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Students' mathematical errors in solving literacy and numeracy problems

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ABSTRACT

Numeracy literacy constitutes one of the core domains evaluated in an assessment administered by the Ministry of Religious Affairs, referred to as AKMI. This assessment functions as a comprehensive diagnostic tool to identify students' proficiencies and deficiencies across three key literacy areas: reading, numeracy, and scientific. This study employed a descriptive qualitative approach, with fifth-grade students as the subjects. The research instruments included a mathematics ability test, a literacy and numeracy assessment, and semi-structured interview guidelines. The students' problem-solving processes were analyzed through four stages: understanding the problem, devising a plan, executing the plan, and evaluating the solution.Findings revealed that students with low mathematical ability frequently encountered difficulties in the planning, execution, and evaluation stages, which collectively accounted for 29.4% of the total errors. A smaller proportion (5.88%) struggled with understanding the problem, while another 5.88% did not exhibit notable errors. Students with moderate ability demonstrated errors in the planning, execution, and evaluation phases, each contributing 25% to the overall errors; however, they showed no difficulty in identifying knowns and unknowns in the problems. High-ability students generally solved the problems without major issues, with 62.5% of their responses being accurate and error-free. Geometry-related problems posed the greatest challenge across all ability levels, resulting in a higher incidence of errors.

INTRODUCTION

Mathematics education in Indonesia, as in many other countries, plays a pivotal role in developing students' logical reasoning, problem-solving ability, and critical thinking skills across educational levels (Ashidiqi & Sugandi, 2023; Coxbill, Chamberlin, & Weatherford, 2013; Maulana et al., 2023). This is because of the importance of the benefits of mathematics in everyday life. Judging from the importance of mathematics, students must be serious about studying it at school (Rohimah et al., 2017; Hasanah et.al., 2021). Cornelius identified five essential functions of mathematics: facilitating logical thinking, solving real-world problems, recognizing patterns and generalizations, fostering creativity, and promoting cultural awareness (Abdurrahman, 2012).

One of the primary goals of mathematics instruction is to equip students with the ability to address practical, real-life problems (Abdurrahman, Halim, & Sharifah, 2021; Blomhøj & Jensen, 2003). This is in line with the opinion Bardu and Beal (2010) mathematical operations require the ability to solve problems. This objective aligns with the growing emphasis on mathematical literacy—defined as the capacity to formulate, apply, and interpret mathematics in a variety of contexts (Ashidiqi & Sugandi, 2023; Yuberta & Firmanti, 2024). In Indonesia, the Ministry of Religious Affairs has initiated the Madrasah Competency Assessment (AKMI), a nationwide program designed to evaluate students' competencies in literacy, numeracy, and character development. AKMI

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integrates Higher-Order Thinking Skills (HOTS) to measure how effectively students apply foundational knowledge, particularly through numeracy-based problem-solving. Literacy is defined as the ability to understand, use, evaluate, and reflect on various types of written text to develop the capacity of individuals as Indonesian citizens and contribute productively to society (Kemendikbud, 2019; Purwanto, 2021; Handayani, 2022).

Lamada et al. (2019) asserted that the progression of literacy warrants significant attention, as it constitutes a foundational competency essential for individuals to navigate future life challenges. Furthermore, mathematical literacy proficiency facilitates an individual's comprehension of mathematics' role and utility in everyday contexts (Puspitasari et al., 2015). Mathematical literacy is among the most crucial that numeracy is the ability to think mathematically, emphasising the use of mathematical concepts, procedures, facts, and tools to solve everyday problems in various relevant contexts for (Arriah & Romba, 2023; Novitasari et al., 2020; Pratama, Hartini, & Misbah, 2019; Sayekti, 2022). Despite these efforts, AKMI results have revealed that many students struggle with literacy and numeracy-based assessments. For instance, Sari (2021) reported that students' performance in geometry questions within the numeracy section was especially low, with only 17.65% achieving correct answers. Such findings point to underlying issues in students' mathematical thinking processes. Understanding the specific nature of these difficulties is essential. Error analysis provides a powerful lens through which teachers and researchers can identify common misconceptions, faulty reasoning patterns, or procedural mistakes. This analysis not only facilitates targeted remediation but also informs pedagogical strategies to support diverse learners (Chen, 2022; Din, 2020).

