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Analysis of elementary school students' errors in multilevel division operations (porogapit) based on skemp's theory

Mohammad Nurwahid[1)*], Bagus Hidayatulloh[2)], Rosmaiyadi[3)]
[1), 2)] Institut Alif Muhammad Imam Syafi'i, Lamongan, Indonesia
[3)] Institut Sains dan Bisnis Internasional, Singkawang, Indonesia
*nurwahid@inamis.ac.id

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Abstract

This study aims to analyze elementary school students' errors in solving multilevel division (porogapit) based on Skemp's Theory of Understanding. The study employed a qualitative descriptive approach involving 20 fifth-grade students who had learned multilevel division. Data were collected through written tests and semi-structured interviews. From the test results, two students who demonstrated representative error patterns and were able to clearly communicate their reasoning were selected as key informants for in-depth analysis. The findings reveal three dominant types of errors: (1) errors related to place value, particularly failure to maintain the positional structure of digits in the quotient; (2) omission of zero digits in the quotient; and (3) incorrect use of approximation strategies in determining quotient digits. These errors indicate that students tend to rely on instrumental understanding rather than relational understanding. The weakest conceptual aspects include students' understanding of place value, the role of zero in division, and the relationship between division and multiplication. This study highlights the importance of strengthening relational understanding in teaching porogapit division to reduce procedural errors.

Keywords: Multilevel Division; Porogapit; Skemp's Theory; Student Errors.

INTRODUCTION

Mathematics is a fundamental subject that plays a crucial role in developing students' logical, systematic, and analytical thinking skills, starting in elementary school. One of the fundamental competencies elementary school students must master is arithmetic operations, particularly division. Division requires not only numeracy skills but also an understanding of place value concepts, relationships between operations, and coherent and precise procedural skills. Therefore, division is a crucial yet challenging topic in elementary school mathematics (Indah et al., 2020).

Multilevel division, also known as the porogapit method, is a formal algorithm commonly used in teaching whole number division in elementary schools. This method requires students to coordinate several mathematical operations simultaneously, such as multiplication, subtraction, and understanding place value. The complexity of these steps often causes students to experience difficulties and make various types of errors. Research shows that errors in multiplication occur not only in the final result, but also in the process and steps taken by students to solve the problem (Sari & Fikrati, 2023; Taufan & Hakam, 2024).

A number of previous studies have examined students' difficulties and errors in the the porogapit of whole numbers. Astuti et al., (2024); Ramdani & Suryaningsih, (2024) found that elementary school students frequently make mistakes in determining quotients, subtracting, and understanding the concept of place value in dividing large numbers. Other research also revealed that division errors are influenced by a weak mastery of the basic operations required and a poor understanding of the concept of division itself (Andriyani & Pranata, 2021; Behera & Pattnayak, 2024).

On the other hand, several studies have analyzed student errors using specific frameworks, such as Newman's theory and the conceptual–procedural–technical error classification. For example Berliani & Dianti (2025); Hadi (2021) utilized Newman's theory to identify student errors in solving mathematics problems, including division. However, this approach focused more on the problem-solving stage and did not fully explore the quality of students' mathematical understanding underlying these errors.

In the context of mathematical understanding, Skemp's Theory of Understanding distinguishes two types of understanding: instrumental understanding and relational understanding. Instrumental understanding refers to the ability to use rules or procedures without understanding the reasons behind them, while relational understanding emphasizes understanding concepts and the relationships between mathematical ideas (Sudrajat, 2022). Research based on Skemp's theory has been widely applied to other mathematical topics, such as probability (Andam et al., 2025), general mathematical understanding (Giriansyah et al., 2023; Hidaiyah et al., 2023) and the concept of inverse functions (Rosita et al., 2021). The results of this study indicate that the dominance of instrumental understanding often results in the emergence of procedural errors and misconceptions.

However, to date, there is still limited research specifically analyzing elementary school students' errors in multilevel division (porogapit) using the Skemp Theory perspective. Most porogapit research focuses more on identifying difficulties or developing learning media (Komang et al., 2025; Manar et al., 2025), without explicitly linking it to the type of mathematical understanding of students. However, Skemp's theory-based error analysis has the potential to provide a more in-depth understanding of whether students' errors stem from purely instrumental understanding or from a failure to develop a relational understanding of the concept of division.

