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MATHEMATICAL REASONING ABILITY OF STUDENTS AT SMA NEGERI 1 BELINYU ON THREE-DIMENSIONAL GEOMETRY

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ABSTRACT

This study aims to analyze the mathematical reasoning ability of 12th-grade students at SMA Negeri 1 Belinyu on three-dimensional geometry. Using a quantitative descriptive method, data were collected through essay tests and interviews. Results showed that students had moderate mathematical reasoning ability, with an average score of 47.14%. Among four measured indicators, students performed best in presenting mathematical statements (65.83%) and constructing proofs (61.39%), but poorly in identifying patterns (38.33%) and drawing conclusions (16.39%). These findings indicate the need for instructional strategies that emphasize critical thinking and structured reasoning. This research contributes to understanding students' difficulties in spatial reasoning and supports curriculum development for geometry learning.

ABSTRAK

Penelitian ini bertujuan untuk menganalisis kemampuan penalaran matematis siswa kelas XII di SMA Negeri 1 Belinyu pada materi geometri dimensi tiga. Dengan menggunakan metode deskriptif kuantitatif, data dikumpulkan melalui tes uraian dan wawancara. Hasil penelitian menunjukkan bahwa kemampuan penalaran matematis siswa berada pada kategori sedang, dengan skor rata-rata sebesar 47,14%. Dari empat indikator yang diukur, siswa menunjukkan performa terbaik pada indikator menyajikan pernyataan matematis (65,83%) dan menyusun pembuktian (61,39%), namun lemah dalam mengidentifikasi pola (38,33%) dan menarik kesimpulan (16,39%). Temuan ini menunjukkan perlunya strategi pembelajaran yang menekankan pada pemikiran kritis dan penalaran yang terstruktur. Penelitian ini berkontribusi dalam memahami kesulitan siswa dalam penalaran spasial dan mendukung pengembangan kurikulum dalam pembelajaran geometri.

Introduction

Mathematics is a school subject that is highly valued in education since it helps pupils think clearly, rationally, critically, accurately, effectively, and efficiently (Sosa-Gutierrez et al., 2024). Mathematics is regarded as a fundamental subject of knowledge required for everyday applications since it is entrenched in so many

facets of life. This viewpoint is consistent with Miksalmina's statement (Abd Algani & Eshan, 2022), emphasizing the ubiquitous use of mathematical principles in real-world settings.

According to the National Council of Teachers of Mathematics (NCTM) (Leinwand et al., 2014), the general objectives of mathematics education include: (1) learning about mathematical values, understanding its evolution, and recognizing its role in society and science; (2) developing confidence in one's mathematical thinking abilities and problem-solving skills; (3) understanding mathematical symbols, notations, and principles; (4) reasoning systematically by formulating conjectures, constructing proofs, and presenting arguments logically; and (5) becoming productive citizens with experience in solving diverse problems while also acquiring the ability to communicate mathematically.

Based on these objectives, mathematical reasoning is a critical competency that students must develop. Enhancing this ability enables students to formulate and expand mathematical concepts (Palinussa et al., 2021). Similarly, Riyanto and Siroj argue that the goal of mathematics education in schools is to apply reasoning in recognizing patterns and properties (Mukuka et al., 2021). Furthermore, mathematical content and reasoning are inseparable mathematical concepts are understood through reasoning, and reasoning itself is developed and reinforced through learning mathematics (Rohati et al., 2023).

Mathematical topics that require reasoning skills include geometry, with one of its core subjects being three-dimensional geometry. A fundamental issue that students encounter in this topic arises from the abundance of abstract diagrams and spatial representations, which demand strong reasoning abilities to comprehend the material effectively (Arifanti, 2020). From a substantive perspective, three-dimensional geometry is considered one of the most challenging mathematical topics for students (Cai & Hwang, 2023; Schoevers et al., 2022).

According to (Amaliyah et al., 2022), when solving three-dimensional geometry problems, students frequently struggle due to a lack of understanding of symbols, place values, diagram interpretation, calculations, and incorrect procedural applications. This aligns with Alamsyah’s assertion that students face difficulties in problem comprehension, fact identification, operational procedures, and understanding mathematical principles and concepts when working on three-dimensional geometry problems (Al-Amrat & Khasawneh, 2022; Zhang, 2021).

