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Analysis of student errors in solving grade 2 number problems based on Kastolan theory at MIN 1 Banyuwangi

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Abstract

While everyone makes mistakes, only the wise are able to learn from them. The purpose of this study was to examine the errors students make when attempting to complete non-routine tasks. Kastolan's theory, which encompasses conceptual, procedural, and technological errors, served as the basis for the error analysis. Students from a prestigious public school in Banyuwangi, Indonesia, located on the eastern tip of Java, participated in this qualitative study. The selected participants were 26 students from class 2A. Data were collected through a written test given to students. The test consisted of five essay questions that had to be answered in two 30-minute sessions. The results were then evaluated. The findings showed conceptual, procedural, and technical errors. This study revealed that conceptual mastery was the main error found in students' answers. Further studies are expected to reduce numerical errors among students.

Keywords: Number problems, Error analysis, Kastolan theory

Abstrak

Semua orang bisa membuat kesalahan, namun hanya orang bijak yang dapat mengambil pelajaran dari kesalahannya. Penelitian ini bertujuan untuk menganalisis kesalahan yang dilakukan siswa dalam menyelesaikan tugas-tugas non-rutin. Teori analisis kesalahan yang digunakan adalah teori Kastolan, yang mencakup kesalahan konseptual, kesalahan prosedural, dan kesalahan teknis. Penelitian kualitatif ini melibatkan siswa dari sekolah negeri terkemuka di Banyuwangi, Indonesia, yang terletak di ujung timur Jawa. Peserta yang dipilih meliputi 26 siswa dari kelas 2A. Data dikumpulkan melalui ujian tertulis yang diberikan kepada siswa. Ujian tersebut terdiri dari lima pertanyaan esai yang harus dijawab dalam dua sesi masing-masing selama 30 menit. Data kemudian dievaluasi. Temuan menunjukkan adanya kesalahan konseptual, prosedural, dan teknis. Penelitian ini mengungkapkan bahwa penguasaan konseptual merupakan kesalahan utama yang ditemukan dalam jawaban siswa. Penelitian lebih lanjut diharapkan dapat mengurangi kesalahan numerik di kalangan siswa.

Kata kunci: Soal bilangan, Analisis kesalahan, Teori Kastolan

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INTRODUCTION

Students' evaluations or assessments can be used to gauge how well a learning process is going (Tanujaya, 2017). Assessing the evolution of educational quality requires evaluation of the learning process (Alqurashi, 2019; Margot & Kettler, 2019; Shernoff et al., 2017). Educational providers use evaluation as a way to answer relevant stakeholders (Halik et al., 2019). Additionally, assessment seeks to gather evidence of students' aptitudes and the degree to which they have met the learning goals following their involvement in the process (Emden et al., 2018). Student ability evaluation can be conducted through various methods, including analyzing students' errors in solving problems (Zainuddin et al., 2019).

According to Kastolan (1992), three categories of mathematical errors may be distinguished: conceptual, procedural, and technological errors. Students who understand terminology, qualities, facts, concepts, and principles incorrectly are said to be making conceptual errors. When a problem is solved, procedural errors occur when symbols are not arranged correctly and when hierarchical, systematic stages or rules are not used. Mistakes like misnotating variables and misinterpreting the situation are examples of technical blunders.

Three categories of student errors in problem solving are covered by this theory, i.e., conceptual, procedural, and technological errors (Fauziah, 2020). When assessing student errors, Kastolan's theory uses a hierarchical approach, which means that conceptual errors must be analyzed first, then procedural errors, and ultimately technological errors (Kusuma & Siska Pramasdyahsari, 2021). Students make conceptual mistakes when they don't grasp the ideas needed to solve problems (Arum et al., 2018). Although their comprehension is limited to reading the entire information offered in the problem-solving process, many students think they have grasped the content presented. According to Puspitasari et al. (2018), conceptual mistakes are frequently observed when students think they understand the teacher's explanation of problem solving but get perplexed when faced with a fresh challenge. In reality, students may easily solve issues in line with the problem-solving process if they understand the fundamental ideas of problem-solving. When pupils answer word problems, where steps must be taken in a sequential and methodical manner to solve the problem, procedural mistakes are commonly seen (Salloum & BouJaoude, 2019).

