Exploring Elementary Students' Mathematical Reasoning through Patterns and Geometric Shapes: A Case Study at MI Salamah, Jambi City

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ABSTRACT

This study examined the mathematical reasoning abilities of elementary students at MI Salamah, in Jambi City, on the topics of patterns and geometric figures. The research was motivated by the limited number of studies that explore students' real-time reasoning processes in elementary geometry contexts. The study aimed to describe how students with different ability levels demonstrate mathematical reasoning when solving pattern and geometry problems. A descriptive qualitative method was applied, involving three purposively selected fifth-grade students representing high, medium, and low ability levels. Data were collected through two open-ended reasoning tasks developed based on four indicators: making conjectures, performing mathematical manipulations, providing justification, and drawing conclusions. The findings revealed clear variations in students' reasoning abilities: high-ability students demonstrated logical reasoning but had difficulty generalizing patterns; medium-ability students showed partial conceptual understanding with inconsistent justifications; and low-ability students relied on guessing without coherent reasoning. These results indicate that students tended to depend on procedural thinking rather than conceptual reasoning. The study contributes to understanding the developmental shift from procedural to conceptual reasoning and offers implications for designing instructional activities that strengthen reasoning in elementary mathematics learning.

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1. INTRODUCTION

Mathematical reasoning plays a central role in developing students' scientific thinking, as it enables them to draw conclusions or generate new statements through logical processes grounded in previously accepted truths [1]. Reasoning also serves as the foundation for understanding mathematical concepts, helping students construct meaning and apply mathematical ideas in various contexts.

The Decree of the Head of BSKAP Number 008/KR/2022 on the Merdeka Curriculum states that one of the objectives of mathematics education is to cultivate students' ability to recognize patterns, perform mathematical manipulations, make generalizations, and justify solutions as part of mathematical reasoning and proof. Geometry is an essential domain for achieving these goals because it strengthens logical, critical, and creative thinking through the study of shapes, space, and measurement [2]. Within geometry, the topics of patterns and plane figures are crucial for helping students connect abstract properties to real-life contexts [3], [4].

International assessments such as PISA 2019 and TIMSS reveal that Indonesian students continue to exhibit low mathematical performance, with most students categorized at low and medium proficiency levels [5]. These findings indicate that learning objectives related to higher-order thinking, including reasoning, have not been optimally achieved. Previous studies in Indonesia similarly found that students' reasoning abilities remain low across grade levels and are often hindered by conventional teaching methods [6], [7], [8], [9]. Several researchers have examined instructional models aimed at improving reasoning; however, few studies have qualitatively analyzed students' real-time reasoning processes when solving geometry and pattern tasks, revealing a clear research gap and the novelty of the present study.

The theoretical framework of this research refers to the reasoning hierarchy proposed by Lithner, which distinguishes between imitative and creative reasoning, as well as the framework of Krulik & Rudnick, which emphasizes logical, analytical, and divergent thinking. These perspectives support the need to examine how students construct ideas rather than merely evaluating their final answers.

Given this context, it is essential to investigate how elementary students think, reason, and connect mathematical concepts while solving problems in patterns and plane figures. Understanding their reasoning processes offers insights not only into the correctness of answers but also into the flexibility and depth of their mathematical thinking [10], [11]. Such information is vital for teachers in designing reasoning-focused and contextually meaningful learning strategies.

Therefore, this study aims to investigate students' mathematical reasoning abilities at MI Salamah, Jambi City, through the topics of patterns and plane figures. Specifically, the research seeks to describe how students of different ability levels demonstrate mathematical reasoning when solving pattern and geometry problems.

2. METHOD

This study employed a descriptive qualitative approach to explore students' mathematical reasoning abilities in solving problems involving patterns and plane figures. This approach was selected to obtain an in-depth understanding of students' thought processes, allowing the researcher to analyze how they constructed conjectures, performed calculations, and justified their solutions rather than merely evaluating final answers. The research subjects were three fifth-grade students from MI Salamah, Jambi City, selected purposively to represent high, medium, and low levels of mathematical ability. The selection of three students was intended to ensure representativeness of different ability groups while enabling an in-depth exploration of each student's reasoning process. The study was conducted during the first semester of the 2025/2026 academic year. Parental consent and institutional approval were obtained prior to data collection.

The instrument used was a mathematical reasoning test consisting of two open-ended contextual problems on patterns and plane figures. The questions were developed based on four indicators of mathematical reasoning: making conjectures, performing mathematical manipulations, providing justification for solution correctness, and drawing conclusions. Indicators and scoring criteria were clearly formatted and properly aligned to ensure consistency.