Based on these findings, it can be concluded that students' errors in answering test questions stem from difficulties in addressing key problem

indicators, such as selecting appropriate patterns or methods, identifying relationships in problem analysis, and estimating answers and solutions.

Students generally experience challenges in understanding three-dimensional geometry, which affects their ability to grasp subsequent mathematical concepts. Furthermore, geometrical proof-related problems present additional difficulties, as stated by Acharya and Ghose (Novita et al., 2018). These struggles are often reflected in the mistakes students make while solving three-dimensional geometry problems. Such difficulties were also observed in the preliminary research conducted by the researcher at SMA Negeri 1 Belinyu.

Prior to conducting the main study, the researcher carried out a preliminary investigation on students' mathematical reasoning abilities at SMA Negeri 1 Belinyu, using a sample of 10 students. The results revealed that four students failed to represent a cube diagram in the mathematical reasoning indicator of presenting mathematical statements using diagrams, and only one student successfully formulated a mathematical conclusion aligned with the given problem. This conclusion involved explaining incorrect statements regarding the position of two lines in space within a cube structure. The test questions in the preliminary study were designed based on mathematical reasoning indicators, including presenting mathematical statements in written and diagrammatic form, performing mathematical manipulations, identifying patterns or properties of mathematical phenomena, and drawing conclusions.

Given the crucial role of mathematical reasoning in developing students' ability to think critically, systematically, and logically, understanding its application in three-dimensional geometry becomes essential. The findings from both previous research and preliminary studies indicate that students face significant challenges in comprehending abstract spatial representations, which in turn affects their problem-solving skills. Difficulties in interpreting diagrams, applying mathematical procedures correctly, and making logical inferences contribute to their struggles in solving three-dimensional geometry problems.

Moreover, prior studies have consistently reported low mathematical reasoning abilities among students, particularly in presenting mathematical statements through diagrams, manipulating mathematical concepts, and drawing conclusions. These difficulties highlight the need for improved instructional strategies and curriculum development to strengthen students' reasoning abilities.

Thus, this study aims to further investigate the mathematical reasoning skills of twelfth-grade students at SMA Negeri 1 Belinyu in the context of three-dimensional geometry. By identifying specific areas of difficulty, the research seeks to provide insights that can inform educational practices, instructional

designs, and pedagogical approaches to enhance students' reasoning abilities in mathematics. However, while prior studies have explored general reasoning difficulties, few have specifically investigated how students at the high school level engage with reasoning tasks in three-dimensional geometry. This study addresses this gap.

Method

This study employs a descriptive research design, which aims to collect information about an existing phenomenon by examining its current state during the research process. Descriptive research is a fact-finding study designed to systematically, factually, and accurately describe, illustrate, or portray a phenomenon (Sugiyono, 2021). The approach used in this study is quantitative, allowing for objective measurement and analysis of the observed variables. This research seeks to describe and analyze students' mathematical reasoning abilities, focusing on written reasoning skills, which are assessed through written test results based on specific mathematical reasoning indicators. These indicators include presenting mathematical statements orally, in written form, and through diagrams; identifying patterns or methods in mathematical phenomena to formulate generalizations; constructing proofs and providing justifications or evidence for the validity of solutions; and drawing conclusions from given statements.

The study was conducted at SMA Negeri 1 Belinyu during the 2023/2024 academic year (second semester), involving 30 students from Grade XII. 2 as research subjects. The research procedure consisted of several stages, beginning with preliminary activities followed by the development of mathematical reasoning test items, validation of test items, and analysis of validation results. The test instrument underwent content validation through expert judgment, using the Gregory formula, and was found to be valid. Reliability was assessed using Cronbach’s Alpha, with a value of 0.76, indicating acceptable internal consistency. The next steps included conducting the study, collecting test data, analyzing the test results, and drawing conclusions. This structured methodology ensures that the study systematically examines students' reasoning abilities and provides objective, data-driven insights into their mathematical understanding.

