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Study of Students' Mathematical Communication Skills in Solving Three-Variable Linear Equation Systems

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Abstract: Mathematical communication skills are essential for students to convey ideas, explain reasons, and solve mathematical problems both orally and in writing. In the context of the Three-Variable Linear Equation System (STLEV), many students face challenges in presenting solutions systematically and explaining their choice of solution methods. This study aims to analyze the mathematical communication skills of tenth-grade students in solving STLEV problems, with a focus on their arguments in choosing solution methods from both oral and written perspectives. Using a mixed-method approach with a descriptive approach, four students were purposively selected to represent diverse academic abilities. Data were collected through written exams and in-depth interviews, then analyzed using a holistic assessment rubric. Results showed variation in students' mathematical communication skills, ranging from moderate to very high, with common difficulties including structuring solution steps and drawing conclusions. Factors such as reading habits, frequency of practice, and teacher consistency were found to influence performance. This research demonstrates the need for explicit training in systematic solution writing and reasoning to enhance conceptual understanding and problem-solving skills in mathematics.

Keywords: learning; mathematical communication; system of three linear equations.

INTRODUCTION

Mathematics learning has important benefits in real life; it's because mathematics can be used to develop science and technology. To master and create technology in the future, strong mastery of mathematical material is required from an early age (Mafutukhin, 2014). Mathematical communication is needed to communicate ideas or solve mathematical problems, either orally, in writing, or visually (Ardianti, Kusmayadi & Fitriana, 2021), both in mathematics learning and outside of mathematics learning (Naimah, Prasetyowati & Rahmawati, 2022). Mathematics learning places more emphasis on written mathematical communication because of the process of learning mathematics using many symbols or illustrations to make it easier to solve the problem (Novferma, Mujahidawati & Setiana, 2021). Algebra is one of the subjects that has so many mathematical communication skills. The ability to think and communicate mathematically in algebraic material includes the ability to use symbols, representations, and mathematical language to explain, understand, and solve algebraic problems, both orally and in writing (Wahyuni & Swastika, 2024).

Mathematical communication thinking skills have high urgency in various aspects of life, especially in the world of education, work, and decision-making (Fajarina, 2023). In learning, this ability helps students understand mathematical concepts in depth and be able to communicate ideas and solutions clearly. In the workplace, many professions require this skill to analyze data, construct numerical arguments, and logically explain calculation results to colleagues or clients (Hapsoh & Sofyan, 2022). In the world of education, algebra is a cognitive bridge between arithmetic and advanced mathematics because algebraic thinking allows for generalization, symbolization, and modeling that facilitate the development of students' mathematical reasoning (Levin & Walkoe, 2022). Beside that, in our daily life, algebra helps individuals solve problems involving patterns, financial calculations, and data analysis for more rational decision-making (Ulya, Sudirman & Rahardjo, 2021). Therefore,

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mastering algebraic materials is essential to improve logical, analytical, and problem-solving thinking skills needed in this modern era, which is full of data-based and technology-based challenges.

Mathematical communication skills are a crucial aspect of mathematics learning. This ability enables students to convey their ideas, thoughts and understanding effectively, both orally and in writing (Rohid, Suryaman & Rusmawati, 2019). However, in learning the Three Variable Linear Equation System (STLEV) at the high school level, many students face difficulties in communicating the solution steps, especially when switching between elimination, substitution, and graphing methods (Septia & Nazilah, 2023). These difficulties often hamper conceptual and procedural understanding of the participants in solving the issues related to STLEV. In addition, errors in interpreting graphs, such as determining the intersection point as a solution, are a challenge for students (Kuncoro et al., 2023). Research conducted by (Djuniakh & Effendi, 2024) shows that the average of mathematical communication skills of students of STLEV material is in the low category, with an average score of 32.01 on a scale of 100. These findings indicate the need for greater attention to improving students' mathematical communication skills on the material. The urgency of this research is further enhanced by empirical findings showing students' difficulty in solving problems involving System of Linear Equations in Three Variables (STLEV). For example, a study at PGRI Wamena High School (Borean et al., 2024). Found that conceptual errors (especially in translating problems into mathematical models) were high, with 8 main mistakes. Procedural errors and errors related to story exploration fall into lower categories, with each category containing up to 7 types of errors. Besides that, at SMA Tamalabang, as many as 83.33% of students made mistakes in creating mathematical models and solving STLEV using elimination or substitution, while 50% of mistakes occurred in creating models based on the questions. It is also supported by data from national exams and several standardized tests, which show that STLEV is often a weak point for students (Legi, Monoarfa, & Regar, 2023).