However, analyzing student errors in computer-based tests like AKMI presents unique challenges, as students' step-by-step reasoning is not always visible. Therefore, this study aims to investigate the types and patterns of mathematical errors made by students when answering numeracy and literacy-based questions, using a qualitative approach that includes written responses and follow-up interviews. The findings will contribute to improving mathematics instruction, especially in integrating literacy and numeracy skills in primary Islamic education settings.

Furthermore, it is important to acknowledge that identifying student errors in the context of literacy and numeracy-based assessments like AKMI (Madrasah Competency Assessment of Indonesia) presents its own challenges (Arriah & Romba, 2023). The computer-based nature of the test makes it difficult for teachers to directly observe students' thought processes and identify the specific steps where errors occur. Therefore, in-depth research that specifically analyzes student responses to AKMI questions becomes crucial. This analysis should not only focus on final incorrect answers but also on the patterns of errors that emerge in partial answers or the reasons students provide. By understanding these patterns, teachers can gain a more accurate insight into the specific misconceptions or difficulties students face in applying literacy and numeracy skills in the context of integrated questions.

The implication of this need for in-depth error analysis is that teachers need to develop skills in interpreting assessment data, including AKMI data, effectively. This involves more than just looking at students' final scores (Rosyadi et al., 2021). Teachers need to be trained to analyze student responses to each item, identify commonly incorrect answers, and try to understand the reasoning behind these errors. For example, did students misunderstand information in the text of the question, have difficulty translating the problem into a mathematical representation, or make procedural errors in calculations? With good error analysis skills, teachers can design more targeted learning interventions that directly address the specific difficulties experienced by particular groups of students.

In addition, the AKMI results showing a trend of students' numeracy abilities at the C3 level in MIS AS-SUNNAH indicate the need for special attention to the development of this ability. Level C3 generally describes students' ability to apply mathematical knowledge and understanding in familiar contexts. To improve students' abilities to a higher level, learning interventions need to be designed to encourage them to think more critically, solve more complex problems, and apply mathematical concepts in less familiar contexts or those requiring the integration of various concepts. The analysis of student errors in answering literacy and numeracy-based AKMI questions can be an important starting point in designing effective interventions to improve students' abilities holistically.

METHODS

This study employed a qualitative descriptive approach to analyze students' mathematical errors in solving numeracy and literacy-based problems. The design was selected to allow in-depth exploration of students' cognitive processes and error patterns through their written responses and verbal explanations. The participants comprised 15 fifth-grade students from a private religion elementary school at Kediri, East Java, Indonesia, during the 2023/2024 academic year. Purposive sampling was used to ensure a varied representation of ability levels. Students were grouped into three categories—low, medium, and high mathematical ability—based on the results of a diagnostic test. Grouping was guided by the standard deviation method as suggested by Arikunto (2006), with the average score and standard deviation used to determine the thresholds. The test sheet consists of two types of questions, namely, mathematical ability test questions and AKMI numeracy literacy test questions. hree instruments were used in this study: First, Mathematical Ability Test. This diagnostic test included: three questions on numerical operations (complex multiple choice), one item on basic statistics (true/false format), and a short-answer question on sequences and series. This test served to categorize students into ability groups and provided a baseline for their general mathematical proficiency. Second, AKMI-Type Numeracy Literacy Test. This consisted of three contextualized mathematical problems aligned with the AKMI framework, focusing on geometry and algebra. These items were designed to assess students' ability to apply mathematical knowledge in real-life contexts. Responses to these items formed the core data for error analysis. Third, Structured Interview Guide. Follow-up interviews were conducted with selected students to clarify their reasoning and explore the thought processes behind their answers. This instrument allowed triangulation of data and provided insights into misconceptions that were not evident in written responses.