Data analysis followed the Miles and Huberman model, which includes (1) data reduction through selection and categorization of students' written responses, (2) data display through organized tables and excerpts illustrating reasoning patterns, and (3) conclusion drawing to interpret students' reasoning characteristics at each ability level. The data were coded manually based on the reasoning indicators. Research validity was established through triangulation of data sources and member checking, supported by peer debriefing to ensure interpretive accuracy.

Table 1. Scoring of the Mathematical Literacy Test

Indicator	Description	Score
Making Conjectures	No conjecture or irrelevant	0
	Conjecture present but illogical	1
	Conjecture is fairly accurate but incomplete	2
	Conjecture is accurate, logical, and supported with clear reasoning	3
Mathematical Manipulation	No solution steps provided	0
	Steps incorrect and result incorrect	1
	Some correct steps, but not systematic	2
	Steps complete, systematic, and result correct	3
Providing Justification	No justification or irrelevant	0
	Justification is weak or illogical	1
	Justification is fairly logical but incomplete	2
	Justification is logical, clear, and consistent	3
Drawing Conclusions	No conclusion written	0
	Conclusion incorrect	1
	Conclusion is fairly accurate but incomplete	2
	Conclusion accurate, complete, and logical	3

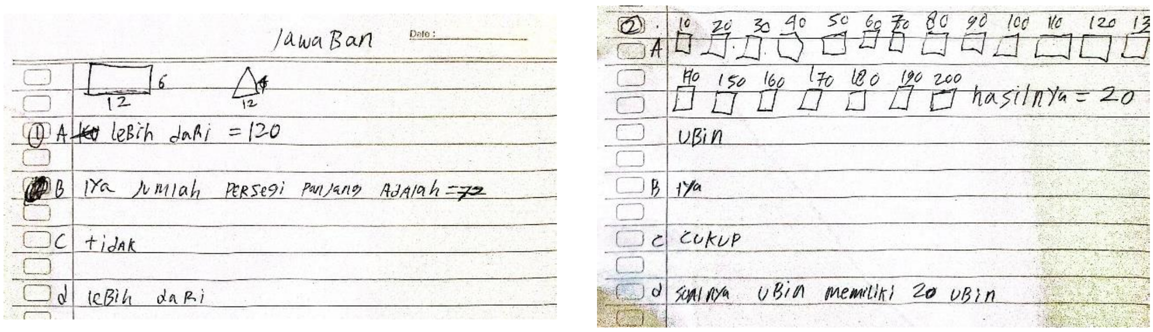
3. RESULTS AND DISCUSSION

After all data were collected through the written test, the next step was to analyze students' responses to trace the mathematical reasoning processes that emerged as they solved problems involving patterns and plane figures. This analysis focused on how students understood the problem, identified patterns and regularities, performed mathematical manipulations, and drew conclusions based on their logical understanding. Through this process, the researcher not only evaluates the correctness of the final answers but also examines the thinking pathways students used to connect basic geometric concepts.

Thus, the analysis yielded deeper insights into how students constructed justifications, verified the correctness of their solutions, and interpreted relationships among geometric figures in a mathematical context. The findings were then presented according to the categories of low-, medium-, and high-ability students, each illustrating variations in thinking strategies and levels of understanding of pattern and plane-figure concepts. In this way, the study offers a comprehensive depiction of the mathematical reasoning characteristics of students at MI Salamah.

3.1. Results

Analysis of students' responses was conducted to trace the processes of mathematical reasoning that emerged as they solved problems related to patterns and plane figures. The analysis focused on how students understood the tasks, recognized patterns and regularities, performed mathematical manipulations, and drew conclusions grounded in their logical understanding. In this stage, the researcher did not merely assess the correctness of the final answers but examined the students' reasoning pathways, including how they connected basic geometric concepts, constructed justifications, and evaluated the validity of their solutions. The findings were classified according to three ability levels: low, medium, and high to illustrate distinct reasoning strategies and conceptual understanding.

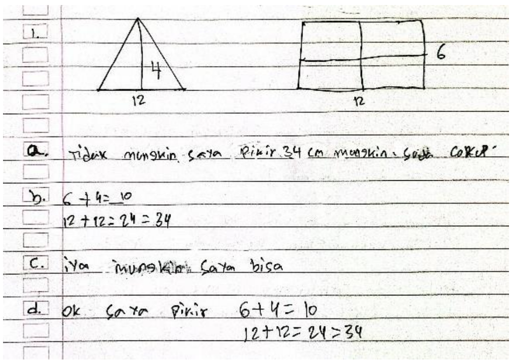


(a) (b)

Figure 1. Students' Responses (S1) (a) question 1 and (b) question 2

The low-ability student demonstrated limited conceptual and procedural understanding [12], [13]. In Question 1, the student wrote *"more than 120"* without showing any calculation steps or reference to the area formulas of rectangles and triangles. When asked to determine the area of the rectangle, the student responded, *"The area is 72,"* but again did not provide supporting calculations. This indicates a misconception commonly observed in early geometry learning: attempting to provide numerical answers without applying formulas accurately.

