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ANALYSIS OF STUDENTS' MATHEMATICAL REASONING DIFFICULTIES IN SOLVING SYSTEMS OF LINEAR EQUATIONS IN TWO VARIABLES

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ABSTRACT The purpose of this study was to describe students' mathematical reasoning difficulties in solving problems involving systems of linear equations in two variables. This research employed a mixed-methods design with an explanatory sequential approach. The participants were 31 eighth-grade students in Class VIII-C at SMP Negeri 14 Bandar Lampung. Data were collected through tests and interviews. The test, consisting of four essay-type questions, was administered to all 31 students, while interviews were conducted with two selected students. The instruments used included a written test and an interview guide. Data analysis was carried out in two stages: descriptive statistical analysis was used for the quantitative data, and the Miles and Huberman model (data reduction, data display, and conclusion drawing) was applied for the qualitative data. The results showed that the average percentage of students' mathematical reasoning difficulties was 54.91%. The stages with the highest levels of difficulty were performing mathematical manipulations (58.33%) and drawing conclusions (76.34%). The analysis revealed that students struggled with algebraic operations and basic calculations when solving systems of linear equations in two variables. Furthermore, the interviews indicated that some students failed to provide final answers either because they had difficulty interpreting the results within the problem context or simply forgot to write them down.

Keywords: mathematical reasoning, student difficulties, systems of linear equations in two variables, algebraic operations

ABSTRAK Tujuan penelitian ini adalah untuk mendeskripsikan kesulitan penalaran matematis siswa dalam menyelesaikan soal yang berkaitan dengan sistem persamaan linear dua variabel. Penelitian ini menggunakan metode campuran dengan pendekatan explanatory sequential design. Subjek penelitian adalah 31 siswa kelas VIII-C SMP Negeri 14 Bandar Lampung. Teknik pengumpulan data dilakukan melalui tes dan wawancara. Tes berupa empat soal uraian diberikan kepada seluruh siswa, sedangkan wawancara dilakukan terhadap dua siswa terpilih. Instrumen yang digunakan meliputi tes tertulis dan pedoman wawancara. Analisis data dilakukan dalam dua tahap, yaitu analisis statistik deskriptif untuk data kuantitatif dan model Miles & Huberman (reduksi data, penyajian data, dan penarikan kesimpulan) untuk data kualitatif. Hasil penelitian menunjukkan bahwa rata-rata persentase

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kesulitan penalaran matematis siswa adalah 54,91%. Tahapan dengan tingkat kesulitan tertinggi adalah melakukan manipulasi matematis (58,33%) dan menarik kesimpulan (76,34%). Analisis lebih lanjut mengungkapkan bahwa siswa mengalami kesulitan dalam operasi aljabar dan perhitungan dasar saat menyelesaikan sistem persamaan linear dua variabel. Selain itu, wawancara menunjukkan bahwa beberapa siswa tidak menuliskan jawaban akhir, baik karena kesulitan menafsirkan hasil perhitungan sesuai konteks soal maupun karena lupa menuliskannya.

Kata-kata kunci: penalaran matematis, kesulitan siswa, sistem persamaan linear dua variabel, operasi aljabar

INTRODUCTION

Mathematics is a universal discipline that has an important contribution in many fields, underlies the development of technology, and helps develop human thinking power logically (Khairani et al., 2023; Kotto et al., 2022). Mathematics learning is considered important because it can develop the ability to reason logically, critically, systematically, analytically, and creatively. In addition, it improves the ability to work together in overcoming various problems both in the learning environment and during the learning process (Gunur & Ramda, 2020; Khaeroh et al., 2020; Yusdiana & Hidayat, 2018). In mathematics learning, the focus is not only on mastering concepts and procedures, but also on honing essential skills and competencies (Lestari et al., 2024). NCTM (2000) defines the goals of mathematics learning as: (1) problem solving; (2) reasoning and proof; (3) communication; (4) connections; and (5) representation. One of the key abilities that can be optimized through mathematics learning is mathematical reasoning. Optimizing mathematical reasoning ability is a crucial factor in building a solid foundation for students in interpreting and mastering mathematics (Wati et al., 2024).

