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Analysis of High School Students' Reasoning Ability in Solving Higher Order Thinking Skill Type Mathematics Problems

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Abstract

This study investigates the mathematical reasoning abilities of high school students in North Sumatra who participated in the Del Mathematics and Science Competition (DMSC). Prior studies have revealed that students' reasoning abilities are generally low; however, limited attention has been paid to their performance in competition-based settings. The purpose of this study is to assess the mathematical reasoning skills of students through higher-order thinking problems adapted from National Science Olympiad (OSN) materials. This research employed a qualitative descriptive method. The participants consisted of 25 high school students who reached the final round of the DMSC. The instrument used was a written mathematical reasoning test consisting of five essay questions. Students' responses were analyzed using descriptive statistics, including mean scores and percentage values based on established scoring rubrics. The results showed that 18 students were categorized as having low reasoning ability and 7 students had a moderate level. The average reasoning score was 63.84%, which falls into the low category. Although students could perform calculations, most of them struggled with argument validation and logical explanation. The findings emphasize the necessity for educators to develop instructional strategies that foster students' mathematical reasoning, particularly through approaches that stimulate higher-order thinking skills.

Keywords: mathematical reasoning, high school students, descriptive statistics, DMSC, problem solving

1. Introduction

Mathematics is a core discipline that plays a crucial role in cultivating systematic, logical, and precise thinking (Muliyana et al., 2024). According to Sugandi et al., (2021) the objective of mathematics education is to foster thinking skills, promote the usefulness of mathematics, and encourage self-confidence and open-mindedness in facing future challenges. Thus, it is essential for every student to have equal opportunities and support in acquiring a profound understanding of mathematical concepts (Fadli & Supratman, 2024; Graham & Fennell, 2001). Understanding mathematical material requires reasoning, while the development and refinement of reasoning skills is facilitated by mathematical knowledge (Bayramov et al., 2024).

Reasoning plays a central role in the learning process of mathematics not only as a means to solve problems but also as a learning goal in itself (Falbiansyah & Pujiastuti, 2021). The acquisition of mathematical knowledge must aim to develop students' problem-solving and reasoning skills. The ability of students to make logical decisions is called mathematical reasoning (Nurazizah & Zulkardi, 2022; Zubainur et al., 2020). The interdependence between mathematical material and mathematical reasoning is a fundamental aspect in mathematics education (Manik & Surya, 2020; Serli Evidiasari, Subanji, 2019; Yanti et al., 2023). This implies that the understanding of mathematical information depends on the application of reasoning, while the development and improvement of reasoning skills are facilitated through the process of learning mathematics (Ministry of Education, 2003). Students with good mathematical reasoning skills will find it easier to understand problems and relate the concepts contained in them (Hasanah et al., 2024; Konita et al., 2019).

However, despite this theoretical importance, many empirical studies report that students' reasoning abilities remain low. For instance, (Sari & Putri, 2021; Wulandari & Machromah, 2024). Ariyanto et al. (2023) documented that the mathematics learning ability of Indonesian children is still lacking. Sofyana & Kusuma (2018) also stated that students still have difficulties in reviewing or analyzing questions. In addition, research conducted by Citra et al. (2021) shows that students' mathematical reasoning ability is still low with a reasoning domain of 3%, as seen from the results of the Final Semester Assessment (PAS) 1 in grade XII students of MAN Se-Bekasi (Citra et al., 2021). The results of observations and interviews conducted by Izzah & Azizah (2019) at SD Negeri Tambakrejo 01 Semarang also showed that. Similar concerns were also identified by Nainggolan et al., (2022), who found that students participating in the Del Mathematics and Science Competition still experienced difficulties in connecting mathematical ideas, especially among those with sensing personality types who tend to process data literally and struggle to form abstract conceptual relationships.

This condition presents a significant concern in mathematics education, particularly when students are required to solve HOTS-type problems, which demand logical reasoning, strategic problem-solving, and the ability to derive conclusions based on available information. Evaluating reasoning ability, therefore, becomes essential to measure the extent to which students have internalized higher-order thinking skills and to identify areas in need of pedagogical improvement.

One relevant context for assessing students' reasoning skills is through academic competitions such as the Del Mathematics and Science Competition (DMSC). Organized by Institut Teknologi Del, DMSC is an academic competition that attracts top-performing students

from various schools. The competition is designed to evaluate students' critical and logical thinking abilities through HOTS-based mathematical problems. As such, this event serves as a diagnostic platform for identifying students' reasoning competencies in an authentic and competitive setting.

