ANALYSIS OF STUDENTS' MATHEMATICAL REASONING ABILITIES ON MATRIX MATERIAL AT SENIOR HIGH SCHOOL

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Article Info	ABSTRACT
	The objective of this study is to describe the mathematical reasoning abilities of eleventh-grade students at public senior high school 1 Limboto, focusing on matrix material. This type of research employs quantitative methods and descriptive approaches. The subjects of the research consisted of 30 students from grade XI (IPA 1). Data collection was conducted through tests designed to measure various indicators of mathematical reasoning abilities. The results indicated that, overall, students' mathematical reasoning abilities fell into the moderate category, with a percentage of 69.33%. Further analysis based on the reasoning indicators revealed varied results: the ability to write mathematical statements was categorized as moderate (82.22%); the ability to perform manipulations was categorized as high (86.67%); the ability to find patterns in mathematical phenomena was moderate (74.67%); and the ability to draw conclusions from solutions was categorized as very low (39.26%). These findings highlight the need for greater attention to drawing conclusions in the learning process so that students can enhance their overall mathematical reasoning abilities.

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1. INTRODUCTION

Mathematics is one of the most important fields of knowledge (Dindyal et al., 2021). This is evidenced by its status as a mandatory subject for students at every educational level. Mathematics is a language and activity for problem-solving and studying patterns and relationships—not just calculations. Moreover, mathematics plays a crucial role in our daily lives and in the workplace, supporting the development of science and technology (Szabo et al., 2020; Bakker et al., 2021). Therefore, it is essential for students to master mathematics as a foundational science, and it should be taught, especially from an early age.

Having a strong understanding of mathematics from an early age or while still in elementary school can make it easier to learn it at a higher level (Clements & Sarama, 2020; Ibrahim et al., 2022). As stated by Maass et al. (2019); Malanua et al. (2024),

mathematics learning plays an important role in the development of human thinking abilities.

The importance of mathematics is not fully recognized by some students. Many still view mathematics as a difficult subject to learn, which negatively impacts their academic performance (Banerjee, 2016; Taha et al., 2022). It is certainly a challenge for a teacher to make the learning process enjoyable and to help students overcome their fear and interest in mathematics (Pauweni et al., 2022). Studying mathematics requires thinking skills that emphasize activities in the realm of reasoning. This aligns with the goals of mathematics education in schools, which prioritize the organization of students' reasoning and the development of their attitudes and skills in applying mathematics (Une et al., 2022). Mathematics and reasoning are closely related concepts. Understanding mathematical material necessitates a reasoning process, while reasoning can be developed through studying mathematics.

Mathematical reasoning ability is a primary objective in mathematics education (Smit et al., 2017; Muzaini et al., 2021). To achieve optimal learning outcomes, students need strong mathematical reasoning skills. Enhancing students' reasoning abilities during the learning process is crucial for success (Mukuka et al., 2021; Supriadi & Suherman, 2024). The higher the level of reasoning that students possess, the faster the learning process accelerates toward achieving educational indicators.

Solving mathematical problems requires more than just memorising formulas; it demands reasoning to connect existing knowledge and draw conclusions (Tambychik & Meerah, 2010; Jonsson et al., 2020). Mathematics reasoning is crucial to studying mathematical concepts. If students do not effectively develop their reasoning skills during the mathematics learning process, they may resort to merely memorising formulas and following existing examples without understanding their meaning. As a result, students often struggle to find solutions when faced with various problems (Jiang et al., 2021; Olsson & Granberg, 2024).

The preliminary study, conducted with mathematics teachers and students at public senior high school 1 Limboto Barat, revealed that students' reasoning abilities in mathematics remain low. One mathematics teacher explained that approximately 55%–60% of eleventh-grade students scored below 80, which is below the "Minimum Completeness Criteria" established by the school. The low academic performance in mathematics is partly influenced by students' inadequate understanding and application of concepts when reasoning through mathematical problems. When it comes to reasoning questions, students still find it difficult to solve problems when the questions do not align with the examples they have been taught. Some students even have difficulty understanding the given questions. This leads many students to opt for waiting for their peers' answers rather than attempting the problems themselves. Factors contributing to the low mathematical reasoning abilities may stem from the students themselves, the teachers, or the quality of the instruction (Yunus et al., 2020; Rohati et al., 2023; Supriadi & Suherman, 2024).

Based on the description and preliminary study provided above, the purpose of this study is to describe the mathematical reasoning abilities that are focused on the matrix material.