Technical mistakes are very important in the process of addressing issues since they affect students' basic problem-solving abilities (Sadik & Yalcin, 2018). According to Graesser et al. (2018), students who struggle with technical issues frequently make mistakes. They thus encounter issues that result in technological mistakes when they confront contemporary situations. Unusual or non-routine practice questions are used to gauge students' comprehension of the course material. Non-routine questions are ones whose answers require more expansive and unconventional thinking since their methods are less well-defined than those covered in class. Analyzing the mistakes pupils make when attempting to solve non-routine analytic geometry problems is the goal of this study. These are contextual inquiries that use ethnomathematical ideas.

This method can test students' comprehension of circular ideas and support more meaningful learning for them.

Students repeatedly fail because they make mistakes in a variety of learning scenarios, including problem solving and active learning (Wan et al., 2023). These recurring mistakes are frequently caused by misunderstandings, namely strong convictions about the wrong objective. Students may provide impromptu, accurate explanations and develop clear understanding of basic topics throughout the thought process, which helps to reduce misunderstandings (Barbieri & Silla, 2024).

When students consistently make mistakes, one popular technique to determine the reasons behind their mistakes is error analysis (Lai, 2012). The technique of examining student work and afterward spotting misunderstood tendencies is known as error analysis. Factual, procedural, or conceptual errors are among the several types of mathematical errors that can arise for a variety of causes. Finding the precise mistakes made by pupils is crucial, especially for those with poor academic proficiency (Fuchs et al., 1994).

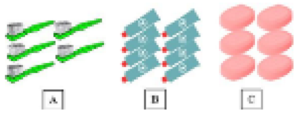
The purpose of this study is to examine the mistakes that students make when attempting to answer non-routine number concept problems. These questions are contextual and integrated with everyday life. In addition to assessing students' understanding of number concepts, this approach can evaluate more meaningful learning for students. The number concept employed consists of non-routine problems developed in a contextual manner (Figure 1). These questions are used to measure students' ability to engage in deep learning. Therefore, these questions are non-routine.

Students' belief in their capacity to achieve the best possible results in mathematics can be adversely affected by the cognitive load they encounter while learning, which emphasizes the necessity of careful planning instructional strategies that control cognitive load in order to promote student motivation and success (Ngu et al., 2025). Figure 1 presents five short-answer questions from the Grade 2 mathematics Mid-Semester Summative Assessment (STS) for the first semester of the 2024–2025 academic year. These questions cover various fundamental mathematical concepts. The questions administered consist of five essay items designed to measure students' capacity for deep learning.

The first question asks students to identify the number that is greater than 18 but less than 20. The second question requires determining the place value of the digit '3' in the number 43. Next, the third question presents three visual representations (A, B, and C) of quantities, and students are tasked with ordering them from smallest to largest. The fourth question is a word problem set in everyday life, in which a farmer carries two baskets of mangoes: basket 1 contains 14 mangoes and basket 2 contains 9 mangoes. Students are required to calculate the total number of mangoes owned by Mr. Tani. Finally, the fifth question is a subtraction problem involving an initial quantity of 19 eggs, from which 4 rotten eggs and 6 broken eggs are subtracted to find the number of eggs that remain intact. These questions serve as a basic assessment tool for fundamental numeracy and problem-solving skills.

ISILAH TITIK – TITIK DI BAWAH INI !

1. Aku adalah bilangan. Aku lebih besar dari 18, tapi aku lebih kecil dari 20. Aku adalah bilangan ….
2. Bilangan 43, angka 3 menempati tempat ….
3. Urutan benda di samping dari yang paling sedikit adalah ….



4. Pak tani memikul 2 keranjang. Keranjang 1 berisi 14 mangga. Keranjang 2 berisi 9 mangga. Jumlah mangga dalam kedua keranjang pak tani adalah ….
5. Ibu membeli telur sebanyak 19 butir. Telur yang busuk ada 4 butir dan telur yang pecah ada 6 butir. Sisa telur ibu sekarang adalah ….

Figure 1. Test questions on numbers

METHODS

This study used qualitative methods and was analyzed descriptively. The study was conducted at Madrasah Ibtidaiyah Negeri (MIN) 1 Banyuwangi. The researcher acted as an educator at the institution. The research participants consisted of 26 students in class 2A. This study analyzes and identifies the errors made by students in completing non-routine tasks (numerical content) in the odd semester summative assessment, based on Kastolan's theory. Data collection was through written tests administered to students. The test consisted of five essay questions that had to be completed within 2x30 minutes. The results were then analyzed.