Based on the study by Hidayat and Pujiastuti (2019) and Mulyati (2016), student errors in answering story-based research questions are defined as deviations made by students in completing the given story-based questions, following Polya's problem-solving steps. The types of errors in the questions include: error in understanding the question, error in formulating a plan, error in carrying out the plan and error in inspecting the solution. A more detailed explanation of the indicators for each error type is presented in Table 1.

Data Analyst

Data analysis was conducted in two stages: Written Response Analysis and Interview Data Analysis. Student responses were coded based on the error type framework in Table 1. Each test item was reviewed to identify the specific stage(s) where the student encountered difficulty. Interview transcripts were analyzed to provide qualitative explanations for the patterns observed in the written responses. Common themes and misconceptions were identified, allowing a deeper understanding of error sources. Students were grouped into ability levels using the following formula from Arikunto (2006) at Kafifah (2019) : Upper threshold (high ability) $n \geq (Mean + SD)$, medium ability $(Mean - SD) < n < (Mean + SD)$, and low ability $n \leq (Mean - SD)$. Were, the main score was 62.22 and standar devation was 18.72. Based on this classification: high ability: Scores > 80.94 (n = 3), medium ability: Scores between 43.5 and 80.94 (n = 9), and low ability: Scores < 43.5 (n = 3). The triangulation of test data and interview insights provided a comprehensive understanding of the types and causes of mathematical errors among primary school students in an Islamic school setting.

FINDINGS

Based on the results of the general mathematical ability test, students were classified into three ability levels using the standard deviation method (Arikunto, 2006). The average score was 62.22, and the standard deviation was 18.72. The cut-off scores for classification were: high ability: > 80.94, medium ability: 43.5 – 80.94, low ability: < 43. From the total sample of 15 students: 3 students were classified as high-ability, 9 students as medium-ability, and 3 students as low-ability.

Table 1.
Error type indicator student

Error Type		Indicator
Error In Understanding the Question	Error determines what is known	a. Students write what is known with Correct b. Students are wrong in writing what is known in the question. c. Student No writes what is known in the question.
	Error determines what was asked.	a. The student writes with correct answers to what is being asked in the question. b. Students are wrong in writing what is being asked in the question. c. Student No writes what is being asked in the question.
Error in Formulating Plan	Error in the write method settlement	a. The student writes the correct method of settlement in accordance with the order question. b. Student writes a method settlement, but not by order question. c. Student No write method settlement question.
	Error determines the steps in the final question.	a. Students write with the correct steps to be taken to finish the question by method taken/determined. b. Students write the steps to be taken and used in the final question, but not by the method taken/determined. c. Student No. Write the steps to be taken used in the final question.
Error In Carrying Out The Plan	Error calculation is complete with the mathematical model that has been made.	a. Students do the calculation with Correct To complete the mathematical model that has been made. b. Students are wrong when doing calculations to complete the existing mathematical model. c. Student No does the calculation to complete the mathematical model that has been made.
	Error determines the conclusion of the settlement problem.	a. Student writes with a Correct conclusion based on the given problem. b. The student writes a conclusion, but not based on the given problem. c. Student No writes a conclusion.
Error In Inspecting The Solution	Error in the order of the steps for settlement in inspecting the return, and the solution obtained.	a. Student inspects the return solution obtained using systematic steps. b. Student inspects the return solution obtained but does not use systematic steps. c. Student No. Inspect the solution obtained.

Table 1 (Continued)

Error Type		Indicator
	Error calculation mathematics in the inspection returns the solution obtained.	a. Student does calculation with Correct when inspecting the return, the solution obtained. b. Students are wrong when doing calculations, when inspecting the solution obtained. c. Student No does the calculations when inspecting the return of the solution obtained.
	Error in obtaining the answer.	a. Students will obtain the answer from the initial data provided. b. Students are to obtain the answer, but not by the initial data provided. c. Student No. to obtain the answer.

