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Analysis of Student Errors in Algebra Material Using a Modern Diagnostic Approach

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ABSTRACT

This study aims to analyze students' errors in solving algebra problems using a modern diagnostic approach based on error analysis. This approach allows for systematic identification of error patterns through classification into conceptual, procedural, and strategic aspects. The research method used was descriptive qualitative with 30 eighth-grade students in a public junior high school as subjects. Data were collected through diagnostic tests and task-based interviews. The results showed that conceptual errors were the most dominant type of error (45%), followed by procedural errors (35%), and strategic errors (20%). These findings revealed that most students did not understand the meaning of variables, the principles of algebraic operations, and the process of simplifying algebraic forms. This study recommends the development of visual reasoning-based instruction, scaffolding, and the use of digital diagnostic technology to improve students' understanding of algebra.

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Introduction

Algebra is a core competency that occupies a central position in the mathematics curriculum at the elementary and secondary levels. Algebraic concepts such as variables, equations, algebraic operations, and relations serve as the foundation for understanding advanced materials such as functions, analytical geometry, statistics, and calculus. A strong grasp of algebra enables students to develop symbolic thinking, reasoning, and problem-solving skills, which are essential for 21st-century mathematics competencies. However, various studies indicate that algebra is also a topic that frequently presents learning barriers for students. Kieran (2018) noted that difficulties in understanding the meaning of variables, the use of symbols, and the rules of algebraic operations are the primary causes of low student performance in mathematics.

The errors students make in algebra problems stem not only from a lack of mastery of the material but also from misconceptions formed early in the course. These misconceptions, for example, relate to combining like terms, manipulating equations, and errors in simplifying algebraic expressions. Seemingly simple errors can develop into long-term learning barriers if not identified and addressed appropriately. Therefore, teachers need a deep understanding of student error patterns as a basis for designing more effective learning interventions.

One approach that can be used to identify the root causes of problems in learning algebra is error analysis. This approach aims to examine students' thought processes through the answers they produce, allowing teachers or researchers to identify the types of errors and their underlying thinking patterns. In recent developments, error analysis is no longer solely conducted manually but has also evolved through modern diagnostic approaches. Modern diagnostic approaches utilize technologies such as digital assessments, process-based data (e.g., student work steps), and error pattern visualization to provide a more accurate picture of student weaknesses (Wilson & Draney, 2020). This approach emphasizes classifying errors

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into three main categories: conceptual errors, procedural errors, and strategic errors (Clements & Sarama, 2015). Each category provides specific information related to the root causes of student difficulties.

In the context of educational implementation in Indonesia, particularly at the junior high school (SMP) level, error analysis based on modern diagnostic approaches has not been systematically applied. Most learning still focuses on delivering solution procedures without emphasizing conceptual understanding and in-depth identification of student errors. As a result, various recurring errors continue to emerge without interventions designed to address the root cause of the problem. This highlights the need for more in-depth research into student error patterns in algebra, particularly using modern diagnostic approaches that can provide a more comprehensive picture of student ability profiles.

Based on this need, this study aims to analyze the types of errors made by junior high school students in solving algebra problems using modern diagnostic approaches. Furthermore, this study also attempts to uncover the factors that contribute to these errors. The results of the analysis are expected to contribute to the development of more adaptive and data-driven learning strategies, enabling teachers to provide targeted interventions to improve students' understanding of algebra.

Method

This study used a qualitative descriptive approach to identify and classify student errors in solving algebra problems based on a modern diagnostic approach. This approach was chosen because it provides an in-depth overview of error patterns and students' thought processes. The research subjects consisted of 30 eighth-grade students from a public junior high school in Indonesia, selected using a purposive sampling technique, which involves deliberately selecting subjects based on specific considerations, particularly regarding the students' representativeness of the problem under study.

The research instruments used included an algebra diagnostic test, an interview guide, and an error classification rubric. The diagnostic test consisted of eight questions covering algebraic operations, value substitution, and simplification of algebraic expressions. This test was designed to elicit various types of errors commonly encountered by students. Furthermore, a task-based interview guide was used to delve deeper into students' thought processes when solving problems and to validate the findings from the test results. The error classification rubric was developed with reference to the three main categories in the modern diagnostic approach: conceptual, procedural, and strategic errors.

The data obtained were analyzed through several steps. First, data reduction was performed by selecting relevant student answers and categorizing the types of errors that emerged. Next, error types were identified based on a predetermined rubric. This process was then triangulated with interview results to ensure consistency and accuracy of the findings. The final stage was data presentation in the form of percentages and narrative descriptions to provide a more comprehensive understanding of student error patterns.

Results and Discussion

Results

Based on the analysis of the diagnostic test answer sheets and task-based interviews, it was found that students made three main types of errors: conceptual errors, procedural errors, and strategic errors. The percentage distribution of each error shows that conceptual errors were the most dominant type of error at 45%, followed by procedural errors at 35%, and strategic errors at 20%. These percentages indicate that most students still face difficulties in understanding basic algebraic concepts before moving on to the procedural and strategic aspects of problem solving.

Table 1. Conceptual Errors

Error Type Percentage	Persentase
nceptual Errors	45%
Procedural Errors	35%
Strategic Errors	20%

Conceptual errors are the most common errors in student answers. These errors generally occur because students do not yet understand the meaning of variables, the relationships between algebraic terms, and the basic rules of algebraic operations. One common error is the inability to distinguish between like and unlike terms. For example, students simplified the expression $3x + 2y^2$ to $5x^2$ ndicating that they assumed variables with different powers could be added directly. Interview findings showed that some students considered x and x^2 to have "similar" symbols, so they felt they could be added together like ordinary numbers.