In Question 2, the student drew a sequence of boxes but was unable to articulate the underlying pattern. The final answer, *"the result = 20 tiles,"* appeared without explanation, reflecting guesswork rather than reasoning. The student did not identify the multiplicative pattern (repeated addition of 10) or relate it to the required length of 200 cm. Overall, the S1 response showed that the student did not meet the reasoning indicators: no conjectures were made, manipulations were incorrect or absent, justifications were missing, and conclusions did not align with mathematical procedures. This aligns with Skemp's idea of instrumental understanding, in which students attempt to answer but lack relational comprehension of the concepts.



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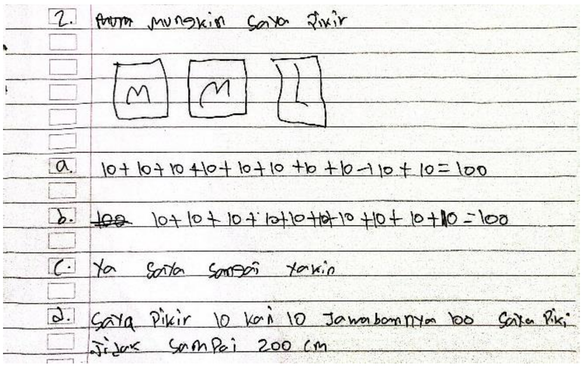
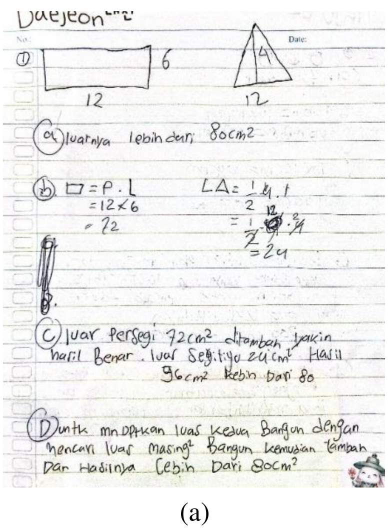


(b)

Figure 2. Students' Responses (S2) (a) question 1 and (b) question 2

The medium-ability student showed better comprehension of the problem context but demonstrated inconsistent reasoning [14], [15]. In Question 1, the student wrote the formulas for the area of a rectangle and a triangle, but did not compute them thoroughly. For example, the student wrote, *"the total is 72"* without explaining how that value was obtained. This suggests incomplete procedural steps, one of the error patterns noted in reasoning tasks [16].

In Question 2, the student labeled the tile sequences as 10, 20, 30,…, 200 and concluded, "T*he result is 20 tiles."* While this shows emerging pattern recognition, the student did not explain the multiplicative relationship or justify the number of tiles in relation to the total distance. Reasoning appeared intuitive but not analytically grounded. Overall, S2 displayed partial conjecture-making and basic manipulations but lacked strong justification and conclusion drawing. According to the Krulik Rudnick reasoning framework, this places the student in the "transitional reasoning" stage, able to identify ideas but not fully articulate connections.



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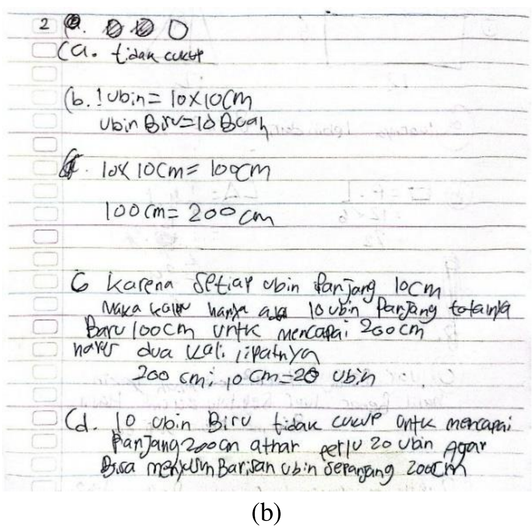

(b)

Figure 3. Students' Responses (S3) (a) question 1 and (b) question 2

The high-achieving student demonstrated strong and integrated reasoning skills. In Question 1, the student systematically calculated: $L = p \times l = 12 \times 6 = 72\text{cm}^2$, for the rectangle and $L = \frac{1}{2} \times a \times t = \frac{1}{2} \times 12 \times 4 = 24\ \text{cm}^2$ for the triangle. then concluded the combined area was *96 cm²*, stating, *"the result is more than 80 cm²."* This shows procedural accuracy combined with verification, consistent with the higher levels of reasoning described.