Table 2.
Types of errors in students

Number Student	Question 1	Question 2	Question 3
SR01 (low ability students 1)	B, C		B, C, D E B, C, D
SR02 (low ability students 2)	B, C, D	A, B, C, D	B, C, D
SS01 (medium ability students 1)	B, C, D	E	B, C, D
SS02 (medium ability students 2)	B, C, D	E	E
ST01 (high ability students 1)	B, C, D	E	E
ST02 (high ability students 2)	E	E	E

Information :
A: Error Understanding the Question
B: Error In Formulating Plan
C: Error In Carrying Out The Plan
D: Error In Inspecting The Solution
E: Not Found Error
F: Question Not Answered

Based on the students' answers to the story-based questions, an analysis was conducted to identify the types of errors made by students and the percentage of each error type. The analysis revealed four types of errors: an Error in understanding the question, an Error in formulating a plan, an Error in carrying out the plan, and an Error in checking the solution.

Table 2 presents the findings on the four types of errors made by students in answering literacy and numeracy AKMI questions, based on the instrument administered by the researchers. The percentage of each type of mistake made by low-ability students is presented in Table 3 below. From Table 3, we can conclude that low-ability students most frequently made errors in formulating a plan, carrying out the plan, and checking the solution, with a percentage of 29.4%. In the Figure 1, we can see these students often wrote solutions without a clear order or made errors in determining the steps and calculations, leading to incorrect conclusions. Errors in checking the solution were also common, resulting in students not being able to arrive at the correct final answer. Students who made errors in understanding the question accounted for 5.88% of the total. The remaining 5.88% did not exhibit any significant errors in their work.

Table 3

Percentage of error types student low ability

Error Type	Presentation
Error Understanding the Question	5.88%
Error In Formulating Plan	29.4%
Error In Carrying Out The Plan	29.4%
Error In Inspecting The Solution	29.4%
Not Found Error	5.88%

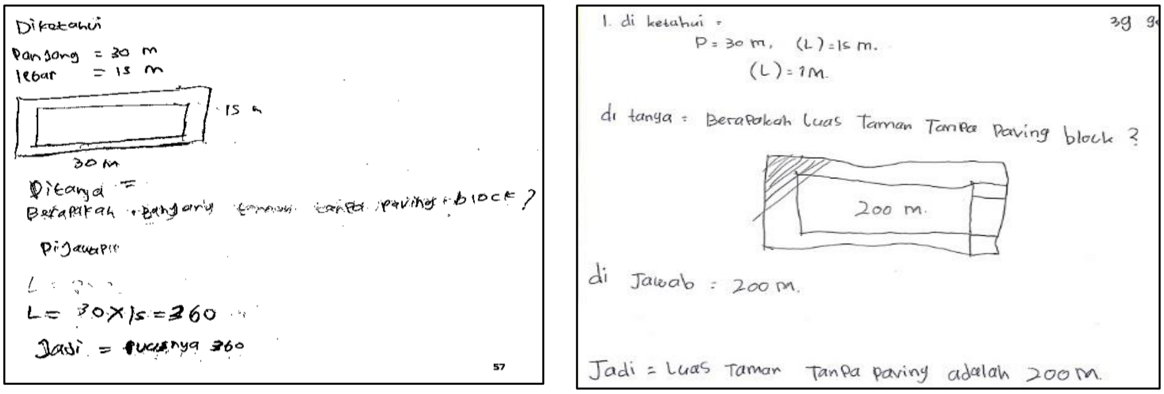
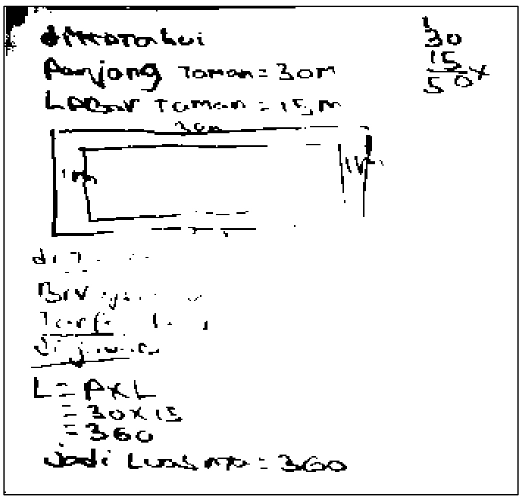