Mathematical reasoning refers to the ability to think in order to draw logical conclusions from mathematical problems based on given statements (Adiputra & Putri, 2022; Lestari et al., 2024). While this definition emphasizes the logical thinking process, the Technical Guidelines of the Directorate General of Primary and Secondary Education, Ministry of National Education Number 506/C/Kep/2004 provide a more operational perspective by outlining specific stages of mathematical reasoning: (a) presenting mathematical statements; (b) making conjectures; (c) performing mathematical manipulations; (d) compiling conclusions, proofs, and reasons for solutions; (e) confirming statements that have been presented; (f) checking the validity of an argument; and (g) identifying structures or characteristics of mathematical phenomena to formulate general conclusions (Alfionita & Hidayati, 2019; Ariati & Juandi, 2022; Atun & Wijayanti, 2020). These stages indicate that mathematical reasoning is not merely about producing an answer, but rather about engaging in a comprehensive process that demands critical evaluation at every step. Prior studies emphasize that developing reasoning skills is essential because it encourages students to move beyond memorization and engage in deeper mathematical understanding (Zannati et al., 2018). Nevertheless, findings in the field indicate that Indonesian students' mathematical reasoning abilities remain far below expectations, signaling a significant gap between curriculum goals and actual classroom practices.

According to the TIMSS 2015 report, Indonesia was ranked 44th out of 49 participating countries, with an average score of 397. Reasoning is one of the cognitive domains assessed in TIMSS (Hamzah et al., 2023). This indicates that the mathematical reasoning ability of Indonesian students is still weak. Consistent with this, several studies have also reported similar conditions. Research by Alfionita & Hidayati (2019), Farida et al. (2018), and Vebrian et al. (2021) showed that students' mathematical reasoning ability remains low, reflecting a persistent and widespread issue. Furthermore, Lestari et al. (2024) highlighted that students' difficulties are evident in their inability to achieve the stages of mathematical reasoning, especially when faced with tasks requiring higher-order thinking skills. These converging findings suggest that the challenge of mathematical reasoning is not an isolated problem but rather a systemic issue in mathematics education in Indonesia.

In this study, the term *difficulty* refers to obstacles or the inability of students to achieve certain stages of the mathematical reasoning process. Alfionita & Hidayati (2019) argue that students are considered to have adequate mathematical reasoning ability if they are able to meet these stages. However, many students experience difficulties when solving contextual problems that require reasoning. One of the mathematics topics that strongly demands reasoning ability is the system of linear equations in two variables (Rizqia et al., 2022). This topic is closely related to contextual problems where students must transform real-world situations into mathematical models. Solving such problems requires not only memorization but also the ability to interpret and reason mathematically. Studies by Fisher et al. (2019) and Widada et al. (2020) revealed that students' reasoning in this topic remains relatively low. Similarly, Yunita et al. (2024) reported that many students still face difficulties, especially with word problems. This condition highlights the need for further analysis of students' mathematical reasoning difficulties in solving problems involving systems of linear equations in two variables. On this basis, the present study aims to describe students' mathematical reasoning difficulties in addressing problems related to this topic.

METHODS

This study employed a mixed methods approach with an explanatory sequential design. This design combines quantitative and qualitative methods carried out in sequential stages, meaning that each method was implemented separately in two phases rather than simultaneously. The flow of the explanatory sequential design is illustrated in Figure 1 (Creswell & Creswell, 2018; Vebrianto et al., 2020).

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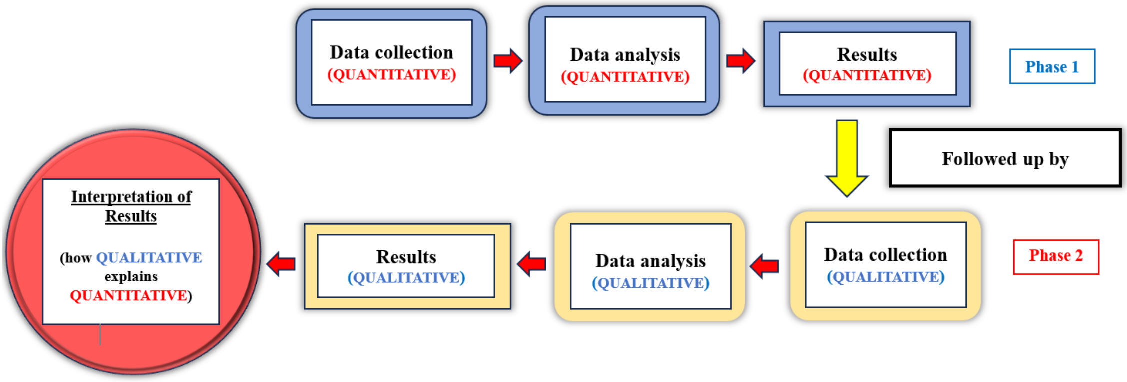

