of rabbits after three years. According to the interview with subject S12, the subject believed that the initial number of rabbits in part (a) should be zero. In part (b), since the question asked for the number of rabbits after three years, subject S12 multiplied $f(0)$ by three.

Subject S12's error reveals another dimension of transformation difficulties: inadequate problem representation and underdeveloped functional thinking. According to Mayer's (2009) framework on problem representation, successful problem-solving requires constructing accurate mental models that mirror the problem structure. Subject S12 did not construct a mental model that properly connected initial conditions ($f(0)$) to subsequent evaluations ($f(3)$). This failure reflects what Hiebert (2013) distinguished as a gap between conceptual understanding (knowing relationships between quantities) and procedural fluency (executing procedures). Subject S12 could execute the mechanical step of substituting numbers but lacked the conceptual understanding that $f(0)$ represents a fixed initial value that remains constant across all function evaluations, and that $f(3)$ represents a different point on the function, not a modification of $f(0)$.

For question number 3, students' transformation errors involved incorrect use of properties of exponent operations. Below is the response of subject S06 to question number 3.

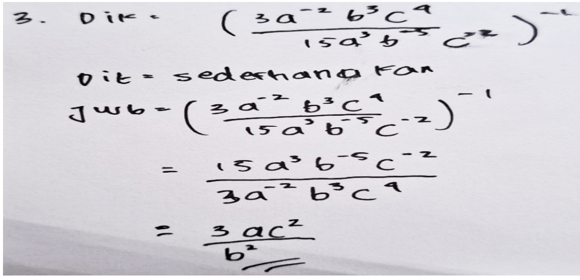

Figure 5. Response of subject s06 to question number 3

Based on Figure 5, it can be observed that subject S06 correctly applied the exponent property $a^{-1} = 1/a$; however, in the subsequent step, the subject failed to correctly apply the property $a^m/a^n = a^{m+n}$. Subject S06 made errors in determining all divisions involving both numbers and variables with exponents. From the interview with subject S06, it was revealed that the mistake in calculating $15/3 = 3$ was a computational error. However, regarding operations on variables with exponents, subject S06 mistakenly added the exponents of each variable, despite the correct exponent rule being subtraction.

The causes of students' transformation errors across the three questions included: (1) an inability to formulate appropriate mathematical models from contextual problems, (2) failure to recognize the underlying mathematical structures (exponential vs. linear), (3) inadequate functional thinking and understanding of function notation, and (4) incorrect internalization of exponent properties without sufficient conceptual grounding. These findings are consistent with Fauzia & Retnawati (2023), who concluded that transformation errors stem from students' inability to translate problem statements into mathematical models, and with Dinnullah, Noni, E., & Sumadji (2019), who identified students' inability to identify suitable methods or strategies for solving given problems.

The consistency of high transformation error rates across different mathematical content and contexts (as documented in the present study and corroborated by Dwinata & Febrian (2018) in their analysis of counting problems, and supported by Nofrianto (2022), on word problems) suggests that transformation error is a pervasive and fundamental challenge in Indonesian mathematics education, likely rooted in instructional approaches that emphasize procedural execution over conceptual understanding and mathematical modeling practices.

Reducing transformation errors requires fundamental shifts in instructional approach: (1) explicit, sustained instruction in mathematical modeling processes (identifying variables, relationships, and appropriate representations), (2) multiple representations (tables, graphs, equations, contextual descriptions) to develop flexible mental models, (3) deliberate practice in recognizing exponential versus linear patterns and understanding when each is appropriate, (4) conceptually-grounded instruction in exponent properties that emphasizes why properties work rather than just how to apply them, and (5) regular practice connecting abstract mathematical representations to real-world contexts to build robust schemas.

Process Skill Errors

Table 2 shows that process skill errors accounted for 21% of the total errors, with 7 instances. A detailed description of students' process skill errors for each question is presented in Table 5 below.

Table 5. Description of students' process skill errors

Question Numbers	Description	f	%
1	Errors in the calculation process	4	100
2	Errors in the calculation process	2	100
3	Errors in the calculation process	1	100

The process skill error made by students on question number 1 was related to mistakes in the calculation process. Below is the response of subject S02 to question number 1.