Results and Discussion

The study titled was conducted at SMA Negeri 1 Belinyu during the 2023/2024 academic year in the even semester. This research aimed to examine the mathematical reasoning ability of 12th-grade students. The class selected as

the research subject was Grade XII.2, consisting of 30 students, with 11 male and 19 female students.

Prior to conducting the study, the researcher first developed a test instrument that aligned with the mathematical reasoning indicators used in the study. The test instrument was then validated by 3 experts, including 2 lecturers from Universitas PGRI Palembang and mathematics teacher at SMA Negeri 1 Belinyu. The validation results indicated that the test instrument was aligned with the subject matter being studied and met the criteria for mathematical reasoning ability indicators, making it suitable for use in the study.

Once the instrument was deemed appropriate by experts, it was piloted with 20 students from Grade XII.1 at SMA Negeri 1 Belinyu. Following the pilot test, validity testing, reliability testing, difficulty level analysis, discrimination index analysis, and descriptive statistical calculations (including mean, median, mode, and standard deviation) were conducted. Based on the results of the pilot study, five valid test questions were determined to be suitable for use as the research instrument.

The descriptive statistical results of students' mathematical reasoning ability can be seen in Table 1.

Table 1
Descriptive Statistical Results of Students' Mathematical Reasoning Ability

Statistic	Score
Number of Students	30
Total Score	1414.05
Mean	48.03
Median	47.50
Mode	47.50
Minimum Score	28.10
Maximum Score	75.00
Standard Deviation	9.73

From Table 1, it is observed that, in general, the mathematical reasoning ability of Grade XII MIPA 2 students at SMA Negeri 1 Belinyu falls into the moderate category, with an average percentage score of 48.03. The results of the mathematical reasoning ability test, based on the indicators of mathematical reasoning ability, yielded data as presented in Table 2.

Table 2
Percentage of Students' Mathematical Reasoning Ability Scores

No.	Indicator	Percentage (%)	Category
1	Presenting mathematical statements verbally, in writing, and through diagrams	65,83	Good
2	Identifying patterns or methods from mathematical phenomena to formulate generalizations	38,33	Poor
3	Constructing proofs and providing justification or evidence for the validity of a solution	61,39	Good
4	Drawing conclusions from statements	16,39	Very Poor

Based on the data analysis results, the achievement of each mathematical reasoning ability indicator in the three-dimensional geometry topic shows that students' mathematical reasoning ability in this topic is categorized as moderate, with an overall average score of 47.14. These findings are consistent with the study conducted by Wahyuni et al. (2019), which also reported an average moderate level of mathematical reasoning ability.

The discussion on the analysis results will be elaborated based on the achievement of each mathematical reasoning ability indicator, as follows:

Indicator 1: Presenting Mathematical Statements in Writing and Diagrams

This indicator was applied to all test questions in the study, with an achieved percentage score of 65.83, placing it in the good category. Students' reasoning processes were evident in their responses, as they successfully presented three-dimensional geometric figures, such as a cube in questions 1, 3, and 4, a rectangular prism in question 2, and a triangular pyramid in question 5. The diagrams were accurately drawn according to the given information and the problem requirements.

These findings align with the study conducted by Hidayati and Widodo (2015), which indicated that students with high mathematical ability could comprehend problems effectively. This was evident in their ability to clearly outline the given information and the required solution, both orally and in writing, in accordance with the problem statement.

However, some students provided incorrect answers. Based on test results and interviews, this was due to a lack of understanding of the problem, leading to incorrect solutions. Some students struggled to present mathematical statements through diagrams as instructed by the problem. Additionally, their diagrams lacked a systematic step-by-step construction process (Ilmi & Wulandari, 2022; Islamiati & Zulkarnaen, 2022).

Indicator 2: Identifying Patterns or Methods for Generalization.

This indicator was applied to every test question in the study, with an achieved percentage score of 38.33, placing it in the low category. This indicator assesses students' ability to identify patterns or methods to develop generalizations and explain the patterns used to solve mathematical problems. Based on the findings, students generally struggled with reasoning in this indicator. Test results and interviews revealed that most students had difficulty formulating explanations for their problem-solving processes and lacked a clear understanding of the material. This finding is consistent with the study by (Bal & Or, 2023) which showed that students often misinterpreted the problem, leading to incorrect solutions.