Although numerous studies have examined students’ errors in division, most of them focus on identifying procedural mistakes or categorizing errors using frameworks such as Newman’s Error Analysis. These approaches primarily describe where errors occur in the problem-solving process but provide limited insight into the nature of students’ mathematical understanding underlying those errors. In the context of multilevel division (porogapit), existing studies tend to emphasize difficulties and instructional strategies without explicitly linking students’ errors to the depth of their conceptual understanding. As a result, it remains unclear whether students’ errors stem from a lack of procedural mastery or from insufficient relational understanding of division concepts.

Skemp’s Theory of Understanding offers a more powerful analytical lens because it distinguishes between instrumental and relational understanding, allowing researchers to examine not only how students perform procedures but also why they make certain errors. Therefore, this study addresses the gap by analyzing students’ errors in porogapit division through the perspective of Skemp’s theory, enabling a deeper interpretation of the relationship between procedural performance and conceptual understanding.

The novelty of this research lies in the use of Skemp's theory as the primary lens in analyzing students' errors in porogapit division, thus not only revealing the form of the error, but also examining the depth of mathematical understanding behind it. Theoretically, this study contributes to the literature on mathematics education by extending the application of Skemp’s Theory of Understanding to the context of multilevel division (porogapit) in elementary school. Previous studies have mainly applied Skemp’s framework to broader mathematical concepts such as functions, probability, or general mathematical understanding. However, limited research has specifically examined how instrumental and relational understanding manifest in students’ procedural errors during algorithmic operations such as long division.

By analyzing students’ errors through this theoretical lens, this study provides a clearer explanation of how procedural mastery may coexist with weak conceptual understanding in elementary mathematics learning. Practically, the results of this study are expected to serve as a basis for teachers in designing division learning strategies that not only emphasize procedures but also strengthen students' relational understanding, so that similar errors can be minimized in the future.

METHODS

This study uses a qualitative approach with a descriptive research type. The qualitative approach was chosen because the study aims to describe the forms of elementary school students' errors in solving multilevel division operations (porogapit) and interpret these errors based on the types of mathematical understanding according to Skemp's Theory, namely instrumental understanding and relational understanding. Error analysis is carried out by examining the student's solution process, not just the final result, so that the source of errors at each step of the multiplication operation can be identified.

The research was conducted in an elementary school during a semester that included multiplication division in mathematics. The initial participants consisted of 20 fifth-grade students who had learned multilevel division (porogapit). The written test was administered to all students to identify general error patterns. Based on the test results, two students who demonstrated representative error patterns and were able to communicate their reasoning clearly were selected as key informants for in-depth analysis through interviews. This purposive selection allowed the researcher to explore the nature of students' errors and their underlying mathematical understanding.

Data collection techniques were carried out through written tests, semi-structured interviews, and documentation. The written test consisted of questions on division in series (porogapit) with two- to four-digit whole numbers with exact results without remainder. This test was used to identify the types of student errors in each step of porogapit, such as determining the quotient, performing multiplication, subtraction, and decreasing numbers according to place value. Semi-structured interviews were conducted with several students who showed dominant errors to explore the students' reasons, thoughts, and understanding of the division steps carried out. Documentation in the form of student answer sheets and interview notes were used as data in the analysis process.

The research instruments included a porogapit division test sheet, interview guidelines, and an error analysis sheet. The error analysis sheet was designed to group student errors based on the steps of porogapit division and then linked to the type of understanding according to Skemp's Theory. Instrumental understanding is characterized by students' ability to carry out porogapit procedures without being able to explain the reasons or meaning of the steps taken, while relational understanding is characterized by students' ability to explain the concept of division, the relationships between operations, and the reasons behind each step of the solution.

The error indicators for multilevel division (porogapit) in this study were compiled based on the findings of previous research that examined elementary school students' errors and difficulties in division operations. Errors in determining the digits of the quotient, multiplication operations, subtraction, and decreasing numbers refer to the porogapit division error patterns frequently found in elementary school students (Astuti et al., 2024; Sari & Fikrati, 2023; Taufan & Hakam, 2024). Findings that division errors are often related to poor mastery of prerequisite operations and understanding of the relationships between operations.

The classification of instrumental and relational understanding in each indicator is arranged based on the Skemp Theory of Understanding framework as operationalized in research on mathematical understanding by (Giriansyah et al., 2023; Hidaiyah et al., 2023; Sudrajat, 2022). Instrumental understanding is characterized by the ability to follow procedures without conceptual explanation, while relational understanding is characterized by the ability to explain the meaning, reasoning, and relationships between steps in solving the division of porogapit. Student error indicators based on Skemp's theory are presented in Table 1.