Figure 1. The answer students with low ability in question 1

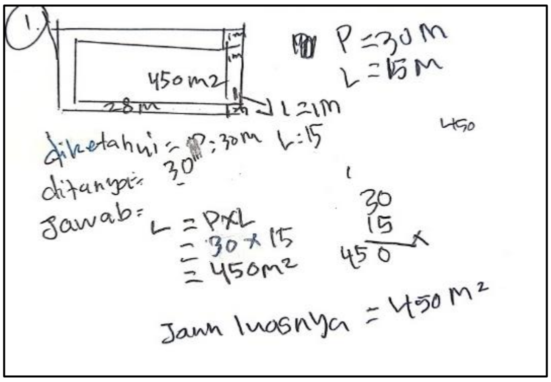
Table 4

Percentage of error types student medium ability

Error Type	Presentation
Error Understanding the Question	-
Error In Formulating Plan	25%
Error In Carrying Out The Plan	25%
Error In Inspecting The Solution	25%
Not Found Error	25%



SS01

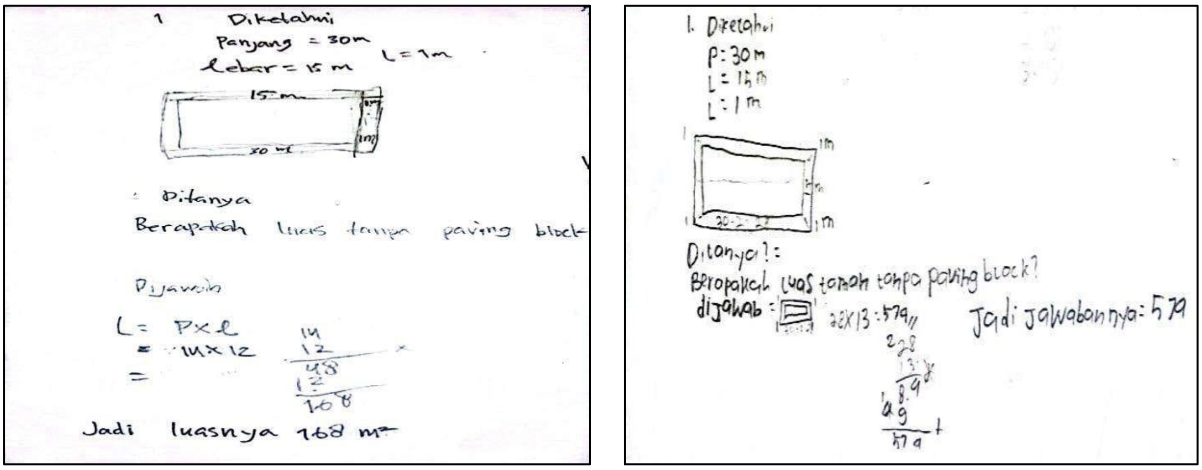


SS02

Figure 2. The answer students with medium ability in question 1

Table 5.
Percentage of error types student high ability

Error Type	Presentation
Error Understanding the Question	-
Error In Formulating Plan	12.5%
Error In Carrying Out The Plan	12.5%
Error In Inspecting The Solution	12.5%
Not Found Error	62.5%



ST01 **ST02**

Figure 3. The answer students with high ability in question 1

The percentage of each type of mistake made by medium-ability students is presented in Table 4. From Table 4, all medium-ability students were able to understand the questions well, as indicated by a 0% error rate in understanding questions. In Figure 2, they made errors in formulating plans, implementing plans, and checking solutions, with each error type accounting for 25% of the total errors. Students struggled with solving problem number 1, often writing solutions without a clear order or making errors in determining the steps and calculations, leading to incorrect conclusions. On problem number 2, no errors were found. For problem number 3, SS01 made errors in formulating a plan, implementing the plan, and checking the solution. However, SS02 did not make any errors in solving problem number 3. Therefore, the percentage of no errors found was 25%.