Figure 1. Explanatory sequential design

The research was conducted on November 22, 2024, at SMP Negeri 14 Bandar Lampung. The primary objective was to identify students' difficulties in mathematical reasoning when solving problems related to the system of linear equations in two variables. The subjects of the study were 31 eighth-grade students of class VIII C, from which four students were purposively selected to represent varying levels of difficulty in mathematical reasoning for follow-up interviews. Subject selection for interviews was carried out using criterion-based purposive sampling. The research procedure was divided into three stages: preparation, implementation, and data analysis.

Data collection techniques included written tests and interviews. The written test, consisting of four descriptive, context-based questions, was designed to assess students' mathematical reasoning processes when solving problems involving systems of linear equations in two variables. The interviews were conducted to obtain more in-depth information regarding students' reasoning difficulties and to triangulate findings from the test results (Lestari et al., 2024).

The data analysis procedure involved both quantitative and qualitative approaches. Quantitative data were analyzed using descriptive statistical analysis. From the test results, the percentages of students who succeeded and those who experienced difficulties at each stage of mathematical reasoning were calculated. Qualitative data were analyzed using the Miles and Huberman model, which includes three stages: data reduction, data display, and conclusion drawing (Lestari et al., 2024; Vebrianto et al., 2020).

Before administering the main test, an instrument trial was conducted to ensure that the items met the criteria of validity, reliability, discriminatory power, and difficulty level. The results of the instrument trial are presented in Table 1.

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Table 1. Recapitulation of Mathematical Reasoning Ability Test Instrument Trial (System of Linear Equations in Two Variables)

No.	Validity	Reliability	Discriminatory Power	Difficulty Level	Interpretation
1	Valid	0.92 (Reliable)	0.26 (Moderate)	0.69 (Medium)	Applied
2	Valid		0.71 (Very Good)	0.52 (Medium)	Applied
3	Valid		0.44 (Good)	0.54 (Medium)	Applied
4	Valid		0.44 (Good)	0.44 (Medium)	Applied

Based on the results in Table 1, all test items met the criteria and were deemed suitable for use in the study. The stages and indicators of mathematical reasoning ability assessed in this study are presented in Table 2.

Table 2. Stages and Indicators of Mathematical Reasoning Ability

No.	Reasoning Stage	Indicator
1	Presenting mathematical statements	Students can identify information in the problems; students can present problems in written and graphical form.
2	Making conjectures	Students can model problems using mathematical symbols; students can choose appropriate problem-solving strategies.
3	Performing mathematical manipulations	Students can solve problems by applying chosen strategies; students can solve problems logically and systematically using mathematical concepts.
4	Drawing conclusions	Students can review the steps of problem-solving; students can conclude results logically according to the context of the problem.

The stages and indicators used in this study were adapted from the Regulation of the Directorate General of Primary and Secondary Education No. 506/C/Kep/PP/2004. These indicators were selected because they encompass nearly all aspects of mathematical reasoning described in other frameworks, showing conceptual alignment across perspectives.

FINDING AND DISCUSSION

Based on the findings of this study, the results are presented to illustrate students' achievements and difficulties in mathematical reasoning when solving problems related to the system of linear equations in two variables. The data are summarized in the following table, which displays the percentage of students who successfully demonstrated reasoning skills as well as those who encountered difficulties at each stage of the reasoning process.

Table 3. Percentage of Achievement and Difficulty of Mathematical Reasoning Ability Stages

No.	Stages of Mathematical Reasoning	Persentage of Mathematical Reasoning Achievement	Percentage of Mathematical Reasoning Difficulty
1.	Presenting mathematical statements	49,73%	50,27%
2.	Make allegations	65,32%	34,68%
3.	Carry out mathematical manipulations	41,67%	58,33%
4.	Draw conclusions	23,66%	76,34%
	Average	45,09%	54,91%

Table 3 shows that the average percentage of students' mathematical reasoning achievement is 45.09%, while the percentage of difficulty is 54.91%. The highest achievement is in the stage of making conjectures (65.32%). The two stages with the lowest achievements are drawing conclusions (23.66%) and performing mathematical manipulations (41.67%). The low achievement in these two stages indicates that students still struggle to perform accurate calculations and to present conclusions that align with the initial problem.