Effective mathematical communication is expected to reduce misinterpretation of solutions and prevent students from simply memorizing procedures without understanding the meaning of the solution. Previous research has explored various methods to improve students' understanding of STLEV. For example, the use of visual media such as interactive graphics (Nugroho & Septianisha, 2025) and the application of problem-based learning models (PBL) (Nisa, 2018) have proven their effectiveness. However, until now there is still limited research discussing how students explain the reasons for selecting the STLEV solution method in detail in their mathematical communication. Although some of their research has discussed students' mathematical communication skills in STLEV material through various learning approaches and media, studies that specifically analyze students' arguments in choosing solution methods are still very limited. Furthermore, few studies have examined this aspect of argumentation in depth from the perspective of both oral and written communication. An analysis that combines both forms of communication is crucial for gaining a more comprehensive picture of how students construct, organize, and convey their rationale for choosing STLEV solution methods. This gap provides an important foundation for researchers to make original contributions through a qualitative approach that comprehensively explores students' mathematical thinking and communication processes.

Therefore, this research aims to analyze the ability of class X students to communicate STLEV solutions through various solution methods and to identify the factors that influence their mathematical communication skills in solving STLEV problems. This research provides a different contribution compared to previous studies because it specifically analyzes in depth the students' arguments in choosing the STLEV solution method by combining oral and written communication perspectives. This approach differs from previous research that

generally only highlights procedural skills and results without reviewing the reasons behind the method selection. Through the qualitative method that combines profound interviews and written answer analysis, this study offers a more comprehensive understanding of the mathematical thinking and communication processes of learners. Researchers hope that the results of this study can contribute to the development of more effective learning strategies to improve the mathematical communication skills of students in learning the material of the Linear Equality System of Three Variables (STLEV).

METHODS

The method that this research uses is mixed method, where the research data is presented descriptively. This research focuses on four students from class X in high school, selected purposively to represent a range of academic abilities: high, middle, and low, as recommended by the math teacher, all of whom have studied STLEV material. The instrument that is used in this research consists of two types, a written test and an interview. Questions are given online via Zoom meetings, which are specially made to explore students' mathematical communication skills in solving STLEV questions. Because the question is classified as a type of open-ended question, researchers can assess the extent of students' mathematical communication skills.

The data collection techniques to determine students' mathematical communication skills in solving STLEV problems are divided into two main stages. First, the written test was given online via Zoom. Students work on the questions independently in their respective places, and then the result of the answers is collected via Google Drive. Second, after the written test is collected, the interview will be done via Zoom Meeting with the four students related to the question that they have done. The data obtained was analyzed through several stages: data reduction, data presentation, and conclusion drawing. In analyzing student responses, a scoring technique was used for communication skills test questions based on the holistic scoring rubrics from Cai, Lane, and Jakabcsin 1996 (Wijayanto, Fajriah & Anita, 2018) as follows.

Table 1 Mathematical Communication Skills Scoring Guidelines

Skor	Kriteria
1	Can answer all aspects of questions about mathematical communication and answer correctly and clearly or completely.
½	Can answer only some aspects of questions about mathematical communication and answer correctly.
0	No answers.

RESULTS AND DISCUSSION

Based on the students' answers, the researchers analyzed them using holistic scoring rubrics (Wijayanto, Fajriah, & Anita, 2018). Therefore, the answers from the first subject were as follows.