2. METHOD

This is quantitative research with descriptive methods. Descriptive research aims to investigate the state, condition, or other specified aspects, with the results presented in the form of a report. The goal of this research is to explain the mathematical reasoning abilities of eleventh-grade students, supported by the data collected, thereby strengthening the analysis for drawing conclusions. The subjects of this study are 30 students from class XI IPA 1 at public senior high school 1 Limboto Barat, with varying abilities.

The data collection procedure in this study was conducted through testing. The researcher collected data using test techniques, which involved administering a set of questions to gather information about students' abilities, particularly in mathematical reasoning. In this research, the researcher used tests to measure students' mathematical reasoning skills when solving mathematical problems.

The data analysis technique used in this study is descriptive analysis. In this research, the data obtained from students' mathematics understanding tests is analyzed in terms of percentages using the following criteria, as presented in Table 1.

Table 1. Criteria for Assessing Mathematics Understanding

Percentage (%)	Category
$86 \leq P \leq 100$	Very High
$76 \leq P < 86$	High
$60 \leq P < 76$	Moderate
$55 \leq P < 60$	Low
$P < 55$	Very Low

3. RESULTS AND DISCUSSION

This study aims to describe the mathematical reasoning abilities of eleventh-grade students at public senior high school 1 Limboto, focusing on matrix material. This study focuses on the data collected from students in grade XI IPA 1 who completed a mathematical reasoning ability test related to matrix material, which includes four achievement indicators: writing mathematical statements, performing manipulations, finding patterns in mathematical phenomena, and drawing conclusions from solutions. The research findings from the mathematical reasoning ability test instruments for each reasoning indicator in Table 2 are presented below.

Table 2. Percentage of Students' Mathematical Reasoning Abilities for Each Reasoning Indicator

Indicator	Percentage (%)	Category
Writing Mathematical Statements	82,22	High
Performing Manipulations	86,67	High
Finding Patterns in Mathematical Phenomena	74,67	Moderate
Drawing Conclusions from Solutions	39,26	Very Low

The results of the students' mathematical reasoning tests are summarized in Table 3 below.

Table 3. Percentage of Students' Mathematical Reasoning

Category	Number of Students	Percentage (%)
Very High	3	10
High	2	6,67
Moderate	20	66,67
Low	1	3,33
Very Low	4	13,33

Indicator I : Writing Mathematical Statements

The students' ability to write mathematical statements, as intended in this study, refers to their capacity to present or express mathematical statements using mathematical models or symbols from the given problems. The following results for the percentage of writing mathematical statements are presented in Table 4.

Table 4. Percentage of Writing Mathematical Statements

Category	Number of Students	Percentage (%)
Very High	14	47
High	0	0,00
Moderate	16	53,33
Low	0	0,00
Very Low	0	0,00

There are 14 students categorized as very high (47%) and 16 students categorized as moderate (53.33%), as presented in Table 4. Although some students fall into the high category for presenting mathematical statements in writing, many students still fall into the moderate category, indicating that their mathematical statements are often incomplete or incorrect when modeling mathematical statements from given problems. This finding aligns with Gustiadi et al. (2021), who state that while the average student has made efforts to work on problems correctly, there are still students who struggle with presenting mathematical statements, particularly in certain word problems.

Indicator II : Performing Manipulations

In this indicator, students demonstrate the ability to manipulate or work through problems in a skillful manner regarding the relationships between numbers and operational procedures, as presented in Table 5 below.

Table 5. Percentage of Performing Manipulations

Category	Number of Students	Percentage (%)
Very High	12	40
High	13	43,33
Moderate	4	13,33
Low	0	0,00
Very Low	1	3,33

Table 5 shows there are 12 students categorized as very high (40%), 13 students categorized as high (43.33%), 4 students categorized as moderate (13.33%), and 1 student categorized as very low (3.33%). Students are considered to meet this second indicator if they can model or translate the given data into mathematical form, specifically into matrices in this study (Lestari et al., 2022).

Indicator III : Finding Patterns in Mathematical Phenomena

The ability to find patterns in mathematical phenomena is referred to in this study, which maintains students' capacity to identify emerging patterns within data or mathematical structures and to understand the relationships between the elements involved. The results of the percentage finding patterns in mathematical phenomena are presented in Table 6 below.

Table 6. Percentage of Finding Patterns in Mathematical Phenomena

Category	Number of Students	Percentage (%)
Very High	6	20
High	7	23,33
Moderate	15	50
Low	0	0,00
Very Low	2	6,67

There are 6 students categorized as very high (20%), 7 students categorized as high (23.33%), 15 students categorized as moderate (50%), and 2 students categorized as very low (6.67%), as presented in Table 6. The results of the indicator III test showed that many students still struggled to estimate answers correctly, but a significant number were also capable of identifying and presenting the solution process for the problems. Students needed to use specific matrix formulas to solve the problems, but some still made errors in performing matrix operations such as addition, subtraction, and multiplication (Khairani & Gustianingrum, 2021; Mareta et al., 2021).