Table 1. Porogapit Division Error Indicators Based on Skemp's Theory

Aspects of Porogapit Division	Error Indicator	Instrumental Understanding	Relational Understanding
Determine the digits of the quotient	Wrongly determining the quotient number or guessing	Determining the quotient without considering place value and being unable to explain the reason	Determine the quotient by considering place value and be able to explain the reasons for selecting digits
Supporting multiplication operations	Incorrectly multiplying the divisor by the quotient	Performing multiplication mechanically or by rote without understanding the division–multiplication relationship	Explains that multiplication is used to check or construct division steps.
Subtraction operation	Wrongly subtracting the result of the multiplication from the number being divided	Subtracting numbers without understanding the meaning of the remainder or difference	Understanding subtraction as the difference from the division process
Decreasing numbers (place value)	Wrongly lowering or missing a number	Lowering numbers by following algorithm steps without understanding place value	Explains that the number is reduced because there is still a value that must be divided.
Determining and interpreting the remainder	Mistakes or omissions of remainders	Deeming the remainder meaningless or unexplained	Understanding remainder as a part that cannot be divided completely
Process explanation	Unable to explain the steps taken	Stating “following the teacher’s way” or “memorizing the steps”	Able to explain the relationship between steps and the concept of division

Data analysis was conducted through the stages of data reduction, data presentation, and conclusion drawing. In the data reduction stage, researchers selected and coded student errors based on test and interview results. Next, the data were presented in the form of descriptions and tables of error categories associated with instrumental and relational understanding. The final stage was drawing conclusions by interpreting student error patterns and the dominant types of mathematical understanding underlying them.

The research procedure was conducted through several stages.

1. Preparation Stage
   The researcher designed the porogapit division test items and interview guidelines based on indicators of division errors and Skemp's theory of understanding.
2. Test Administration
   The written test consisting of several multilevel division problems was administered to 20 fifth-grade students who had previously learned the porogapit method.
3. Identification of Error Patterns
   Students' answer sheets were analyzed to identify common types of procedural and conceptual errors in each step of the division algorithm.
4. Selection of Research Subjects
   Based on the analysis results, two students who demonstrated representative error patterns were selected as key subjects using purposive sampling.
5. Interview Stage
   Semi-structured interviews were conducted to explore students' reasoning, strategies, and understanding when performing the porogapit division steps.
6. Data Analysis
   The data from written tests and interviews were analyzed by categorizing the errors and interpreting them based on instrumental and relational understanding according to Skemp's theory.

RESULTS AND DISCUSSION

Based on the written test results, Student 1 (S1) and Student 2 (S2) were able to solve the division problem 468:6 with the correct answer using the multilevel division procedure (porogapit). The results of the students' work on this problem are presented in Figure 1.

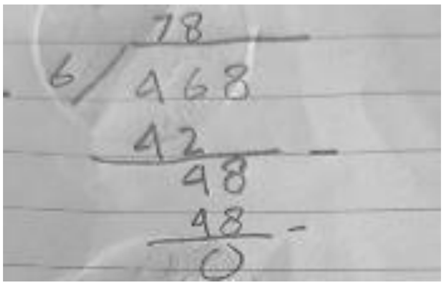

Figure 1. Student's work results for question 1

In completing the problem, both students demonstrated a sequential application of the porogapit algorithm, including determining quotient digits, performing multiplication and subtraction, and bringing down digits according to place value. No errors were identified in either the process or the final result.

However, interview findings reveal that students' success was primarily grounded in procedural recall rather than conceptual understanding. S1 stated that he "followed the steps as shown on the board," while S2 explained that he "did it step by step and the result was correct." These responses indicate that students evaluated correctness based on conformity to learned procedures, not on an understanding of the underlying mathematical concepts.

This finding suggests that the correctness of students' answers in this case does not necessarily reflect relational understanding. Instead, it indicates procedural fluency supported by instrumental understanding, as defined by Skemp (Sudrajat, 2022), where students are able to apply rules without explaining the reasoning behind them. The structure of the problem, which does not involve complex conditions such as zero in the quotient or challenging place value adjustments, allows students to rely on routine procedures without deeper conceptual engagement.