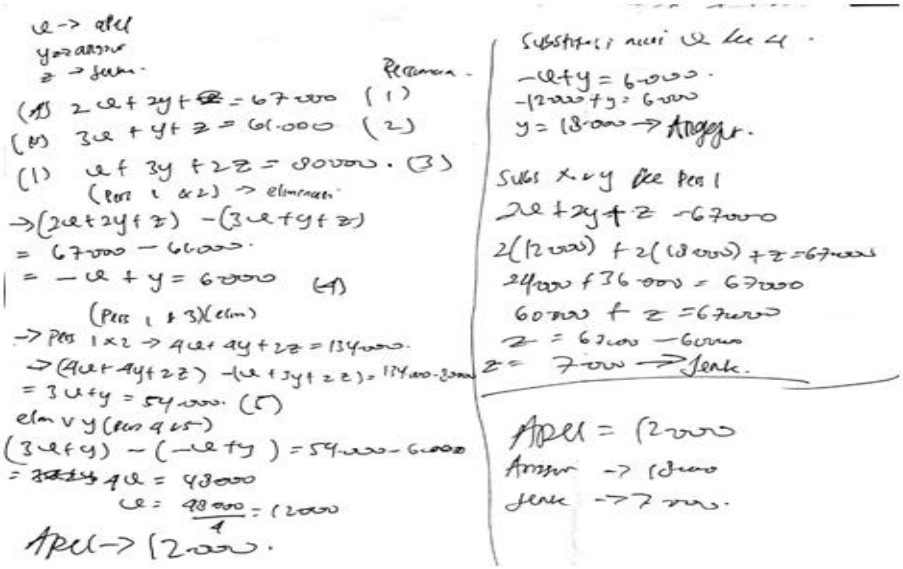

Figure 1. Subject 1's Answer

Based on the analysis of Subject 1's answers, it appears that the presentation of the solution steps is not well structured because it does not include known and asked information. The writing of the solution is also not neat, and the conclusion only includes the final result without explaining the initial conditions. The completion time is relatively fast, namely 10 minutes, indicating a smooth understanding of STLEV problems, even though the writing is not systematic.

The interview results show that Subject 1 is aware of three STLEV solution methods (substitution, elimination, and combination) and chose the combination method, as it was deemed more effective. The main difficulty is in questions with large numbers. Subject 1 also realized the importance of writing down the steps but chose not to write them down because Subject 1 already understood the flow in the head. The habit of reading and practicing makes it relatively easy for Subject 1 to understand story problems. Based on the mathematical communication skills indicator, Subject 1 is included in the high category with an achievement percentage of 90%.

Next, the answers from the second subject are as follows.

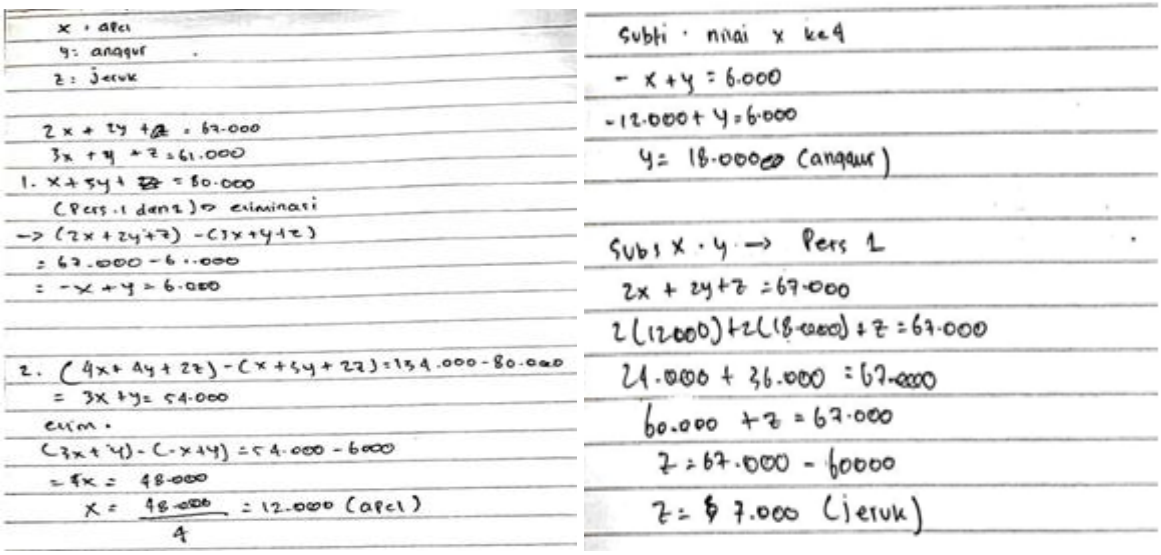

Figure 2. Subject 2's Answer

In Figure 2, Subject 2 also did not include known and asked information and did not write conclusions. The answers were quite neat, but the structure of the solution was not clear. From the interview, Subject 2 was familiar with three STLEV methods and was more comfortable using the elimination method. Subject 2 admitted that Subject 2 had difficulty working on story problems because it was difficult to determine the variables, especially due to Subject 2's habit of not liking to read long questions. They consider step-by-step writing important, but their answers do not reflect this. Based on the indicators, Subject 2 falls into the moderate category with an achievement percentage of 70%.