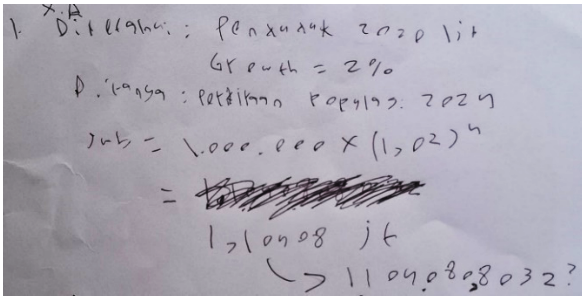

Figure 6. Response of subject s02 to question number 1

In Figure 6, it can be observed that subject S02 made a calculation error when computing $(1{,}02)^4$. Subject S02 wrote the result as 1.104, whereas the correct value is 1.082. Based on the interview with subject S02, it was revealed that the subject mistakenly multiplied 1.02 five times instead of four times.

For question number 2, there was also a calculation error during the problem-solving process, as shown in the response of subject S10.

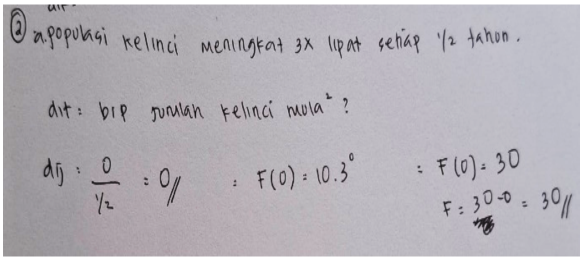

Figure 7. Response of subject s10 to question number 2

In the figure, it can be seen that subject S10 made a calculation error by stating that $3^0 = 3$, whereas the correct result is $3^0 = 1$. The interview with subject S10 confirmed that during the problem-solving process, the subject mistakenly determined the result and did not have enough time to review the answer.

Subject S11 also made process skill errors on question 3. Below is the response of subject S11 to question number 3.

In Figure 8, subject S11 made errors in calculating the exponentiation operations involving b and c. The correct operations should be $b^{3-(-5)} = b^8$ and $c^{4-(-2)} = c^6$. However, subject S11 mistakenly performed the subtraction with negative integers. Based on the interview with subject S11, it was revealed that the subject assumed subtracting a negative number would result in a negative value.

The process skill errors made by students in questions 1, 2, and 3 were attributed to carelessness in performing calculations and misconceptions regarding the addition or subtraction of negative integers. These findings align with Hidayanto, Subanji, & Hidayanto, (2017) research, which found that errors in process skills are caused by students' misconceptions and mistakes in basic computational operations.

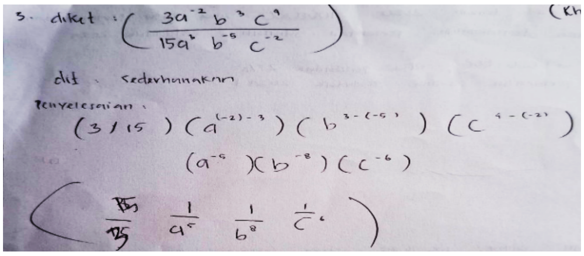

Figure 8. Response of subject s11 to question number 3

While superficially attributed to "carelessness" or "rushing," process-skill errors reflect deeper issues related to procedural fluency and automaticity in arithmetic. According to Ericsson (2008) theory on deliberate practice and automaticity, procedural fluency (the ability to execute mathematical procedures quickly and accurately without excessive cognitive effort) requires extensive deliberate practice to achieve true automaticity. Many students in this study had not yet developed sufficient automaticity in basic arithmetic operations, particularly with operations involving negative numbers, fractional values, and exponent properties applied in sequence.

The high error rate in calculating operations with negative numbers (exemplified by S11's misconception about subtracting negative integers) exemplifies what Transfer Theory describes as negative transfer or interference effects (Resnick, 1992; Siegler & Stern, 1998). Students may have overlearned incorrect rules or mental models earlier in their mathematical experience (e.g., from oversimplified instruction or pattern-matching errors), such as "subtracting something makes it smaller," which interfere with the correct principle that subtracting a negative quantity is equivalent to adding. This competitive activation of conflicting mental models leads to systematic errors rather than random mistakes.

Furthermore, from a Cognitive Load Theory perspective (Sweller et al., 2011), students attempting to manage multiple procedural steps simultaneously (applying exponent division rules while executing negative number operations to while tracking multiple variables) experience intrinsic cognitive overload. This excessive working memory demand leaves insufficient capacity for accurate procedural execution, resulting in computational lapses. The finding that most process skill errors occurred in multi-step problems (Questions 1 and 2), particularly in problems requiring operations with negative numbers, supports this explanation: students have the procedural knowledge but lack the working memory capacity or automaticity to execute it reliably under cognitive load.