This result is consistent with previous studies (Ramdani & Suryaningsih, 2024; Taufan & Hakam, 2024), which found that elementary students tend to perform well on standard porogapit problems with simple numerical structures. However, as emphasized by Behera & Pattnayak (2024), success in such routine problems cannot be taken as evidence of full conceptual understanding, as difficulties often emerge when students encounter variations in problem structure.

Therefore, this case highlights an important distinction between procedural accuracy and conceptual understanding. Although students arrived at the correct answer, their reasoning indicates a reliance on instrumental understanding. This finding serves as a baseline for interpreting errors in subsequent problems, where more complex numerical structures reveal the limitations of purely procedural knowledge.

An error was identified when students solved the division problem 624:6. Both Student 1 (S1) and Student 2 (S2) obtained the answer 14, whereas the correct result is 104. The results of the students' work are presented in Figure 2.

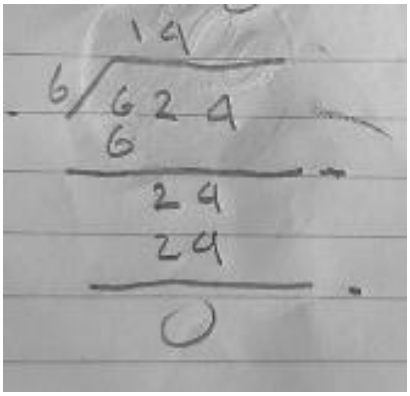

Figure 2. Student’s work results for question 2

At the procedural level, both students demonstrated a coherent application of the porogapit algorithm. They were able to determine the initial quotient digit, perform multiplication and subtraction correctly, and continue the division steps sequentially. However, a critical error occurred when the partial dividend became smaller than the divisor. In this situation, both students failed to write the zero digit in the quotient, resulting in the omission of an entire place value position.

This error indicates a specific conceptual difficulty related to the structure of place value in division. The zero digit in the quotient is not merely a placeholder, but represents the absence of value at a particular place. By omitting this digit, students disrupted the positional meaning of the quotient, leading to an incorrect final result despite otherwise correct procedures.

Interview data further clarify this issue. S1 stated that he “did it the same way as the previous problem,” while S2 explained that “the steps were correct because he followed the example.” These responses suggest that students relied on previously learned procedures without adapting them to the structural demands of the current problem. In other words, students generalized the algorithm mechanically without recognizing the need to represent zero in the quotient when required by place value.

From Skemp’s Theory of Understanding, this case reflects instrumental understanding with a specific weakness in place value reasoning. Students were able to execute the division steps but were unable to explain why a zero must be written when no value can be obtained at a particular stage. This shows that their understanding of division is procedural rather than structural.

This finding is in line with the results of previous research, each of which highlights specific aspects related to the error identified in this research. Behera & Pattnayak (2024) found that errors in division frequently occur when students rely on procedural strategies without fully understanding the role of place value, particularly when dealing with zero in the quotient. This aligns with the current finding, where students omitted the zero digit despite correctly following the division steps. Similarly, Astuti et al. (2024) reported that one of the dominant difficulties experienced by elementary school students in multilevel division is determining the correct quotient digits, especially in cases involving zero. This supports the result of this study, where students failed to represent zero as part of the quotient structure. In addition, Sari & Fikrati (2023) identified that students often ignore or omit zero in the quotient because they do not fully understand its function within the place value system. This finding directly corresponds to the error observed in this study, where the omission of zero led to a misrepresentation of the final result.

Therefore, this case reveals that the main source of error lies in students' inability to maintain the positional structure of numbers during division. It also demonstrates that procedural fluency alone is insufficient when students encounter conditions that require conceptual interpretation, such as the presence of zero in the quotient. This distinguishes the case from the previous problem and highlights place value as a critical aspect of relational understanding in porogapit division.

The next error occurred in solving the division problem 21042:7. In this case, two distinct error patterns were identified between Student 1 (S1) and Student 2 (S2), although both arrived at the same incorrect answer, 306 instead of 3006. The results of the students' work are presented in Figure 3.