Next, the answers from the third subject are as follows:

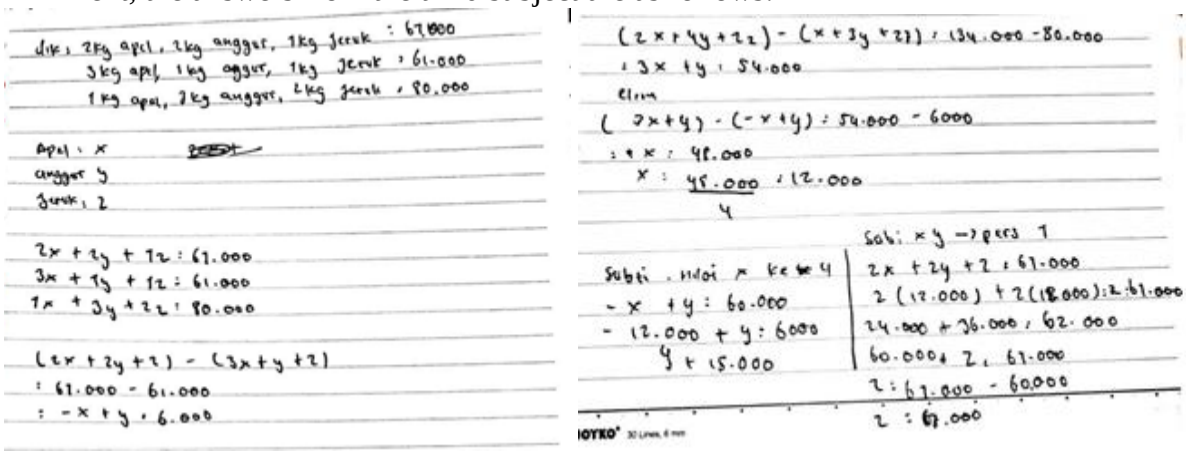

Figure 3. Subject 3's Answer

Figure 3 shows that Subject 3 has written down what is known and what is being asked; although the conclusion is not included, the writing is neat and clear. The interview results indicate that Subject 3 is familiar with four STLEV methods, namely substitutions, elimination, combination, and graphing. Subject 3 prefers the graphing method but realizes that the elimination method is more efficient for certain cases. Based on the indicators, subject 3 falls into the moderate category with an achievement percentage of 80%.

Next, the answers from the fourth subject are as follows.

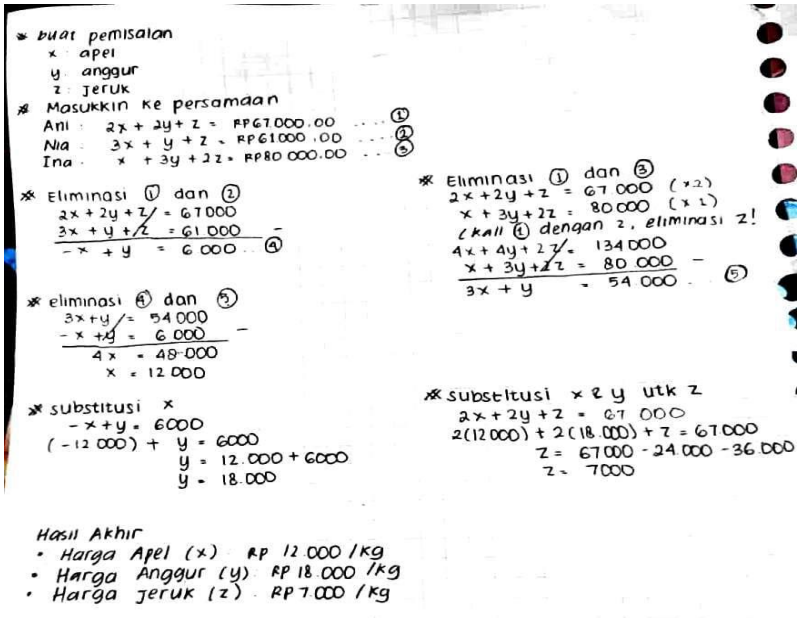

Figure 4. Subject 4's Answer

In Figure 4, Subject 4 neatly wrote down the steps to solve the problem but did not include the given and asked information. The conclusion provided was more detailed than other subjects. The interview revealed that Subject 4 was familiar with five STLEV methods, including matrices and matrix inverses. Subject 4 was more comfortable using a combination of substitution, elimination, and combination. The main difficulty was the complex calculation involved in the matrix method. Based on the indicators, Subject 4 falls into the very high category with a 100% achievement rate.