DMSC challenges students not only to arrive at correct answers but also to demonstrate understanding, formulate structured solutions, and communicate their problem-solving process in a logical and coherent manner. This competition provides valuable insights for educators regarding students' preparedness in dealing with complex, non-routine problems and offers a real-world context in which reasoning abilities can be observed and assessed

Based on the issues described above, this study aims to analyze the mathematical reasoning abilities of high school students in solving higher-order thinking skill (HOTS) type mathematical problems, particularly within the context of the Del Mathematics and Science Competition (DMSC). The findings of this study are expected to provide a comprehensive overview of students' reasoning patterns and serve as a foundation for designing more effective instructional strategies aimed at enhancing mathematical reasoning. Furthermore, the study is intended to encourage educators and policymakers to place greater emphasis on the development of higher-order thinking skills within the mathematics curriculum and instructional practices.

2. Methods

This research was conducted in November 2024 with the aim of identifying and analyzing students' mathematical reasoning abilities during the Del Mathematics and Science Competition (DMSC). A qualitative research design was adopted, allowing for a detailed exploration of student responses and performance.

The DMSC involved high schools across North Sumatra, with a total of 463 registrants. This study focused specifically on the mathematics track, analyzing data from the 25 students who advanced to the final round after initial selection from 160 semifinalists.

The research instrument was a mathematical reasoning test consisting of five open-ended questions adapted from OSN (National Science Olympiad) problems. The test aimed to measure students' ability to reason mathematically across multiple dimensions.

Although the reasoning test was not piloted with students due to time limitations, the five essay questions adapted from National Science Olympiad (OSN) problems underwent a content validation process by two mathematics lecturers from Institut Teknologi Del. This review was conducted to ensure that the items measured the intended mathematical reasoning indicators and were appropriate for high school students.

The validation focused on three aspects: content relevance, language clarity, and the alignment of cognitive demand with higher-order thinking skills (HOTS). As a result of the expert feedback, several adjustments were made to adapt the questions to the students' level, simplify technical terminology, and improve the logical structure of the problems.

This expert validation approach aligns with research practices in recent mathematics education studies (Wulandari & Machromah, 2024), which emphasize the importance of expert judgment when constructing instruments intended to assess abstract reasoning skills.

Data were analyzed using descriptive statistics, including the calculation of mean scores and percentages. The use of percentages aims to evaluate the level of reasoning ability, adopting calculations based on formulas proposed by experts (Rohana et al., 2021)

$$KP = \frac{Score\ obtained}{M\ aximum\ score} \times\ 100\%$$

With

KP = percentage of mathematical reasoning ability

Reasoning abilities were evaluated based on four indicators Berkle et al., (2023) as presented in Table 1.

Table 1.
Reasoning Indicator

Reasoning	Indicator
Formulating evidence for the correctness of a solution	Students can provide reasons or evidence for the correctness of a solution, particularly through investigation
Examining the validity of an argument	Students can investigate the truth of a given statement.
Drawing conclusions from statements	Students can utilize their thinking processes and apply their knowledge to generate coherent reasoning.
Performing mathematical manipulations	Students can solve a problem using various methods to achieve the desired objective.

The classification of students' reasoning ability was adapted from Rosydah et al.,(2021) as shown in Table 2.

Table 2.
The Classification of Students' Reasoning

Percentage Achievement	Category
$KP \geq 90{,}4$	High
$69{,}6 \leq KP \leq 90{,}4$	Medium
$KP < 69{,}6$	Low

Student responses were scored using the rubric developed by Asoraya & Ruli (2023), as shown in Table 3.

Table 3.
Reasoning Assessment Rubric

Score	Criteria
5	Perfect answer with systematic and correct reasoning process completed
4	Provides an answer by solving the problem with minor errors
3	Provides an answer by solving the problem but with inaccuracies.
2	Provides an answer but does not successfully solve the problem
1	Lists all the information from the problem without providing a solution
0	No solution provided

3. Result and Discussion

3.1 Result

From the results of the written test for 25 students who participated in the Olympiad in the form of a mathematical reasoning ability test instrument, there were 5 description questions. The results of this study are data obtained from the analysis of student answers based on the reference of the scoring category of mathematical reasoning ability according to Asoraya & Ruli (2023),

Tabel 4.
Results of Mathematical Reasoning

o	Student Code	Total Score	Percentage	Reasoning Clasification
	S1	15	60	Low
	S2	18	72	Medium
	S3	14	56	Low
	S4	16	64	Low
	S5	16	64	Low
	S6	19	76	Medium
	S7	11	44	Low
	S8	11	44	Low
	S9	20	80	Medium
	S10	13	52	Low
0				