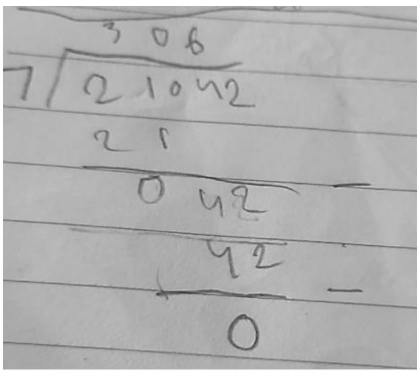

Figure 3. Results of students' answers to question number 3

S1 followed the porogapit procedure sequentially. The student began by dividing 21 by 7 to obtain 3, then brought down the next digit (0) and continued the process until reaching 42, which was divided by 7 to produce 6. However, when the partial dividend became smaller than the divisor, S1 failed to write the zero digit in the quotient. As a result, the positional structure of the number was disrupted, and the final answer was written as 306 instead of 3006. This error is consistent with the previous case, indicating a persistent difficulty in maintaining place value, particularly in representing zero within the division process.

In contrast, S2 demonstrated a different strategy that deviates from the standard algorithm. Instead of processing the division step-by-step, S2 directly selected a multiplier (30) such that 7×30 = 210, and treated this as the initial step. The student then subtracted 210 from 21042, obtained 42, and divided it by 7 to get 6, resulting in the final answer 306. This approach reflects an approximation-based strategy, where the student focuses on finding a value close to the dividend rather than adhering to the structural rules of the division algorithm.

The comparison between S1 and S2 reveals that similar incorrect results can emerge from fundamentally different reasoning processes. S1's error stems from incomplete control of place value within a sequential algorithm, while S2's error reflects a misapplication of multiplicative reasoning that ignores the positional structure required in division. Thus, this case highlights not only the presence of error, but also the diversity of underlying cognitive strategies.

Interview findings support this interpretation. S1 stated that he "followed the steps one by one as usual," indicating reliance on procedural routines, whereas S2 explained that he "looked for numbers that could be multiplied to approximate the dividend," indicating a shift toward heuristic reasoning. Despite these differences, both students evaluated the correctness of their answers based on procedural plausibility rather than conceptual validity.

From Skemp's Theory of Understanding, both error types can be categorized as instrumental understanding, but with different characteristics. S1 represents a form of rigid procedural application without full awareness of place value structure, while S2 demonstrates flexible but conceptually unsupported reasoning. In S1's case, the weakness lies in understanding the necessity of writing zero as part of the quotient structure. In S2's case, the weakness lies in failing to recognize that each step of division must correspond to a specific place value position, not merely to numerical proximity.

This finding is supported by several previous studies that highlight different aspects of students' errors in division. Astuti et al. (2024) found that students often experience difficulties in determining quotient digits, particularly when division involves multi-digit numbers. This is relevant to the present study, where students struggled to maintain accuracy when handling more complex numerical structures.

Sari & Fikrati (2023) reported that errors in multilevel division frequently stem from students' misunderstanding of place value, especially when the division process requires careful attention to digit positions. This aligns with the current finding, where students failed to maintain the correct structure of the quotient when encountering zero within the division steps.

Meanwhile, Behera & Pattnayak (2024) emphasized that students tend to use approximation strategies in division by selecting multipliers that are numerically close to the dividend, rather than following the structural rules of the algorithm. This is clearly reflected in the present case, where one student applied an approximation-based approach that led to an incorrect result.

Therefore, this case provides a deeper insight than the previous problems. It shows that students' difficulties are not limited to a single conceptual aspect, but involve both the maintenance of place value and the control of division strategies. This reinforces the need for instructional approaches that explicitly connect division procedures with their underlying mathematical structures, so that students can apply them accurately across varying problem contexts.

The next error occurred in the problem 225:25. In this case, both Student 1 (S1) and Student 2 (S2) applied the multilevel division procedure (porogapit), even though the problem can be solved more directly by recognizing the inverse relationship between division and multiplication (25×9 = 225). The results of the students' work are presented in Figure 4 below

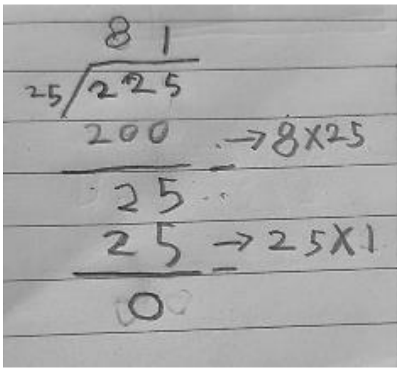

Figure 4. Answer results for question number 4

S1 began the solution by focusing on the first two digits (22) and selected 8 as the initial quotient digit because 25×8 = 200, which is close to 225. The student then subtracted and obtained a remainder of 25, followed by determining the next digit (1) since 25×1 = 25, resulting in a final answer of 81. This pattern indicates that S1 treated the quotient as a sequence of separate multiplication results rather than as a unified representation of the division outcome.