In Question 2, the student wrote, "Each tile is 10 cm. To reach 200 cm, $200 \div 10 = 20$ tiles," explaining that blue tiles alone were insufficient. This demonstrates logical pattern recognition, use of multiplicative reasoning, and the ability to synthesize geometric and numerical concepts. S3 met all indicators: constructing conjectures, performing valid manipulations, providing logical justifications, and drawing conclusions that aligned with calculations.

3.2. Discussion

The results of the study show that students' mathematical reasoning abilities in the topics of patterns and plane figures at MI Salamah Kota Jambi vary across ability levels. These differences appear in how students interpret problem contexts, formulate solution strategies, perform calculations, and provide logical explanations for their answers. This variation indicates that mathematical reasoning extends beyond computational skills; it requires conceptual understanding, the ability to connect information, and the use of logical and reflective thinking [17], [18].

Students with low ability generally exhibit procedural tendencies without deeper conceptual comprehension. Although they can recognize given geometric shapes or patterns, they struggle to integrate information and construct coherent solution steps. This condition is consistent with [19], which states that weak conceptual understanding is a key factor limiting students' mathematical reasoning [20]. In Skemp's (1976) terms, these students rely primarily on instrumental understanding, performing steps mechanically without grasping the relational meaning behind them.

Students with moderate ability demonstrate transitional reasoning. They begin to identify patterns, write formulas, and carry out basic calculations, yet their justifications remain incomplete [21]. They understand *what* needs to be done, but cannot fully explain *why* it must be done. This aligns with the Krulik–Rudnick framework, which describes a middle phase where reasoning is emerging but not yet systematic. These findings also refine the claims in [6] and [22] by showing that conceptual understanding alone is insufficient; students must also engage in tasks that promote explicit reasoning to move beyond intuitive or partial explanations.

High-ability students show more advanced reasoning processes. They can identify key information, apply formulas accurately, and justify each step logically. Their work reflects systematic reasoning: recognizing patterns, performing accurate manipulations, and drawing conclusions consistent with the problem's structure. This balance between conceptual and procedural knowledge aligns with Polya's stages of problem solving: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution, and supports the findings in [23], although the present study reveals a deeper integration of pattern recognition within geometric contexts. Similar to [24] and [25], these students exhibit reasoning as an intentional cognitive process used to analyze problems and draw valid conclusions.

Across these three categories, it becomes clear that students' mathematical reasoning develops gradually. Logical explanation and justification do not emerge spontaneously; they require continuous engagement in reasoning-oriented tasks. This supports [16], who argued that Indonesian students' low reasoning performance stems from instructional practices that emphasize final answers over thinking processes. To strengthen reasoning, students must be given opportunities to conjecture, explain, reflect, and revise their approaches, activities central to conceptual understanding as described by Skemp and to the problem-solving cycles outlined by Polya.

Pedagogical implications drawn from these findings include the need for teachers to embed reasoning-focused questioning, scaffolding, and reflective dialogue within geometry learning, rather than relying solely on procedural demonstrations. Instruction should encourage students to articulate their thinking, compare strategies, and justify relationships among geometric concepts. Limitations of this study include its small sample size, which limits generalizability. Future research may expand the sample size, investigate additional mathematical domains, and incorporate broader forms of qualitative evidence, such as interviews and classroom interactions, to provide deeper insight into the development of mathematical reasoning.

4. CONCLUSION

This study highlights that students demonstrate varying levels of mathematical reasoning, emphasizing the importance of conceptual understanding and reflective learning experiences in supporting their reasoning development. The findings imply that elementary mathematics instruction should integrate reasoning-focused activities that encourage students to explain, justify, and connect mathematical ideas, rather than rely solely on procedural approaches. The study is limited by its small sample size and focus on a single content area, which constrains the generalizability of the results. Future research should involve broader participant groups, explore other mathematical domains, and incorporate richer qualitative data to deepen insights into students' reasoning processes. Overall, this research contributes to the broader educational community by reinforcing the need to embed conceptual reasoning frameworks within primary mathematics education to support students' transition from procedural to conceptual thinking.

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of the results. Future research should involve broader participant groups, explore other mathematical domains, and incorporate richer qualitative data to deepen insights into students' reasoning processes.

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