Indicator IV : Drawing Conclusions from Solutions

Drawing mathematical conclusions refers to the ability of students to make or derive conclusions from a given mathematical question. Below are presented the results of the percentage of drawing conclusions from solutions in Table 7.

Table 7. Percentage of Drawing Conclusions from Solutions

Category	Number of Students	Percentage (%)
Very High	2	7
High	1	3,33
Moderate	1	3,33
Low	4	13,33
Very Low	22	73,33

As presented in Table 7, there are 2 students categorized as very high (7%), 1 student categorized as high (3.33%), 1 student categorized as moderate (3.33%), 4 students categorized as low (13.33%), and 22 students categorized as very low (73.33%). This is due to many students still being unable to draw conclusions related to matrix solutions, resulting in a very low categorization. The ability to draw conclusions from the relationship between two variables, as well as the ability to conclude based on proportions, can be summarized (Utami & Haerudin, 2021).

This is evident from students' work, as many did not carry their answers through to completion and made errors in calculations. Calculating by indicator provides a clear picture of students' mathematical reasoning regarding matrix material. Students can solve mathematical reasoning problems and understand the questions, but some still struggle with accurately formulating their solutions (Anggraini et al., 2023; Olsson & Granberg, 2024; Säfström et al., 2024). Overall, students' mathematical reasoning abilities are still categorized as moderate, as evidenced by the percentages for each reasoning indicator. Based on the test results, several factors influence students' mathematical reasoning abilities, including difficulties in identifying problems, determining solutions, and drawing conclusions from the obtained solutions.

4. CONCLUSION

The conclusion of the study shows that students' mathematical reasoning abilities regarding matrix material at public senior high school 1 Limboto Barat are classified as moderate, with a percentage of 69.33%. The results of the mathematical reasoning tests, analyzed by each indicator, are as follows: the ability to write mathematical statements is categorized as moderate, with a percentage of 82.22%; the ability to perform manipulations is categorized as high, with a percentage of 86.67%; the ability to find patterns in mathematical phenomena is categorized as moderate, with a percentage of 74.67%; and the ability to draw conclusions from solutions is categorized as very low, with a percentage of 39.26%.

As a suggestion, the results of this study can be a reference for teachers in improving students' mathematical reasoning abilities. Furthermore, we recommend conducting further research on a larger scale, rather than solely focusing on one specific mathematical material.

REFERENCES

Anggraini, A., Syofiana, M., & Ramadianti, W. (2023). Analisis kemampuan penalaran matematis siswa berbasis masalah pada materi bilangan pecahan. *RANGE: Jurnal Pendidikan Matematika*, *4*(2), 267-277.

Bakker, A., Cai, J., & Zenger, L. (2021). Future themes of mathematics education research: An international survey before and during the pandemic. *Educational Studies in Mathematics*, *107*(1), 1-24.

Banerjee, P. A. (2016). A systematic review of factors linked to poor academic performance of disadvantaged students in science and maths in schools. *Cogent Education*, *3*(1), 1178441.

Clements, D. H., & Sarama, J. (2020). *Learning and teaching early math: The learning trajectories approach*. Routledge.

Dindyal, J., Schack, E. O., Choy, B. H., & Sherin, M. G. (2021). Exploring the terrains of mathematics teacher noticing. *ZDM–Mathematics Education*, *53*(1), 1-16.

Gustiadi, A., Agustyaningrum, N., & Hanggara, Y. (2021). Analisis Kemampuan Penalaran Matematis Siswa dalam Menyelesaikan Soal Materi Dimensi Tiga. *Jurnal Absis: Jurnal Pendidikan Matematika Dan Matematika*, *4*(1), 337-348.

Ibrahim, R. Y., Arsyad, A., & Katili, N. (2022). Analisis kesulitan pada materi operasi hitung bilangan pecahan kelas 5 sekolah dasar. *Laplace: Jurnal Pendidikan Matematika*, *5*(1), 12-18.

Jiang, R., Liu, R. D., Star, J., Zhen, R., Wang, J., Hong, W., ... & Fu, X. (2021). How mathematics anxiety affects students' inflexible perseverance in mathematics problem-solving: Examining the mediating role of cognitive reflection. *British Journal of Educational Psychology*, *91*(1), 237-260.