The percentage of each type of mistake made by high-ability students is presented in Table 5. From Table 5, it can be concluded that, in general, high-ability students did not experience significant difficulties in their work. This is evidenced by the fact that 62.5% of the answers were error-free. We can see in figure 3 that across all ability groups, errors in geometry-related problems were the most prevalent.

One high-ability student (ST01), for example, made errors in planning, execution, and evaluation for a geometry-based task, suggesting that visual-spatial reasoning remains a challenge even for advanced learners. High ability student (ST01 and ST02) were able to formulate definitions and write arguments, as well as read and comprehend a problem and articulate it into an idea, despite making multiplication errors(execution). Consequently, their derived conclusions were incorrect. Therefore, interviews were conducted with ST01 and ST02 as follows:

Interview with ST01

P	:	*What information did you gather from question number 1?*
ST01	:	*The length and width, the length is 30, the width is 15, and the perimeter of the garden is 1 meter*
P	:	*What was asked in the question?*
ST01	:	*What is the area of the garden without the paving blocks?*
P	:	*How did you solve it?*

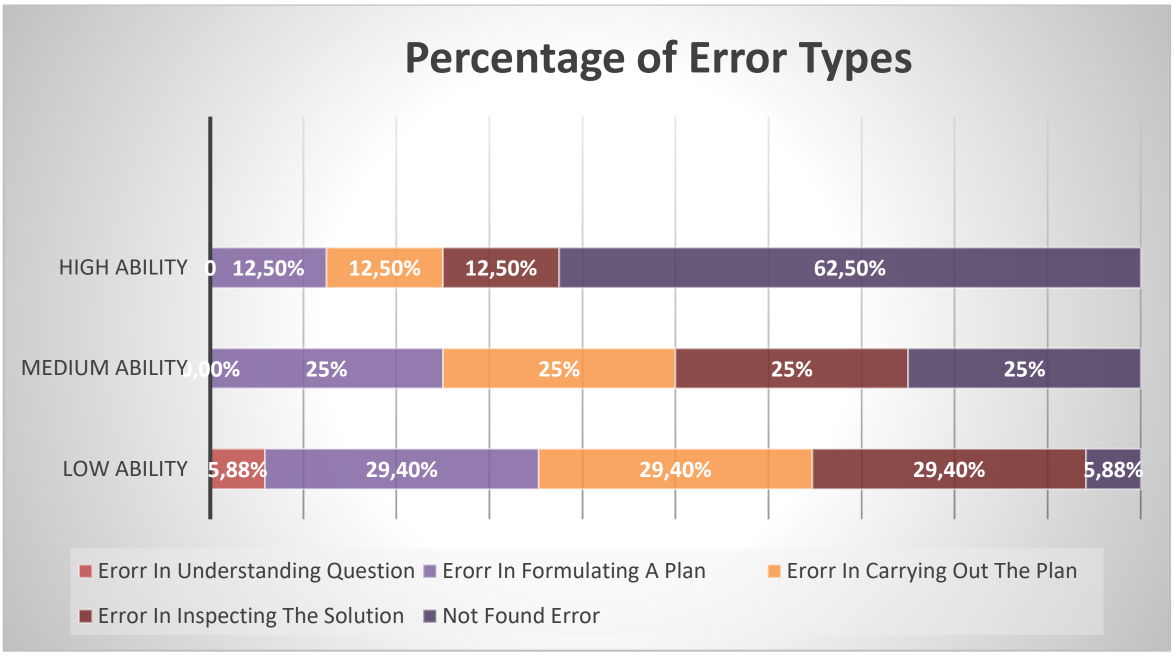


Figure 4. Percentage of error types

ST01 : *Length multiplied by width*
P : *What is the length without the paving blocks?*
ST01 : *10 m*
P : *Where did you get 10 m from? and where did you get 14 from?*
ST01 : *15 m minus 1 meter. Sorry, I'm not sure, I'm still confused*