Based on the data obtained from Subject 1, Subject 2, Subject 3, and Subject 4 their mathematical communication skills can be represented in the table below:

Table 2. Results of Test and Interviews on Mathematical Communication Skills

Name	Category	Precentage
Subject 1	High	90%
Subject 2	Moderate	70%
Subject 3	Moderate	80%
Subjek 4	Very High	100%

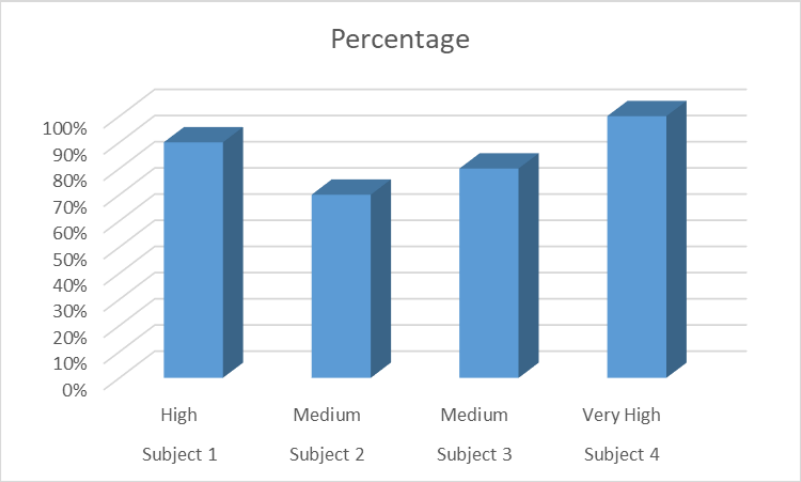

Figure 5. Percentage diagram of test results and interviews

Of the four students who were the subjects of the study, two were in the moderate category, one in the high category, and one in the very high category in terms of mathematical communication skills. This is in line with the findings of (Sitopu et al., 2022), who found that students' mathematical communication skills can develop significantly through a learning approach that encourages students to think critically and actively communicate their ideas. Participants in the high and very high ability categories showed a tendency to systematically organize solution steps and were able to explain the reasons for choosing a particular solution method. This is consistent with high self-confidence and good communication skills; they are better able to present mathematical solutions in a structured manner.

Furthermore, based on the interview results, it was found that students who are accustomed to discussing or reading questions carefully have an advantage identifying important information and organizing it into mathematical models. This is consistent with the findings of a study by (Siswadi, Saragih & Wardana, 2023) which states that the use of a learning model with an approach that encourages students to think critically and actively communicate their ideas is superior to an expository model because it provides space for exploration and articulation of students' mathematical ideas.

In general, students with high to very high mathematical communication skills tend to present systematic solution steps, include reasons for choosing a method, and be inconsistent in writing down initial information. A clear relationship is evident with good study habits. Such as diligent reading, practice and discussions. This correlates positively with the quality of mathematical communications. Students who rarely read or dislike reading long problems tend to have less organized answer structures and find it difficult to explain their thought processes. This finding aligns with research (Kumala, Waluyo & Siswanto, 2019) showing that self-confidence and practice habits influence the quality of mathematical communication (Naimah, Prasetyowati, & Rahmawati, 2022). It has also been reported that students who are accustomed to discussing and writing down solution steps have higher communication skills. (Ulya, Sudirman & Rahardjo, 2021) found that a common difficulty in STLEV lies in converting story problems into mathematical models, a finding also observed in the moderate category subjects in this study. Therefore, the recommended learning strategy is to provide explicit practice in writing down solution steps, encourage group discussion, and provide structured feedback on mathematical communication aspects, not just the final results.

External factors such as changes in subject teachers were also found to influence the continuity and consistency of student learning. When new teachers do not provide explicit instructions in structuring steps or in providing feedback on students' mathematical communication, these skills tend to stagnate or even decline. Therefore, it is important for teachers to implement learning strategies that explicitly encourage mathematical communication. Thus, mathematical communication is not only about procedural skills but also includes the ability to construct arguments, explain thought processes, and present solutions to the class. Recent research supports that the PBL (Problem-Based Learning) approach is highly effective in enhancing this ability (Purwati & Darussyamsu, 2021), especially when combined with learning tools that facilitate discussion, reflection, and mathematical writing practice.

CONCLUSION

Based on the results of a study conducted on four tenth-grade students regarding their mathematical communication skills in solving a three-variable linear equation system (STLEV), it can be concluded that, in general, students have been able to demonstrate mathematical communication skills at various levels of ability, ranging from moderate to high to very high. Students demonstrated varying levels of understanding in explaining mathematical ideas, organizing solution steps, and drawing final conclusions from solving STLEV problems. Students with high communication skills were able to organize steps and conclusions, while other students still faced difficulties in the structure of the presentation and drawing conclusions. These results emphasize the importance of strengthening mathematical communication skills to enhance students' conceptual understanding and problem-solving abilities.

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