The results of the error classification based on Kastolan's theory were then converted into percentages (Kartini & Zakiyah, 2023). The percentage of errors will be classified based on Table 1 (Amir & Zakaria, 2019). The error percentage was calculated using Equation 1.

Table 1. Error Percentage Categories

Percentage	Category
$x < 11\%$	Very Low
$11\% \leq x < 20\%$	Low
$20\% \leq x < 35\%$	Moderate
$35\% \leq x < 45\%$	High
$45\% \leq x < 100\%$	Very High

$$Error\ percentage = \frac{Number\ of\ errors\ per\ type}{Total\ number\ of\ error\ type} \times 100\% \quad (1)$$

Data analysis encompassed data collection, categorization, visualization, and the formulation of conclusions. Concurrent with data collection, analysis was conducted to refine the observational focus and identify themes pertinent to the issue under examination. Data analysis during the data-gathering phase was crucial for researchers to discern observations relevant to the issues under investigation. Concurrently, data analysis followed systematic data gathering, yielding insights derived from prior analyses. Ensure that the created ideas, hypotheses, concepts, or patterns were grounded in empirical evidence. Researchers revised existing data when they recognized incompleteness, prioritizing the research focus.

RESULTS AND DISCUSSION

Based on the three categories of mistakes described in Kastolan's theory, technical, procedural, and conceptual faults, error analysis was carried out. As a result, question categories form the basis of the description. Following that, an analysis will be conducted to determine the causes of these types of mistakes made by pupils. According to Hoth et al. (2022), students' cognitive errors in learning mathematics encompass several interrelated aspects. Conceptual misunderstandings arise when students interpret symbols or keywords literally without considering the context, for example, assuming the word "get" always means addition and "give" always means subtraction in a word problem.

Table 2. Causes of errors by students

Type of error (Kastolan)	Student Answers	Students' Thinking Styles (Causes of Errors)
Conceptual	Adding “2 baskets” as a number, interprets the contents of the question as not appropriate to the context (question no. 4). Student Answer	Students are not yet able to differentiate between the units being counted (mangoes) and the containers (baskets); words/phrases in the questions are directly connected to arithmetic operations without understanding their meaning.
Procedural	Stop the answer at “A toothbrush” without ordering A, C, B completely (question no. 3).	Students have the idea of “choosing the least” but have not yet mastered the “sorting” procedure; they tend to apply one-step strategies as in routine problems.
Technical and Conceptual or Procedural (mixed)	Just subtract 4 from 19 and ignore the 6 broken eggs (problem no. 5).	Students fail to perform complete calculations and fail to verify that all information has been used. This demonstrates a lack of thoroughness.

Inappropriate strategy use is evident when students choose problem-solving procedures based on word associations or memorized steps, rather than on a logistical understanding of the mathematical structure. Failure to generalize occurs when students are unable to apply the same concept across different problem contexts, leading to errors when faced with a variety of problems. Furthermore, some students have difficulty constructing accurate mental representations of mathematical situations, particularly in problems related to real-world contexts or modeling. Reliance on routine procedures is evident in students' tendency to follow algorithms or standard steps without understanding the conceptual rationale behind them. Finally, a lack of metacognition is demonstrated by students' inability to recognize errors and by the absence of strategies to monitor, reflect on, and correct their own thinking processes. In this study, Kastolan's Theory can also be used as a tool to understand the causes of errors, as in Table 2.

Hoth et al. (2022) highlighted several types of cognitive errors, including conceptual misunderstanding, inappropriate strategy use, failure to generalize, difficulty constructing mental representations, reliance on routine procedures, and a lack of metacognition to recognize and correct one's own errors. In general, they assert that “routine components” (memorized procedures) are the primary source of errors, as ingrained, long-standing procedures inhibit conceptual change and trigger cognitive conflict when results do not match reality or visual representations. This study analyzed errors based on Kastolan's theory: conceptual errors (wrong concepts/definitions), procedural (unsystematic steps), and technical (wrong calculations/writing). The results showed that the proportion of errors in class 2A was approximately 86.36% conceptual, 4.54% procedural, and 9.10% technical, indicating that the majority of students made errors in understanding concepts and interpreting questions, not just in arithmetic operations. When related, Kastolan's conceptual errors strongly overlap with Hoth's "conceptual misunderstandings, generalization failures, and mental representation difficulties," as seen in students misinterpreting the meaning of context (e.g., the mango basket problem) and failing to model the situation correctly. The procedural and technical errors in the article align with Hoth's "reliance on routine procedures" and "inappropriate strategy use," where students are fixated on the usual methods taught, making the wrong choice of arithmetic operations or stopping at only one step (e.g., only listing one order of objects in a problem about ordering many objects).