As previously explained, difficulty in this study is interpreted as the difficulty or inability of students to achieve the stages in the mathematical reasoning process. The results of the study show that this difficulty occurs most often at the stage of performing mathematical manipulation and drawing conclusions, as will be discussed in the following analysis which will be shown by the results of student responses and interview findings.

Students' Difficulty to Perform Mathematical Manipulation

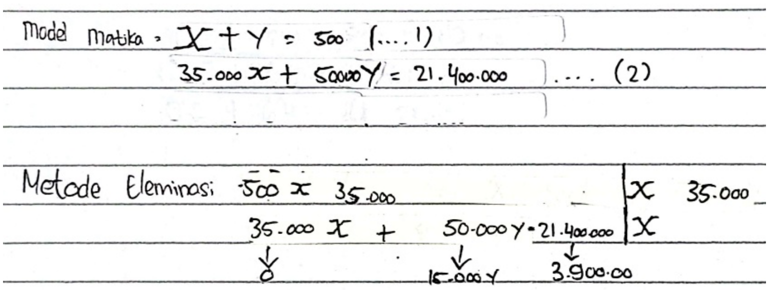

Figure 2. Aira's Answer Indicating Difficulty in Performing Mathematical Manipulation

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Based on Figure 2, it appears that Aira has been able to submit a correct conjecture by compiling two equations that are in line with the information in the problem, but had difficulty in carrying out mathematical manipulation, namely when applying the elimination method. Aira's error was seen when the student tried to use the elimination method by multiplying the first equation by 35,000 so that the variable x could be eliminated. However, during the calculation process, the student did not do it correctly. The student did not seem to rearrange the equations that had been multiplied systematically. This caused the elimination of the variable x not to be carried out correctly, so that the student could not achieve a valid final result. This error indicates that the student had difficulty in the mathematical manipulation stage, because he was unable to carry out the algebraic transformation correctly to solve the SPLDV. This can also be caused by a lack of understanding of basic concepts or procedural errors in arithmetic operations.

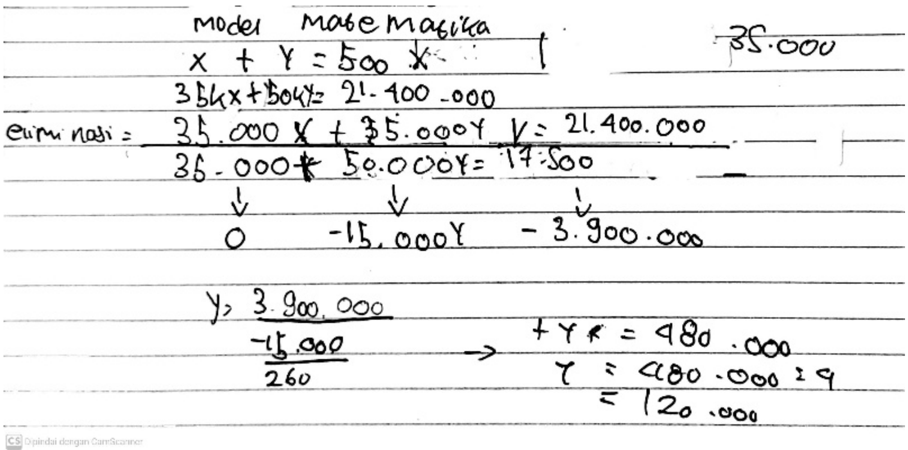

Figure 3. Haikal's Answer Indicating Difficulty in Performing Mathematical Manipulation

Based on Figure 3, it can be seen that Haikal has also been able to compile two equations that are in line with the information in the problem, but there were also errors in carrying out mathematical manipulation. The student used the elimination method to solve the SPLDV problem, but there were several errors in the calculation. The error occurred when the student multiplied the first equation by 35,000. The result obtained when multiplying the first equation by 35,000 should be 35,000x + 35,000y 17,500,000, but the student wrote 35,000x + 35,000y 21,400,000. This error makes the subsequent elimination steps invalid. The errors made by Haikal indicate that students still experience obstacles when carrying out mathematical manipulation, especially in algebraic operations and basic calculations in solving SPLDV.

The following is a snapshot of an interview between the interviewer and Aira, who experienced difficulty in performing mathematical manipulation.

Q: "When doing calculations, do you feel confused or have difficulty?"