The determination of quotient digits was based on local approximations rather than on the overall structure of the division.

S2 demonstrated a similar but more outcome-oriented approach. The student selected multipliers that could reduce the remainder to zero and explicitly stated that “the important thing is that the remainder is zero.” This indicates that S2 evaluated the correctness of the solution based on the final condition of the process rather than on whether the quotient accurately represented the division. As a result, S2 also obtained the incorrect answer of 81.

Unlike the previous cases, the main issue in this problem is not related to place value or the use of zero, but to the failure to understand the relationship between division and multiplication as inverse operations. Both students relied entirely on procedural steps and approximation strategies, without recognizing that the problem could be interpreted as finding a factor of 225. This indicates that students did not connect the division operation to previously learned multiplication concepts.

From Skemp’s Theory of Understanding, this case reflects instrumental understanding at a deeper level. Students were able to carry out multiplication and subtraction procedures correctly, but were unable to use conceptual relationships to simplify or verify the solution. The strategy of “approximating and completing the remainder” appears procedurally valid, yet it is conceptually flawed because it ignores the meaning of the quotient as a single value.

This finding is supported by several previous studies that highlight different dimensions of students’ difficulties in division. Behera & Pattnayak (2024) found that students frequently rely on approximation strategies by selecting multipliers that are numerically close to the dividend, without considering whether the result is structurally correct. This is consistent with the present finding, where students used an approximation approach that led to an incorrect quotient. Astuti et al. (2024) reported that students often experience difficulties in determining appropriate quotient digits in multilevel division, particularly when they depend on estimation rather than a structured understanding of the algorithm. This aligns with the current case, where students’ estimation-based reasoning resulted in an inaccurate final answer.

Similarly, Sari & Fikrati (2023) identified that students tend to prioritize procedural completion over conceptual accuracy, which can lead to errors when approximation strategies are used without proper understanding. This supports the finding of this study, where students considered their solutions correct as long as the procedure appeared complete. In addition, Djong et al. (2025) emphasized that understanding division as an inverse operation of multiplication remains a significant conceptual challenge. This is clearly reflected in the present study, where students failed to recognize the division problem as a factorization task, and instead relied entirely on procedural methods.

Taken together, these studies reinforce that students' errors are not only related to the misuse of strategies such as approximation, but also to a deeper conceptual gap in understanding the fundamental meaning of division. Therefore, this case highlights a different dimension of students' errors compared to the previous problems. While earlier errors were associated with place value and algorithm stability, this error reflects a lack of relational understanding of mathematical operations. It demonstrates that students use procedures as an end in themselves, rather than as tools for reasoning.

Overall, this finding emphasizes that effective learning of porogapit division must go beyond procedural training. Instruction should explicitly connect division to multiplication, emphasize the meaning of the quotient, and encourage students to interpret division as a process of determining factors. Without such conceptual connections, students are likely to persist in procedural approaches that produce mathematically incorrect results despite appearing logically consistent.

CONCLUSION

This study shows that elementary school students are generally able to apply the multilevel division (porogapit) procedure sequentially and according to the steps taught, as evidenced by their success in solving routine division problems. However, when faced with problems involving more complex numerical structures, particularly those related to place value and zero digits in the quotient, students tend to make systematic errors. The most dominant errors identified in this study include the omission of zero digits in the quotient and the use of approximation strategies in determining quotient digits, which result in incorrect final answers despite procedurally correct steps.

These errors indicate specific conceptual weaknesses, namely: (1) limited understanding of place value as a structural component in division, (2) lack of awareness of the role of zero in maintaining the positional meaning of the quotient, and (3) inability to recognize division as an inverse operation of multiplication. From Skemp's Theory of Understanding, these findings show that students' understanding is predominantly instrumental, as they rely on procedural steps without fully understanding the underlying mathematical concepts.

The implications of this study suggest that learning multilevel division (porogapit) should not only emphasize procedural fluency, but also explicitly develop students' conceptual understanding. Teachers need to design instructional activities that focus on the structure of place value, the meaning of zero in division, and the relationship between division and multiplication. In addition, students should be encouraged to explain their reasoning, reflect on each step, and verify their results conceptually. Such efforts are essential to foster relational understanding and to reduce recurring errors in division. Further research is recommended to develop instructional strategies or learning media that specifically support the development of relational understanding in multilevel division.

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