The researcher also found that many students did not write down the step-by-step process for mathematical generalization, making it impossible to assess their performance on this indicator. However, from a mathematical problem-solving perspective, skipping certain steps does not necessarily indicate a lack of understanding. This omission contributed to the low average percentage score for this indicator.

Indicator 3: Constructing Proofs for the Validity of Solutions.

This indicator was applied to test questions 1, 3, and 4, with an achieved percentage score of 61.39, placing it in the good category. This indicator assesses students' ability to construct proofs to validate their solutions, particularly as a continuation of the generalization process from the previous indicator. Based on students' responses, their reasoning processes were generally evident, and most students were able to structure their solutions correctly and accurately.

Students with high mathematical ability are capable of estimating the solution process effectively by formulating structured steps for problem-solving. The ability to construct proofs and provide justifications for the correctness of a solution is essential in determining whether students' answers are accurate and aligned with their reasoning skills. This finding is also consistent with the research by (Ellu et al., 2022), which indicated that students' responses to proof-based questions often lacked completeness and clarity. Similarly, (Price et al., 2021) emphasized that the process of estimating a solution and providing explanations supports the formulation of a well-structured problem-solving plan.

Indicator 4: Drawing Conclusions.

Based on test results and interviews, it was found that most students did not formulate conclusions, as some students were unable to complete their responses, and many lacked understandings of the material. This indicator, which involves drawing conclusions from statements, was assessed through test

questions 1, 3, and 4, with an average achievement score of 16.39, placing it in the very poor category. In this indicator, students were expected to formulate conclusions based on the validity of the solution proofs established in the previous indicator. The reasoning process for this indicator was evident in students who successfully wrote conclusions from their problem-solving steps.

The data indicated that most students did not draw conclusions from their solution validation process, leading to a low score in this reasoning ability indicator. This finding aligns with the study by (Ilmi, 2021), which noted that students with low mathematical ability struggle to draw logical conclusions. Additionally, most students did not provide responses in this indicator, as they did not pay attention to the structured arguments or had errors in their problem-solving process. This aligns with (Islamiati & Zulkarnaen, 2022) that students should be able to draw conclusions from given statements and verify the validity of arguments.

Conclussion

Based on the research conducted at SMAN 1 Belinyu, the findings indicate that the mathematical reasoning ability of Grade XII.2 students in solving mathematical problems related to three-dimensional geometry achieved an average percentage score of 47.14, which falls into the moderate category. The percentage scores for each indicator vary, with the highest score of 65.83 in the indicator of presenting mathematical statements verbally, in writing, and through diagrams, placing it in the good category. The indicator of identifying patterns or methods from mathematical phenomena to formulate generalizations scored 38.33, which is categorized as low. Meanwhile, the indicator of constructing proofs and providing justification or evidence for the validity of a solution obtained a score of 61.39, also categorized as good. However, the lowest score was recorded for the indicator of drawing conclusions from statements, with a percentage of 16.39, placing it in the very poor category. The low performance in drawing conclusions may indicate that students struggle to synthesize information across steps in problem-solving. This suggests that instruction should not only focus on procedural skills but also on metacognitive reflection and reasoning.

To improve students' mathematical reasoning abilities, particularly in identifying patterns and drawing conclusions, teachers can implement learning strategies that encourage problem-solving discussions, guided practice, and inquiry-based learning. Providing more structured exercises that emphasize the importance of step-by-step reasoning and conclusion formulation can help students develop a deeper understanding of mathematical concepts. Additionally,

integrating real-world applications of mathematical reasoning and using interactive teaching methods, such as group discussions and hands-on activities, may enhance student engagement and comprehension. Regular formative assessments and personalized feedback can also support students in strengthening their reasoning skills over time.

Declarations

Author contribution. SA and H conducted the literature review, developed the instruments, and performed the validation. H collected the data. SA and H analyzed the data. SA wrote the article.
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