The error pattern also connects to metacognitive regulation. Subject S10's mention of lacking "enough time to review the answer" suggests that students did not implement self-checking strategies that would catch computational errors. This reflects what Flavell (1976) termed metacognitive monitoring failure: the ability to track one's own performance and identify potential errors was insufficient, likely because the computational tasks themselves already taxed working memory.

Reducing process skill errors requires targeted interventions addressing multiple dimensions: (1) building automaticity through deliberate practice on foundational operations (particularly negative integer operations and basic exponent evaluations), with explicit error correction to prevent persistence of incorrect rules, (2) reducing extraneous cognitive load through scaffolding and step-by-step problem presentation to preserve working memory capacity for accurate calculation, (3) explicit teaching of metacognitive monitoring strategies such as reasonableness checks and verification procedures, and (4) focused remediation on the specific misconceptions identified (particularly regarding negative number operations and exponent properties) using multiple representations and concrete examples. Students would benefit from manipulative-based instruction or visual models that concretize the meaning of operations with negative numbers.

Answer Encoding Errors

Based on Table 1, it is evident that answer writing errors made by students account for 18%, with a total of six errors. A detailed description of students' answer writing errors is presented in Table 5 below.

Table 5. Description of students' answer writing errors

Question Number	Description	f	%
2	Incorrect Final Answer Submission	2	67
	Omission of Final Answer	1	33
3	Incorrect Final Answer	3	100

Answer writing errors are evident in students who either do not write the final answer or write an incorrect final answer. Below is the response of subject S17, who made an error in writing the final answer on question number 2.

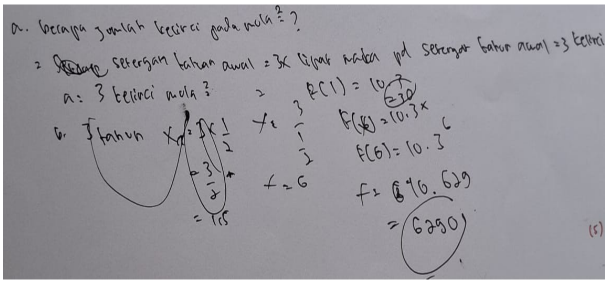

Figure 9. Answer result of subject s17 for question number 2

In Figure 9, it is observed that subject S17 performed the correct steps; however, when writing the final answer, S17 recorded 6,290 instead of the correct value of 7,290. An interview with subject S17 revealed that this mistake in writing the final answer was due to a miscalculation and a lack of carefulness.

Answering errors are also indicated by students who omit the final answer. Below is the response of subject S11, who did not write the final answer for question number 2.

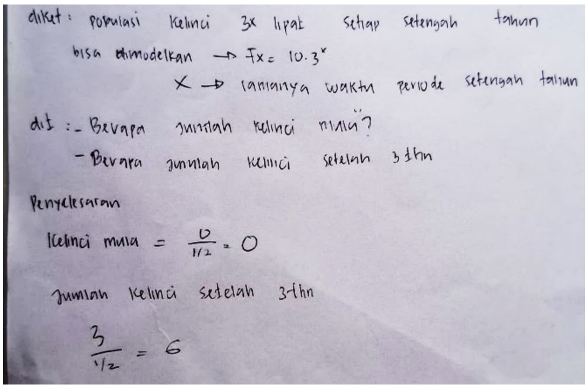

Figure 10. Answer result of subject s11 for question number 2

In Figure 10, it is evident that subject S11 did not write the final answer requested in the problem. Subject S11 only reached the stage of determining the exponent of the exponential function to solve the given problem. Based on an interview with subject S11, it was revealed that the subject did not know the subsequent steps and therefore did not continue the problem-solving process.

In question number 3, there were also students who made errors in determining the final answer. Below is the response of subject S10 for question number 3.