Interview with ST02

P : *What were the steps to solve that problem?*
ST01 : *Well, there's 1 and 1 on the side, so 30 minus 2 results in 28, then this one also becomes 15 minus 2 results in 13. Then I multiplied them*
P *Is the result correct?*
ST01 *Just a moment, I'll work it out again 364*
P *So, what's the conclusion?*
ST01 *I made a calculation error, it should have been 364.*

Based on the interview results with ST01 and ST02, we know that students with high-level thinking abilities still make calculation and execution errors, even if they are minor. In contrast, algebraic problems were generally better handled, especially by medium- and high-ability students. This highlights the need for targeted interventions focusing on geometrical reasoning and spatial understanding in primary-level mathematics education.

DISCUSSION

Based on the results of the mathematical errors, students with low ability have erorr in understanding question 5.88% but medium ability and high ability there is no problem with this case. All students have problems in formulating plan, carrying out the plan, and erorr in inspevcting the solution with the percentages showing 29.40% for low ability, 25% for medium ability and 12.50% for high ability. We can see all the problems in the graphic below.

This study analyzed students' mathematical errors in solving literacy- and numeracy-based problems from the Indonesian Madrasah Competency Assessment (AKMI). Using Polya's four-stage problem-solving framework, the findings reveal a consistent trend across ability levels: the most frequent errors occurred in the stages of devising a plan, carrying out the plan, and checking the solution, rather than in understanding the problem. This suggests that students can comprehend problem statements but face challenges in strategy formulation, procedural execution, and solution validation.

Comparison across ability levels

Low-ability students were most prone to multi-stage errors, particularly in procedural and evaluative tasks. This aligns with prior findings by Rachmawati et al. (2021), who identified calculation and conclusion errors as dominant among students with weaker mathematical foundations. Medium-ability students demonstrated better comprehension but still struggled with strategy development and execution, reflecting a need for deeper conceptual understanding and structured problem-solving guidance.

Interestingly, even high-ability students made occasional errors particularly with geometry-based problems underscoring that higher procedural fluency does not always translate to conceptual mastery, especially in visual-spatial domains.

Error patterns and geometry-specific challenges

Geometry emerged as the most error-prone topic across all groups. This is consistent with findings from Sari (2021), who reported significantly lower student performance in geometry in the context of the AKMI. The abstract and spatial nature of geometry can make it particularly challenging for young learners, especially in computer-based assessments where drawing or physically manipulating shapes is not possible.

The novelty of this study lies in its focus on error types within a religious school context (madrasah), specifically in relation to AKMI—a national but under-studied assessment framework. Unlike many existing studies that focus on general math performance, this research dissects where and why students fail in integrated literacy-numeracy tasks, offering a rare lens into primary-level error diagnosis.

Pedagogical implications

The results have direct implications for instructional design. Teachers must go beyond focusing on final answers and instead address cognitive missteps that occur during planning and execution phases. This calls for: error-based instruction: embedding examples of common errors into classroom discussions to help students recognize and correct faulty strategies. Explicit teaching of problem-solving stages: Guiding students through each stage of Polya's model with visual aids or scaffolding. Emphasis on geometry: Incorporating more hands-on and contextualized activities to build spatial reasoning skills, such as the use of manipulatives or digital geometry tools. Additionally, teachers need training on interpreting computer-based assessment results like AKMI not just at the score level, but at the process level. That is, identifying not only which questions were answered incorrectly, but understanding how students approached those problems.

Alignment with previous studies

These findings are supported by previous research. Hidayah et al. (2020) found that students' errors often stem from shallow conceptual understanding and difficulty in transferring knowledge across contexts. Similarly, Alfiani et al. (2022) emphasized that even prospective teachers make conceptual and procedural errors in problem-solving, highlighting the systemic nature of this issue. Contextual learning models have been shown to reduce such errors by linking abstract concepts to familiar real-life situations (Islahiyah et al., 2021; Madrazo & Dio, 2020). Thus, integrating contextual learning with error analysis may be key to enhancing mathematical literacy among primary students. This approach could also help bridge the gap between routine problem-solving and higher-order thinking as emphasized in AKMI.