Furthermore, some students demonstrated misconceptions in understanding algebraic rules related to the use of signs, combining terms, and the concept of coefficients. For example, when given the problem 4a – 2a + a, some students gave inconsistent answers, such as 4a – 2a + a = 3a, These errors indicate that students do not yet understand the role of coefficients as factors that multiply variables.

Procedural Errors

Procedural errors occur when students incorrectly apply solution steps even though they actually understand the basic concepts of algebra. These errors often occur in problems involving value substitution and expression simplification. For example, when asked to substitute the value x = 4 into the expression x + 3, some students calculate it as x + 3 = 5. Interviews indicate that some students forget that the symbol x + 2x means "two times x" instead of "two plus x".

Other procedural errors are seen in incomplete or skipped steps in the solution, resulting in an incorrect final answer. For example, in a simplification problem involving distributions, such as 3(x+2), some students immediately wrote the result 3x+2 without multiplying 2 by 3. This indicates that students are not yet accustomed to applying procedures consistently or are still confused about determining the correct steps.

Strategic Errors

Strategic errors occur when students choose an approach or solution strategy that is inappropriate for the characteristics of the problem. This error occurred in 20% of students and was generally found in problems that could actually be solved simply. For example, some students used the factoring method to solve problems that only required basic simplification, thus making the steps taken even more difficult.

Furthermore, some students chose the substitution strategy even though the problem did not require value substitution. This indicates that students are not yet able to identify the most efficient procedure or strategy. Interview findings showed that some students used this strategy because they were accustomed to a particular pattern taught by the teacher without understanding the strategy's purpose. As a result, students experience difficulties when facing problems that require flexible method selection.

Overall, the research results indicate that these three types of errors are interrelated. Conceptual errors are often the root of procedural and strategic errors. Without a strong conceptual understanding, students tend to choose inappropriate strategies or perform inaccurate procedures. Therefore, in-depth error identification is a crucial step in helping teachers provide more targeted learning interventions.

Discussion

The results of this study indicate that conceptual errors are the most common type of error made by students. The prevalence of conceptual errors indicates that students' basic understanding of algebraic concepts has not yet been firmly established. Many students still

view variables as ordinary symbols, rather than as representations of values or quantities that can change. For example, the simplification error of 3x+2x to 5x reflects that students do not yet understand the structural differences between like and unlike terms. This finding aligns with Kieran's (2018) findings, which assert that misconceptions about variables and algebraic symbolic structure are the source of fundamental difficulties in learning algebra. In other words, the root of the problem lies not in arithmetic ability, but in how students interpret mathematical symbols.

Procedural errors also emerged significantly, indicating that although students understand the basic concepts, they lack the skills to systematically apply the steps to solve them. Errors in substitution steps, such as calculating 2x + 3x for 2x = 4x = 4 to become 2x + 3x + 3x, indicate that students are inconsistently applying basic operating rules. These types of errors often arise when students memorize steps without truly understanding the rationale behind the procedure. This finding supports Clements and Sarama's (2015) finding that procedural errors typically arise when students lack directed practice or don't understand how to verify their own work. In a simple analogy, students are like following a cooking recipe without knowing the function of each ingredient; when one ingredient changes, they don't know how to adjust the steps.

Strategic errors, although lower in percentage, are still important to note because they indicate that students are not yet able to choose the solution strategy that best suits the characteristics of the problem. Some students resort to more complex methods for simple problems, such as factoring expressions that only need to be simplified. This indicates that their strategy selection is inflexible and tends to be based on routine, rather than understanding. According to Wilson and Draney (2020), modern diagnostic approaches help uncover error patterns like these through process data collected from student responses. With this approach, teachers can see not only what went wrong, but also why students chose certain strategies.

The findings of this study also reinforce the need for instruction that emphasizes visual reasoning and the use of educational technology. The use of digital diagnostic tools, such as GeoGebra, or artificial intelligence-based applications, not only helps teachers identify errors more quickly and accurately but also provides students with a more interactive learning experience. Algebraic visualizations, such as dynamic graphs or interactive symbol manipulation, can help students understand the relationships between variables more intuitively. Furthermore, scaffolding strategies—providing incremental assistance that is then reduced as students' abilities improve—can help address fundamental conceptual errors. Through this approach, students are encouraged to understand the process, not just the end result.

Overall, the research results indicate that all three types of errors are interconnected. Conceptual errors often lead to procedural and strategic errors. Therefore, instructional improvements need to begin with reinforcing basic concepts with a multi-representational approach, structured procedural practice, and familiarizing students with selecting appropriate solution strategies. Thus, learning algebra can be more meaningful and effective for students.

Conclusion

This study concludes that eighth-grade students make three main types of errors when solving algebra problems: conceptual, procedural, and strategic errors, with conceptual errors being the most dominant. The main causes are misconceptions about variables, weak procedural skills, and inappropriate strategy selection. Modern diagnostic approaches are effective in identifying error patterns and can serve as a basis for designing more targeted learning. Teachers are advised to use digital diagnostic assessments, visual reasoning-based instruction, and scaffolding to improve students' understanding of algebra.

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