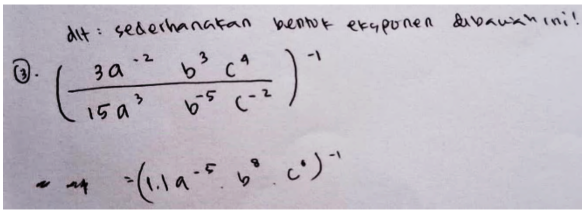

Figure 11. Answer result of subject s10 for question number 3

In Figure 11, subject S10 applied the exponent division property to simplify the given exponential expression. However, S10 did not continue simplifying the expression using the property $(a^m)^n = a^{mn}$, resulting in an incomplete final answer that did not meet the question's requirements. The student simplified to an intermediate form ($1/(abc^2)$) but did not complete the final simplification step. Based on an interview with S10, it was revealed that the subject lacked sufficient time to complete the problem and, due to rushing, did not think to or did not recognize the need to multiply all exponents by -1 in the final step.

Encoding errors, while relatively low in frequency, are theoretically significant as indicators of executive function and metacognitive regulation deficits. According to Executive Function Theory (Miyake et al., 2000; Diamond, 2013), completing complex problem-solving requires three interdependent executive functions: (1) working memory to maintain the problem goal and intermediate results, (2) inhibitory control to avoid impulsive or habitual responses, and (3) cognitive flexibility to adjust strategies when initial approaches prove inadequate.

Subject S11's failure to provide a final answer despite progressing partway through the solution reveals a breakdown in goal maintenance; the student did not retain or prioritize the objective of reaching and communicating a final numerical answer. This may reflect either exhaustion of working memory capacity (the cognitive load of the problem consumed resources needed to maintain goal representation) or a deficit in executive metacognitive strategies for maintaining focus on the ultimate objective.

Subject S10's incomplete final answer indicates insufficient metacognitive monitoring. The student demonstrated procedural knowledge of simplifying algebraic expressions with exponents, but failed to recognize that the answer remained in an intermediate form rather than fully simplified. This represents what Flavell (1976) termed metacognitive monitoring failure, which refers to the inability or failure to assess one's own performance against the stated requirements. Effective problem-solving requires continuous monitoring of whether each step brings one closer to the goal state (a fully simplified expression in this case).

Subject S17's computational error in the final step, despite correct prior work, reflects working memory depletion near problem completion. Following Cognitive Load Theory, by the final stages of multi-step problem-solving, students' working memory may be substantially depleted or taxed to capacity, reducing available resources for accurate transcription or final verification of answers. The time-related comments in several interviews (students rushing toward deadlines) provide external validation for this explanation. The pattern of encoding errors, concentrated in problems with higher demands (Questions 2 and 3), aligns with predictions from Cognitive Load Theory about the effects of cumulative processing demands on working memory capacity.

Reducing encoding errors involves developing students' executive function and metacognitive competencies through: (1) explicit instruction in problem-solving completion strategies, such as requiring students to state the problem goal at the beginning and check whether their final answer actually addresses that goal, (2) structured problem-solving templates that maintain goal representation throughout the solving process and include verification steps before final answer submission, (3) teaching and modeling error-checking and answer-verification routines as integral parts of the problem-solving process, (4) time management instruction to prevent rushed final steps where errors are most likely, and (5) fostering metacognitive awareness through reflective practices where students evaluate their own performance against rubrics or exemplars.

Additionally, the pattern observed (errors concentrated in multi-step problems under time pressure) suggests that alternative assessment formats might provide a more accurate picture of student competency. For instance, untimed or open-ended assessments, or providing intermediate checkpoints with feedback, might substantially reduce encoding errors while maintaining assessment rigor.

IV. Conclusion

Based on the findings regarding the types of student errors according to Newman's procedure on the topic of exponents, it can be concluded that the errors made by students in solving exponent problems are as follows: reading errors accounted for 12%, transformation errors for 49%, process skill errors for 21%, answer encoding errors for 18%, and no students were found to make comprehension errors.

The analysis of these five types of errors indicates that the most frequent error occurred at the transformation stage. Transformation errors were caused by students' inability to formulate a mathematical model from the given problem. Reading errors resulted from students being inattentive and rushing through the problems. Process skill errors were due to students' lack of understanding of basic computational operations. Answer encoding errors stemmed from students' inability to use the given information effectively to solve the problem. The absence of comprehension errors suggests that students understood what was known and what was being asked in the problems.

However, we have acknowledged that this study has several limitations. First, the sample size was relatively small and drawn from a single school, which may limit the generalizability of the results to broader student populations. Second, the study focused only on internal factors influencing errors, excluding potential external factors such as instructional practices or classroom learning environments. Third, the test instrument consisted of only three essay items, which may not fully capture the diversity of exponent-related competencies. Future research may involve larger and more diverse samples, incorporate external contextual factors, and utilize a wider range of assessment formats to provide a more comprehensive understanding of students' errors.