Generally, from a cognitive perspective, the primary errors made by students lie in the routine component, that is, the procedures they employ to solve problems. Errors in routine procedures directly affect the quality and accuracy of the visual representations (visual mediators) that students produce. The root cause of these errors lies in the strong influence of students’ prior knowledge and experiences in learning mathematics, particularly number concepts. Students tend to repeat procedures they are familiar with and believe to be correct, even when those procedures may not be fully relevant or appropriate for the context of a new problem. As a result, this deeply ingrained memory impedes conceptual change, even when students are confronted with contradictory evidence, thereby triggering cognitive conflict. This cognitive conflict arises from a strong belief in the correctness of routine procedures, while at the same time, the resulting visual or conceptual outcomes are perceived as incorrect.

The pedagogical implications of these findings are highly significant. Mathematics instruction should not focus solely on memorizing routine procedures; instead, it should encourage exploration and the development of deep conceptual understanding. Students need support in recognizing and resolving cognitive conflicts, as well as in developing a well-connected understanding of concepts and procedures rather than merely following steps mechanically. Thus, mathematics education can be more effective in helping students build a robust, adaptive cognitive structure for problem-solving. Errors in routine procedures are significantly influenced by strong memory traces of prior knowledge and experiences acquired during mathematics learning. This strong memory of prior knowledge can prevent students from revising their conceptual understanding, thereby creating cognitive conflict. The results of the error categorization for each student are presented in the following Table 3.

Table 3. Number of Student Errors by Error Type

Question Number	Error Types in Grade 2A		
	Conceptual	**Procedural**	**Technical**
1	1	0	0
2	3	0	0
3	3	1	0
4	7	0	1
5	5	0	1
Total	19	1	2
Average (%)	86,36	4,54	9,10

Based on the information obtained from Table 2, the distribution of student errors by type, from highest to lowest, is as follows: 86.36% conceptual errors, 4.54% procedural errors, and 9.10% technical errors. Based on these results, three sample responses will be selected for each error type. The samples were selected from the questions with the highest frequency for each error type: question four for conceptual errors, question three for procedural errors, and question five for technical errors. The test required students to solve questions on number concepts (see Figure 1), which were aligned with the grade-level and assessment indicators for Grade 2 mathematics number concepts.

Conceptual Errors

Based on the student's response to question 4 (Figure 2), the student did not understand the question. The student interpreted the problem as adding 14 mangoes to the two baskets, then adding the result to the number of mangoes in the second basket. In this case, the student assumed that the baskets themselves represented quantities of mangoes. The student lacked a proper understanding of the problem and therefore did not apply the basic concept that should have been used, namely, adding the number of mangoes in each basket. The student was unable to determine the correct formula or forgot the formula while solving the problem. This is consistent with Mathaba et al. (2024), who found that the most frequent error type in their study was problem-solving errors, followed by unpreparedness errors, which accounted for 73% of the total. When pupils fail to complete a mathematical problem, leave the answer blank, or exhibit inadequate procedural and conceptual understanding, they are committing unprepared errors. However, 49% of calculations were inaccurate because they were either performed improperly or failed to conduct addition or subtraction operations. Whereas Zhang (2025) noted that students who merely memorize formulas without understanding algebraic structure do not demonstrate deep understanding.

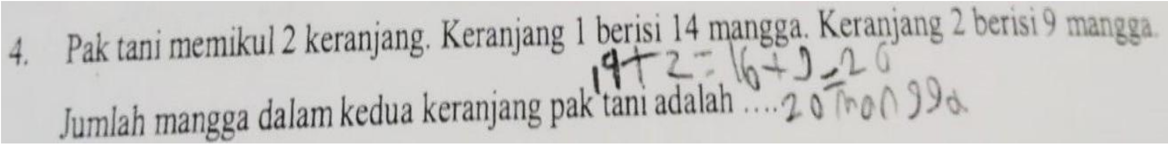

4. Pak tani memikul 2 keranjang. Keranjang 1 berisi 14 mangga. Keranjang 2 berisi 9 mangga.
14+2=16+9=20
Jumlah mangga dalam kedua keranjang pak tani adalah ....20 mangga

Figure 2. Student responses to question number 4 of the number concepts test

The error in the problem comprehension stage was made by the student in Figure 2, with the indicator of a conceptual error being the incorrect recording of answer information. This can be seen in how the statements of what is given and what is asked were written, which do not align with the intended meaning of the question. The student wrote the answer as follows: $14 + 2 = 16 + 9 = 20\ mangoes$. The steps taken by the student to solve the problem were incorrect. The student added 14 mangoes to the 2 baskets carried by Mr. Farmer, then added 16 to the 9 mangoes in basket 2. This resulted in 20 mangoes in total. In this case, the student has not yet mastered addition, resulting in an incorrect answer.