Jonsson, B., Granberg, C., & Lithner, J. (2020). Gaining mathematical understanding: The effects of creative mathematical reasoning and cognitive proficiency. *Frontiers in psychology*, *11*, 574366.

Khairani, B. P., & Gustianingrum, K. (2021). Analisis kesalahan siswa kelas XI SMA pada materi matriks. *Mosharafa: Jurnal Pendidikan Matematika*, *10*(3), 505-514.

Lestari, M., Subanji, S., & Irawati, S. (2022). Analisis Kemampuan Penalaran Matematis Siswa SMA pada Materi Matriks. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 11(1), 550.

Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *Zdm*, *51*, 869-884.

Malanua, M. K., Pomalato, S. W. D., & Damayanti, T. (2024). Kemampuan Literasi Matematika Siswa Dalam Menyelesaikan Soal Cerita Aljabar Ditinjau Dari Self Efficacy Matematika. *FIBONACCI: Jurnal Pendidikan Matematika dan Matematika*, *10*(1), 1-20.

Mareta, A., Sa'dijah, C., & Chandra, T. D. (2021). Analisis Kesalahan Siswa SMA dalam Menyelesaikan Soal Cerita Materi Matriks. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *5*(2), 1238-1248.

Mukuka, A., Mutarutinya, V., & Balimuttajjo, S. (2021). Mediating Effect of Self-Efficacy on the Relationship between Instruction and Students' Mathematical Reasoning. *Journal on Mathematics Education*, *12*(1), 73-92.

Muzaini, M., Hasbi, M., & Nasrun, N. (2021). The Role of Students' Quantitative Reasoning in Solving Mathematical Problems Based on Cognitive Style. *Vygotsky: Jurnal Pendidikan Matematika dan Matematika*, *3*(2), 87-98.

Pauweni, K. A., Uwange, D. I., Ismail, S., & Kobandaha, P. E. (2022). Peningkatan Hasil Belajar Siswa pada Materi Teorema Pythagoras Menggunakan Aplikasi Geogebra di

Kelas VIII SMP Negeri 15 Gorontalo. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *6*(3), 2660-2672.

Olsson, J., & Granberg, C. (2024). Teacher-student interaction supporting students' creative mathematical reasoning during problem solving using Scratch. *Mathematical Thinking and Learning*, *26*(3), 278-305.

Rohati, R., Kusumah, Y. S., & Kusnandi, K. (2023). Exploring students' mathematical reasoning behavior in junior high schools: A grounded theory. *Education Sciences*, *13*(3), 252.

Säfström, A. I., Lithner, J., Palm, T., Palmberg, B., Sidenvall, J., Andersson, C., ... & Granberg, C. (2024). Developing a diagnostic framework for primary and secondary students' reasoning difficulties during mathematical problem solving. *Educational Studies in Mathematics*, *115*(2), 125-149.

Smit, R., Bachmann, P., Blum, V., Birri, T., & Hess, K. (2017). Effects of a rubric for mathematical reasoning on teaching and learning in primary school. *Instructional science*, *45*, 603-622.

Supriadi, N., & Suherman, S. (2024). The role of learning anxiety and mathematical reasoning as predictor of promoting learning motivation: The mediating role of mathematical problem solving. *Thinking Skills and Creativity*, *52*, 101497.

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability*, *12*(23), 10113.

Taha, R., Badu, S. Q., & Arsyad, A. (2022). Meningkatkan Hasil Belajar Siswa Melalui Model Pembelajaran Kooperatif Tipe Team Assisted Individualization. *Jambura Journal of Mathematics Education*, *3*(2), 147-154.

Tambychik, T., & Meerah, T. S. M. (2010). Students' difficulties in mathematics problem-solving: What do they say?. *Procedia-Social and Behavioral Sciences*, *8*, 142-151.

Une, D. F., Hulukati, E., Ismail, Y., Abdullah, A. W., & Usman, K. (2022). Hubungan Antara Gaya Belajar Dengan Kemampuan Kognitif Matematika Pada Materi Lingkaran di SMP Negeri 2 Limboto. *Research in the Mathematical and Natural Sciences*, *1*(1), 54-60.

Utami, A. K. S., & Haerudin, H. (2021). Analisis kesulitan siswa dalam menyelesaikan soal kemampuan berfikir logis matematis. *ANARGYA: Jurnal Ilmiah Pendidikan Matematika*, *4*(1), 55-61.

Yunus, N. A., Hulukati, E., & Djakaria, I. (2020). Pengaruh pendekatan kontekstual terhadap kemampuan penalaran matematis ditinjau dari gaya kognitif peserta didik. *Jambura Journal of Mathematics*, *2*(1), 30-38.