A: "If there are difficulties, there will definitely be some, ma'am.

Q: "Where is the difficulty?"

A: "In the elimination section, ma'am."

Q: "Apart from the difficulty in the elimination part, is there also any difficulty in the ....counting process?"

A: "The counting part is quite difficult, but not as difficult as eliminating it, ma'am."

At this stage, most students make mistakes in algebraic operations, such as making mistakes in formulating equations, making mistakes in applying solution methods, and being less careful in basic calculations. These mistakes indicate that students do not fully understand the algebraic manipulation procedures needed to solve SPLDV problems. This finding is in line with the results of a study conducted by Suprihatin et al., (2018) which found that no students succeeded in meeting the indicators for performing mathematical manipulation when solving the problems given. The study stated that students could not carry out mathematical manipulation on contextual problems because the contents of the questions were not well understood by the students. A study conducted by Vebrian et al., (2021) also found that students' reasoning abilities at the stage of performing mathematical manipulation were very low. The study stated that students had difficulty in carrying out mathematical manipulation based on the information presented in the questions, either in the form of variables, images, or symbols.

Students' Difficulty to Draw Conclusions

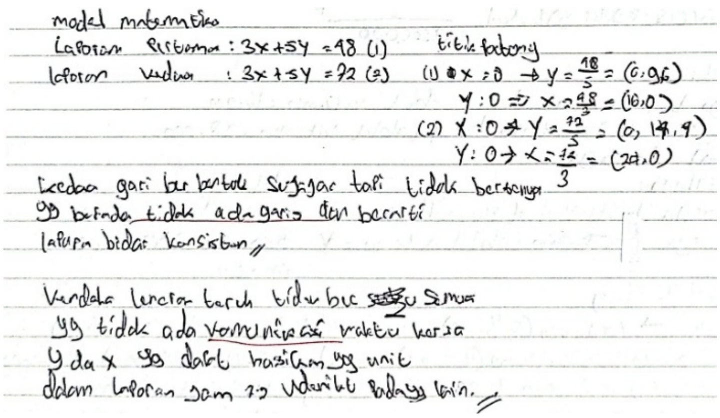

Figure 4. Hafiz's Answer Who Difficulty to Draw a Conclusion

Based on Figure 4, it can be seen that Hafiz has been able to make a conjecture by creating a mathematical model and is able to carry out mathematical manipulation by finding the intersection point with the coordinate axis for each equation correctly. However, it can be seen that the student had difficulty when drawing a conclusion. This can be seen from the conclusion written by Hafiz which appears very confusing and unclear. The student wrote a conclusion with sentences that are not mathematically relevant, such as "all. Which there is no communication working hours" which have no direct connection to the concept of the system of equations. This error indicates that the student has difficulty in interpreting the calculation

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results according to the context of the problem. Although the student has succeeded in determining the intersection point and recognizing that the lines are parallel, the student has not fully understood that this condition indicates a system of equations that has no solution.