Several relevant studies support these findings. Jusniani (2018) found that students made errors in understanding questions (4.4%), formulating a plan (16.5%), carrying out the plan (17.0%), and checking the solution (14.8%). Errors in carrying out the plan were often due to carelessness in calculations and a lack of care in determining conclusions (Rachmawati, Cholily, & Zukhrufurrohmah, 2021). Similarly, in "Analysis Of Students' Answer Errors In Mathematical Understanding Abilities Through Contextual Learning" found that many errors were related to mathematical concepts, understanding different methods, and developing concepts. Students often made significant errors in identifying properties of concepts and determining conditions (Rosyadi, Sa'dijah, & Rahardjo, 2022). The results of classroom observations showed that contextual learning can help reduce student errors and improve their mathematical understanding.

Other relevant studies reinforce these findings by highlighting the variety of errors students make when solving math problems. The study "Analysis of Student Errors in Solving Mathematical Problems on Set Material" found that errors weren't just limited to the execution phase of the solution plan, but also occurred in understanding the question, formulating the plan, and even when checking the answers (Adhikari, 2024). Errors in carrying out the plan were often due to carelessness in calculations and a lack of thoroughness in drawing conclusions (Nur et al., 2022). This indicates that interventions aimed at improving students' math problem-solving skills need to comprehensively address each stage of the problem-solving process, not just focus on calculation aspects alone.

Furthermore, Hidayah et al. (2020) the study in "Analysis of Students' Answer Errors in Mathematical Understanding Abilities Through Contextual Learning" provides additional insight into the root causes of student errors. This research found that many errors stemmed from a shallow understanding of mathematical concepts, difficulty in connecting different solution methods, and weaknesses in developing concepts fully. Significant errors often occurred when students failed to identify the essential properties of a concept and in determining the necessary conditions for applying that concept correctly. This finding underscores the importance of learning that doesn't just emphasize memorizing formulas, but also strong conceptual understanding and the ability to connect mathematical concepts in various contexts.

Interestingly, the results of classroom observations in Islahiyah, Pujiastuti, and Mutaqin (2021) research showed that implementing contextual learning has significant potential in reducing student error rates and improving their overall mathematical understanding. Contextual learning, which links mathematical concepts to real-world situations relevant to students, helps them build more meaningful understanding and reduces excessive abstraction (Madrazo and Dio 2020). Thus, the implications of these various studies are the need for innovative and concept-understanding-centered learning approaches, thoroughness in each step of problem-solving, and relating material to contexts familiar to students to minimize the occurrence of errors in mathematics learning.

CONCLUSIONS

This study examined the types of mathematical errors made by fifth-grade students at a private religion elementery school in solving literacy- and numeracy-based questions from the Indonesian Madrasah Competency Assessment (AKMI). By analyzing student responses using Polya's four-stage framework, several key findings emerged: low-ability students most frequently made errors in devising a plan, carrying out the plan, and checking the solution, with each error type comprising 29.4% of their total errors. Errors in problem comprehension were minimal (5.88%), indicating basic reading ability but difficulty in applying mathematical strategies. medium-ability students also showed consistent issues in the stages of planning, execution, and checking, each accounting for 25% of their total errors. These students demonstrated adequate comprehension of problem statements but struggled with mathematical reasoning and accuracy. high-ability students generally performed well, with 62.5% of their responses error-free. However, errors still occurred in complex items, particularly in geometry-based problems, indicating areas for targeted reinforcement. Overall, geometry emerged as a significant challenge for students across all ability levels. The results underscore the importance of implementing instructional strategies that strengthen students' conceptual understanding, procedural fluency, and reflective thinking.

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AUTHOR'S DECLARATION

Authors' contributions	:	AAPR: data collection, data analysis, and writing - original draft; AK: investigation, methodology, supervision, and writing - review &

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