The student in Figure 2 demonstrates a conceptual misunderstanding by assuming the basket itself represents the quantity of mangoes (14 + 2 = 16, then 16 + 9 = 20), instead of adding the basket's contents (14 + 9 = 23). This reflects a failure in generalization from Hoth et al., where students fail to apply basic addition concepts to new word problem contexts, as well as difficulty with mental representation, as they do not form an accurate mental image of the "basket's contents." This connection reinforces Kastolan's main finding that conceptual errors are dominant (86.36%).

Technical Errors and Conceptual or Procedural Errors

In Figure 3, the students' calculations show that after subtracting 4 rotten eggs from 19 whole eggs, there are 15 eggs remaining ($19 - 4 = 15$). The 6 broken eggs should also be subtracted from the remaining eggs to get the final number of usable eggs. However, the students did that. Therefore, the total number of eggs that cannot be used is $4\ (rotten\ eggs) + 6\ (broken\ eggs) = 10\ egss$. Subtracting these 10 eggs from the initial 19 eggs leaves 9 eggs that can be used. Therefore, the result of subtracting the remaining eggs obtained contains a technical error. In addition, based on the error analysis above, failure to complete the solution steps falls within the procedural realm (incomplete steps), while understanding that "remaining eggs" means subtracting all reducing factors falls within the conceptual realm (not understanding the concept of remainder).

The students' steps to solve the problem were incorrect because they did not subtract the number of broken eggs. The student's answer stops only at subtracting the whole eggs from the rotten eggs: $19 - 4 = 15$ eggs. However, the question actually asks for the current number of eggs remaining with Mother, which should be calculated as intact eggs-rotten eggs-broken eggs =the current number of eggs Mother has (eggs).

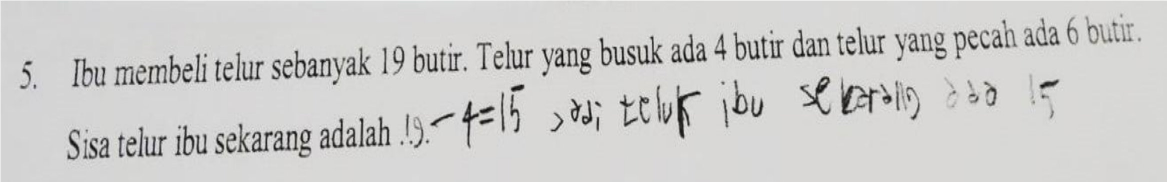


Figure 3. Student responses to question number 5 of the number concepts test

In Figure 3, the student only subtracted the rotten eggs (19-4=15) without considering the broken eggs (should be 19-10=9). This indicates a lack of metacognition, as the student failed to recognize their partial error or to use self-evaluation strategies. Hoth's theory explains this as an inability to correct one's own thinking, resulting in a technical error (9.10%). This integration demonstrates how prior knowledge can create cognitive conflict, where routine procedures hinder conceptual change, resulting in hierarchical errors that interconnect (basic errors triggering further errors).

Procedural Errors

The student made a mistake in answering the question in Figure 4, writing only one answer, namely A (toothbrush). The student's answer stops at 1, whereas the student should have ordered the 3 objects in the question. However, based on the interview results, students thought they were asked to find the smallest number of objects. Therefore, the other objects were not mentioned. The order of items from the least in the question is toothbrushes (A) totaling 5 pieces, toothpaste (B) totaling 8 pieces, and soap (C) totaling 6 pieces.