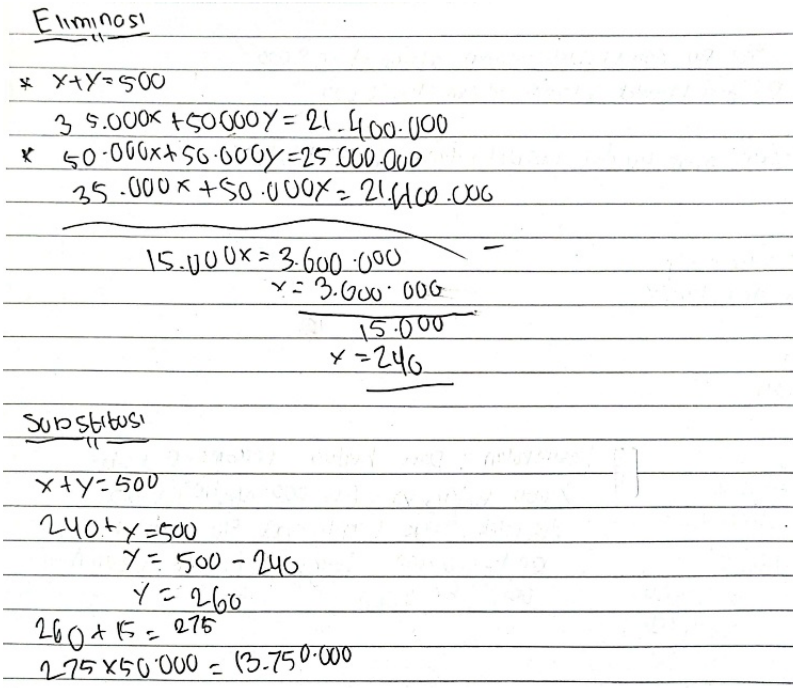

Figure 5. Iqbal's Answer Who Difficulty to Draw a Conclusion

Based on Figure 5, it can be seen that Iqbal has been able to propose conjectures and carry out mathematical manipulations correctly and systematically, but showed difficulty in reaching the stage of drawing conclusions. The student did not include a final conclusion in line with the results obtained. The absence of this conclusion indicates that Iqbal may not understand the importance of writing the final interpretation of the calculations that have been carried out or is not aware that a mathematical solution must end with a statement that answers the initial problem. This could also reveal that students focus more on the calculation procedure than the meaning of the final result, which is a crucial aspect of mathematical reasoning.

The following is an excerpt from an interview between a researcher and Iqbal, who experienced difficulty in drawing conclusions.

Q: "Do you think your answer is complete to the end or are there still stages?"

What's missing?"

A: "I think it's the end, ma'am."

Q: "So do you think it is necessary to write down the final conclusion of solving the problem?"

A: "Actually, it's necessary, ma'am, but I didn't write it down there, ma'am."

At this stage, the majority of students did not include the final answers derived from their calculations, while some others provided conclusions that were either unclear or inconsistent with the context of the problem. This situation indicates that students still experience difficulties in linking the results of their calculations to the answers required by the initial question. A limited understanding of the problem context also contributed to students' inability to interpret their calculation results as part of the solution to problems involving systems of linear equations in two variables.

This finding is consistent with Vebrian et al. (2021), who reported that among the various stages of mathematical reasoning, the stage of drawing conclusions was the weakest. Students often described only the steps of the solution without engaging in deeper analysis. Lestari et al. (2022) further noted that students sometimes failed to write conclusions due to time constraints. In the current study, interview results revealed that some students omitted conclusions because they either forgot or assumed that presenting the final calculation alone was sufficient as an answer.

Taken together, both the test results and interview findings highlight that many students encountered significant difficulties in achieving the stages of mathematical reasoning when solving problems related to systems of linear equations in two variables. The overall percentage of difficulties exceeded 50%, confirming that students' reasoning abilities remain underdeveloped (Alfionita & Hidayati, 2019). The most challenging stages were mathematical manipulation and drawing conclusions. Although some students managed to construct mathematical models that aligned with the given problems, they often struggled to perform accurate calculations and to interpret the meaning of the results within the problem's context.

Mathematical reasoning plays a pivotal role in helping students solve problems both within academic settings and in real-life situations. Therefore, strengthening mathematical reasoning ability is essential. As noted by Gustiadi et al. (2021) and Rohmatulloh et al. (2022), reasoning is one of the fundamental aspects that must be developed through mathematics learning. To address the difficulties identified in this study, teachers should provide more practice tasks grounded in real-life contexts and adopt learning strategies that foster reasoning skills (Putri et al., 2024; Wati et al., 2024). In addition, the implementation of active learning approaches where students are encouraged to express their mathematical ideas is vital for developing reasoning skills (Farida et al., 2018). Through such approaches, students can be trained to solve problems more logically and systematically, particularly in the context of systems of linear equations in two variables.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and discussion, it can be concluded that most students still face difficulties in achieving the stages of mathematical reasoning when solving problems related to systems of linear equations in two variables, particularly in

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performing mathematical manipulations and drawing conclusions. The average achievement of mathematical reasoning was 45.09%, while the difficulty rate reached 54.91%, with the greatest challenge occurring at the stage of drawing conclusions (76.34%). These difficulties are largely due to obstacles in algebraic operations, basic calculations, and interpreting results within the problem's context.

The findings highlight the need for improvements in mathematics learning, especially in strengthening students' reasoning skills. Teachers should provide more practice on symbolic manipulation and guide students to draw conclusions based on their solution steps. Active learning strategies that encourage exploration of solution methods and mathematical communication are also important to foster better reasoning.

This study is limited to one school with a small number of participants and focused only on systems of linear equations in two variables. Future research should involve larger, more diverse samples and address other mathematical topics to gain broader insights into students' reasoning difficulties.

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