References

Anggraini, D., & Siregar, R. M. R. (2020). Analisis kesalahan siswa dalam menyelesaikan soal eksponen melalui pembelajaran online di masa pandemi kelas X SMA Swasta Tamansiswa Binjai. *Serunai: Jurnal Ilmiah Ilmu Pendidikan*, 6(2), 86–91. https://doi.org/10.37755/sjip.v6i2.331

Annisa, A., Prayitno, S., Kurniati, N., & Amrullah, A. (2021). Analisis kesalahan dalam menyelesaikan soal cerita matematika materi relasi dan fungsi berdasarkan prosedur Newman ditinjau dari perbedaan gender pada siswa kelas VIII SMP Negeri 22 Mataram tahun pelajaran 2021/2022. *Jurnal Ilmiah Profesi Pendidikan*, 8(1), 323–334. https://doi.org/10.29303/jipp.v8i1.1141

Baroody, A. J., Feil, Y., & Johnson, A. R. (2007). An alternative reconceptualization of procedural and conceptual knowledge. *Journal for Research in Mathematics Education*, 38(2), 115–131.

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

Blum, W., & Leiss, D. (2007). How do teachers deal with modelling in statistics lessons? In C. Haines, P. Galbraith, W. Blum, & S. Khan (Eds.), *Mathematical modelling (ICTMA 12): Education, engineering and economics* (pp. 133–144). Horwood Publishing.

BSKAP. (2024). *Capaian pembelajaran pada pendidikan anak usia dini, jenjang pendidikan dasar, dan jenjang pendidikan menengah pada Kurikulum Merdeka*. Jakarta: Kemdikbudristek.

Clarke, D., & Roche, A. (2018). Enhancing students' understanding of exponential relationships through representations. *Australian Mathematics Teacher*, 74(2), 3–10.

Clarkson, P. (1991). Language comprehension errors: A further investigation. *Mathematics Education Research Journal*, 3(2), 24–33. https://doi.org/10.1007/BF03217225

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, 64, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dinnullah, R. N. I., Noni, E., & Sumadji, S. (2019). Analisis kesalahan siswa pada penyelesaian soal cerita berdasarkan tahapan Newman. *Jurnal Tadris Matematika*, 2(2), 175–184. https://doi.org/10.21274/jtm.2019.2.2.175-184

Dwinata, A., & Febrian, F. (2018). Analisis kesalahan siswa dalam pemecahan problematika kaidah pencacahan titik sampel. *Jurnal Gantang*, 3(2), 121–129. https://doi.org/10.31629/jg.v3i2.479

Ericsson, K. A. (2008). Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Academic Medicine*, 84(10 Suppl), S1–S11.

Fauzia, T. I., & Retnawati, H. (2023). Analisis kesalahan siswa SMA dalam mengerjakan soal literasi matematika model AKM. *Jurnal Pedagogi Matematika*, 9(2), 143–156. https://doi.org/10.21831/jpm.v9i2.19624

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), *The nature of intelligence* (pp. 231–235). Lawrence Erlbaum. https://doi.org/10.4324/9781032646527-16

Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of Learning Disabilities*, 37(1), 4–15. https://doi.org/10.1177/00222194040370010201

Gunawan, M. S., & Fitra, D. (2021). Kesulitan siswa dalam mengerjakan soal eksponen dan logaritma. *Mosharafa: Jurnal Pendidikan Matematika*, 10(2), 257–268. https://doi.org/10.31980/mosharafa.v10i2.875

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Hidayanto, T., Subanji, S., & Hidayanto, E. (2017). Deskripsi kesalahan struktur berpikir siswa SMP dalam menyelesaikan masalah geometri serta defragmentingnya: Suatu studi kasus. *Jurnal Kajian dan Pembelajaran Matematika*, 1(1), 72–81.

Hiebert, J. (2013). Conceptual and procedural knowledge: The case of mathematics. In S. P. Lajoie (Ed.), *Computers as cognitive tools: No more walls* (pp. 381–398). Lawrence Erlbaum. https://doi.org/10.4324/9780203063538

Jitendra, A. K., George, M. P., & Sood, S. (2019). Mathematical problem-solving: Errors, misconceptions, and strategies. *Journal of Learning Disabilities*, 52(6), 523–536.