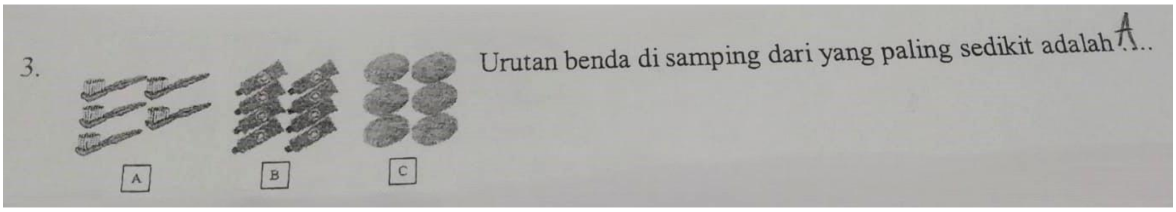


Figure 4. Student responses to question number 3 of the number concepts test

The students mentioned only one item, namely toothbrushes (A), totaling 5 items, while the other two orders, toothpaste (B), totaling 8 items, and soap (C), totaling 6 items, were not mentioned. Thus, this may affect students' answers to that problem. The correct answer is the order of items from least to most in the question: toothbrushes (A) totaling 5 pieces, soap (C) totaling 6 pieces, and toothpaste (B) totaling 8 pieces. In this case, the student made a procedural error in solving question number 3. As noted by Yap & Wong (2024) it is essential for students to understand fundamental mathematical concepts and the reasoning behind the steps required to address errors in mathematical problem solving. The student in Figure 4 mentioned only "A toothbrush" (5 pieces), ignoring the complete sequence (A=5, C=6, B=8), reflecting the use of inappropriate strategies and an overreliance on routine procedures as they followed the "least" memorization without a systematic procedure for comparing the three images. Interviews confirmed this misconception, consistent with Hoth's lack of metacognition, where the student failed to reflect on the task's demands.

Discussion

The types of errors identified in this study were as follows: conceptual errors occurred in 19 cases (86.36%), procedural errors in 1 case (4.54%), and technical errors in 2 cases (9.10%). Students, instructors, and the institution use these findings as a foundation for their own self-evaluations. According to earlier research, conceptual mistakes occur when formulas or definitions are used incorrectly or when the conditions or circumstances required to apply the formula are not met (Yuliani & Kartini, 2020). Procedural errors include unsystematic work procedures and the inability to carry out or execute procedures to solve a problem (Utami et al., 2020). Meanwhile, technical or arithmetic errors refer to mistakes in calculation or problem solving. Previous studies also used routine problems as the instrument (Fitriyah et al., 2020). To avoid being taken aback or perplexed by novel issues that might otherwise lead to mistakes, students should also practice addressing non-routine tasks. This is consistent with the view of Ruffini et al. (2025) that reading comprehension and general cognitive performance may both be improved by practicing executive function skills, or mental capacities, through reading exercises.

As stated by Chen et al. (2025), students' learning trajectories and cognitive profiles vary. Students with high reading ability follow shorter learning trajectories and require less support, whereas students with low reading ability need more explicit and implicit guidance and tend to overlook the tutor's role in learning support. This highlights the need for adaptive, differentiated design across instruction, learning materials, and assessment. Thus, students must always engage in mathematical logical thinking to carry out activities independently. This study implied that students need more varied practice problems aligned with everyday life, thereby enhancing their ability to solve non-routine mathematical problems (Zhang et al., 2025).

After evaluations, it is advised to provide students with principle-based feedback (i.e., why a problem should be addressed in a specific manner) and, when students are experiencing a high cognitive load, to flexibly provide procedure-based feedback (i.e., how to solve the problem). According to the findings, these pupils eventually achieved improved learning outcomes.

CONCLUSION

This study analyzed the errors made by 2A grade students of Madrasah Ibtidaiyah Negeri 1 Banyuwangi when solving non-routine number problems using the Kastolan theory. The main findings indicated a dominant conceptual error rate of 86.36%, followed by procedural errors at 4.54%, and technical errors at 9.10%. This was based on an analysis of responses from 26 students to five essay questions from the Mid-Semester Summative Exam. Conceptual errors most often occur when students fail to understand the problem's context, such as treating 'baskets' as the number of mangoes in a word problem. Procedural errors arise from unsystematic steps, such as simply ordering one item without completing the whole sequence. Technical errors involve incomplete calculations, such as ignoring one of the subtractors in the egg problem. The study recommends comprehensive teaching of numerical concepts, varied contextual problems, and greater flexibility in thinking to reduce errors and promote in-depth understanding. This approach aligns with the need for non-routine problem practice to encourage students to think logically and adaptively in real-life situations.

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