1	S11	15	60	Low
2	S12	16	64	Low
3	S13	13	52	Low
4	S14	14	56	Low
5	S15	16	64	Low
6	S16	21	84	Medium
7	S17	15	60	Low
8	S18	20	80	Medium
9	S19	19	76	Medium
0	S20	14	56	Low
1	S21	21	84	Medium
2	S22	22	88	Medium
3	S23	13	52	Low
4	S24	14	56	Low
5	S25	13	52	Low
	Average	**15.96**	**63.84**	**Low**

The table above shows that of the 25 students who took part in DMSC, there were 7 students who had reasoning skills with a medium category, and 18 students with reasoning skills with a low category. Overall, the average ability of students who follow the DMSC is 63.84 which is relatively low, based on the classification criteria presented in Table 2, where scores below 69.6% fall into the low reasoning ability category.

3.2 Discussion

Based on the data listed in the table, it can be concluded that the mathematical reasoning ability of the 25 selected students from North Sumatra is relatively low. This is shown by the average score of 63.84, which according to the classification table, falls into the low category.

Furthermore, 7 students were classified into the medium category, with the highest reasoning score reaching 88. This indicates that only a minority of the participants were able to solve problems by providing answers with minor errors, while the majority (18 students) remained in category 3, where answers were given by solving the problem but not precisely.

These findings are in line with the study of Gustiadi et al., (2021) and Cahyani & Sritresna (2023), which revealed that many students can perform basic mathematical operations, but still make mistakes in precision and logical structuring, especially when validating arguments or drawing conclusions. Similarly, Zahra Nur Shafira et al. (2023) emphasize that a significant portion of students fall into the third level of reasoning performance, where solutions are attempted, but reasoning steps are not coherent or systematic.

This study also echoes Permatasari & Marlina (2022), who found that students with low reasoning ability tend to give partially correct answers without considering the validity of their solution steps. Hidayat & Pujiastuti (2019) also note that most students do not habitually recheck their solutions, which further contributes to inaccuracy.

Thus, this study reinforces the conclusion that students' average performance corresponds to category 3 reasoning, which includes answering by solving calculation problems but with inaccuracies. This is reflected in their limited ability to compile valid evidence, verify arguments, and reach justified conclusions. Hence, efforts are needed from teachers especially those with strong content knowledge to help students develop logical and systematic argumentation, as supported by Vygotsky's theory of learning, which emphasizes the role of interaction with more knowledgeable others in advancing cognitive abilities.

In light of this, educators are encouraged to adopt learning strategies that stimulate students' reasoning ability, such as student-centered learning, problem-based learning, or the use of interactive learning media designed to promote mathematical thinking and logical coherence.

One limitation of this study lies in the number of essay questions used to assess students' reasoning abilities, which was limited to five. This choice was based on the consideration that each question was designed to measure different dimensions of higher-order thinking skills such as logical reasoning, argument validation, and conclusion drawing within a limited time frame. Using fewer but more cognitively demanding items allowed for a deeper exploration of students' reasoning processes without causing test fatigue. Although formal empirical validation procedures such as pilot testing and statistical analysis were not conducted due to time constraints, the test items were developed based on established materials from the National Science Olympiad (OSN), which are known for their rigor and alignment with reasoning objectives. In addition, the test was reviewed by mathematics educators and competition mentors to ensure content validity. Nonetheless, future research should consider increasing the number of items and incorporating formal validation techniques to enhance the reliability and generalizability of the findings.

4. Conclusion

The findings of this study reveal that the mathematical reasoning abilities of high school students participating in the DMSC are predominantly low. With only 28% of students scoring in the medium category, and an average score of 63.84%, the results highlight the urgent need for pedagogical reforms aimed at enhancing reasoning skills. Students particularly require support in constructing logical arguments and validating solutions. For instance, based on student responses, many participants demonstrated the ability to carry out algebraic manipulations correctly but struggled to provide justification for their answers or explain the reasoning behind each step. One example is a student who arrived at the correct final result through computation but left the reasoning section blank, indicating a lack of emphasis on argument construction. This discrepancy suggests that students may be more familiar with procedural techniques than conceptual understanding, possibly reflecting classroom instructional practices that prioritize computation over reasoning. Implementing student-centered instructional methods that encourage critical thinking and problem-solving is therefore essential for fostering higher-level reasoning in mathematics education.

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