Kazemi, F., & Rafiepour, A. (2015). Students' difficulties in modeling exponential growth problems. *International Journal of Mathematical Education in Science and Technology*, 46(7), 1058–1071.

Kramarski, B., & Mevarech, Z. (2003). Enhancing mathematical reasoning: Effects of metacognitive training on problem solving. *American Educational Research Journal*, 40(1), 281–310. https://doi.org/10.3102/00028312040001281

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Murtiyasa, B., & Wulandari, D. (2020). Analisis kesalahan siswa dalam menyelesaikan soal eksponen melalui pembelajaran online di masa pandemi kelas X SMA Swasta Tamansiswa Binjai. *Serunai: Jurnal Ilmiah Ilmu Pendidikan*, 6(2), 86–91. https://doi.org/10.37755/sjip.v6i2.331

Newman, M. A. (1977). An analysis of sixth-grade pupils' errors on written mathematical tasks. *Victorian Institute for Educational Research Bulletin*, 39, 31–43.

Nofrianto, A. (2022). Student errors in mathematics word problems: What can be learned? *Jurnal Gantang*, 7(1), 59–67. https://doi.org/10.31629/jg.v7i1.4426

Nurianti, E., & Ijudin, R. (2015). Analisis kesalahan siswa dalam menyelesaikan soal matematika materi pecahan bentuk aljabar di kelas VIII SMP. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa*, 4(9).

Rahma, A. F., & Khabibah, S. (2022). Analisis kesalahan siswa SMA dalam menyelesaikan soal eksponen. *MATHEdunesa*, 11(2), 446–457. https://doi.org/10.26740/mathedunesa.v11n2.p446-457

Rahmawati, D., & Permata, L. D. (2018). Analisis kesalahan siswa dalam menyelesaikan soal cerita program linear dengan prosedur Newman. *Jurnal Pembelajaran Matematika*, 5(2). https://doi.org/10.30656/gauss.v2i1.1406

Resnick, L. B. (1992). From protoquantities to operators: Building mathematical competence on a foundation of everyday thinking. In G. Leinhardt, R. Putnam, & R. A. Hattrup (Eds.), *Analysis of Arithmetic for Mathematics Teaching* (pp. 373–429). Lawrence Erlbaum. https://doi.org/10.4324/9781315044606-

7
Ron, G., Dreyfus, T., & Hershkowitz, R. (2020). Students' reasoning about exponential functions: A structural analysis. *Educational Studies in Mathematics*, 103, 155–176.

Rosyadi, A. A. P., Kafifah, A., Cholily, Y. M., & Inganah, S. (2024). Students' mathematical errors in solving literacy and numeracy problems. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, 9(2), 105–116. https://doi.org/10.23917/jramathedu.v9i2.10464

Şenay, Ş. C. (2024). Analysis of misconceptions and errors regarding exponential and radical expressions through the theory of reducing abstraction. *Research on Education and Psychology*, 8(2), 281–295. https://doi.org/10.54535/rep.1520588

Siegler, R. S., & Stern, E. (1998). Conscious and unconscious strategy discoveries: A microgenetic analysis. *Journal of Experimental Psychology: General*, 127(4), 377–397. https://doi.org/10.1037/0096-3445.127.4.377

Stacey, K., & Vincent, J. (2009). Modes of reasoning in algebra. *Journal of Mathematical Behavior*, 28(1), 1–12.

Star, J. R., & Stylianides, G. J. (2013). Procedural and conceptual knowledge: Exploring the relationship in mathematics. *Journal for Research in Mathematics Education*, 44(2), 238–248.

Susanti, W., & Kartini, K. (2024). Analisis kesalahan siswa Madrasah Aliyah dalam menyelesaikan soal materi eksponen berdasarkan prosedur Kastolan. *El-Khuwailid: Journal of Multidisciplinary Studies*, 1(1), 1–11. https://doi.org/10.63826/el-khuwailid.v1i1.1

Sweller, J., Ayres, P., & Kalyuga, S. (2011). Cognitive load theory in education: An overview. *International Journal of Educational Research*, 50(5–6), 431–435. https://doi.org/10.1007/978-1-4419-8126-4

Yodiatmana, Y., & Kartini, K. (2022). Analysis of student errors in solving basic logarithmic problems using Kastolan error analysis. *Jurnal Gantang*, 7(2), 129–136. https://doi.org/10.31629/jg.v7i2.4689

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