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# The Influence of Mathematical Representation Ability on Students' Mathematical Communication Skills

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**ABSTRACT**

Mathematical communication skills and mathematical representation skills are two important skills in mathematics learning. However, students' mathematical communication skills remain relatively low, so a study is needed to identify the factors that affect them, including mathematical representation ability. This study aims to examine the influence of mathematical representation skills on students' mathematical communication skills in grade VII C at SMP Al Washliyah Sumber. This study uses a quantitative approach with an explanatory correlational design and simple linear regression. The research sample consisted of 31 students selected through purposive sampling. The research instrument is in the form of a description test developed based on indicators of mathematical representation ability and mathematical communication ability, which have met the criteria for validity and reliability. The study's results show that mathematical representation ability has a positive, significant effect on students' mathematical communication skills. These findings suggest that students with good mathematical representation skills tend to have better mathematical communication skills. This research suggests that mathematics learning should facilitate the use of various forms of mathematical representation to improve students' mathematical communication skills.

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## 1. INTRODUCTION

The development of science and technology in the 21st century requires the education system to be oriented not solely to material mastery but also to the development of high-level thinking skills, problem-solving, communication, and mathematical representation [1]. In mathematics learning, these skills are an important part that supports the formation of a deep and meaningful understanding of concepts [2]. The *National Council of Teachers of Mathematics* (NCTM) emphasized that the standard mathematics learning process includes problem-solving, reasoning, communication, connection, and representation skills that must be developed in an integrated manner in the learning process. Therefore, mathematical communication and representation skills are two essential competencies that require serious attention in modern mathematics learning [3].

Mathematical communication skills are students' ability to convey ideas and mathematical thinking processes systematically, both orally and in writing [4]. This ability includes the use of symbols, notations, diagrams, tables, and mathematical language appropriately to explain a concept and solve mathematical problems [5]. Students who have good mathematical communication skills tend to be able to organize mathematical ideas logically, making it easier for problem-solving and academic interactions in the classroom [6]. However, various studies show that students' mathematical communication skills in Indonesia remain relatively low. The Programme for International Student Assessment (PISA) results in 2022 show that Indonesian students' mathematics achievement is still below the OECD average, indicating that their ability to understand, represent, and communicate mathematical ideas still needs improvement [7].

Students' low mathematical communication skills are suspected to be closely related to underdeveloped mathematical representation skills. Mathematical representation skills are students' ability to present mathematical ideas or information in various forms of representation, such as visual, verbal, symbolic, and numerical representations [8]. Mathematical representations serve as a means for students to understand concepts, build relationships between concepts, and communicate mathematical ideas more clearly and systematically [9]. Through mathematical representations, students can transform abstract information into more concrete forms, making the process of mathematical thinking easier to understand [10]. Therefore, mathematical representation skills not only serve as an internal thinking tool but also as a medium that supports the development of effective mathematical communication [11].

Several previous studies have shown a relationship between mathematical representation skills and students' mathematical communication skills. Tupamahu et al.'s research found that students who could use various forms of mathematical representation tended to have an easier time explaining the systematic process of solving problems [3]. Ismail et al.'s research also found that the use of mathematical representations in learning can improve junior high school students' mathematical communication skills [4]. In addition, Izzati and Listiyani's research shows that multi-representation-based learning positively influences students' mathematical representation and communication skills [11]. Other research has also shown that visual and symbolic representations contribute to students' ability to convey mathematical ideas appropriately [12]. These findings show that mathematical representation and communication are interrelated in the mathematics learning process.

Nonetheless, most previous research has still focused on applying specific learning models to improve mathematical representation or communication skills separately. Research on mathematical representation skills generally focuses more on analyzing students' ability profiles or the influence of certain factors on students' mathematical abilities [13]. Meanwhile, research on mathematical communication is more focused on the influence of learning models and the descriptive analysis of students' abilities [14][15]. Studies that specifically test the influence of mathematical representation skills on mathematical communication skills through a simple linear regression approach, especially in junior high school students, are still relatively limited. This condition indicates a research gap that warrants further study to gain an empirical understanding of the functional relationship between mathematical representation skills and students' mathematical communication skills.

Based on this description, this study aims to examine the influence of mathematical representation ability on the mathematical communication ability of grade VII junior high school students using a quantitative, explanatory correlational design and simple linear regression analysis. This study offers a novel approach in testing the predictive power of mathematical representation as a predictor variable for mathematical communication ability among junior high school students within a single inferential statistical analysis framework. The results of this study are expected to make a theoretical contribution in strengthening the study of the relationship between mathematical abilities, especially mathematical representation and communication. In addition, this research is expected to have practical implications for mathematics teachers in designing learning experiences that systematically develop mathematical representation skills as a basis for strengthening students' mathematical communication skills.

## 2. METHODS

The approach used in this study is quantitative with an explanatory correlational research design (*Explanational correlational design*) to examine the influence of mathematical representation skills on students' mathematical communication skills without special treatment [16]. This design is used to explain the relationships between variables while testing the research hypothesis through relevant inferential statistical analysis [16]. In this study, the ability to represent mathematics serves as an independent variable (X), while the ability to communicate mathematics serves as a bound variable (Y). A conceptual model of this relationship is presented in Figure 1.


Figure 1. Research Conceptual Model

The relationship between variables is mathematically stated as follows.

$$\mathrm{Y} = a + bX \tag{1}$$

Where represents the predictive value of mathematical communication ability, represents the mathematical representation ability, is a constant (interception), and is a regression coefficient that shows the magnitude of the influence of each unit of change variable on Y $X\ a\ bXY$.

The population in this study includes all grade VII students of SMP Al Washliyah Sumber, consisting of grades VII A and VII C, with a total of around 60 students. The research sample was 31 students in grade VII C, who were selected through purposive sampling techniques, considering that the class had diverse mathematical ability characteristics and was in accordance with the research objectives.

The applied measuring instrument is an instrument that is systematically developed with reference to the relevant theoretical foundation, which is then poured into the instrument grid to ensure alignment between the indicator and the question item. The mathematical representation ability instrument is prepared based on four main indicators, namely visual, verbal, symbolic, and numerical representations, which reflect students' ability to present and process mathematical information in various forms [12]. Meanwhile, mathematical communication ability instruments are developed based on indicators that include the ability to use mathematical terms, symbols, and notations appropriately in solving problems, express mathematical ideas through visual representations such as pictures or diagrams, interpret visual representations or mathematical models into clear verbal explanations, and transform contextual problems into mathematical language forms and symbols [13]. The instrument of mathematical representation ability at the initial stage consists of 8 questions; the validity test results indicate that 5 are valid and the other 3 are invalid, so they are not used in the final instrument. The mathematical communication ability instrument also consisted of 8 questions in the initial stage, of which 5 met the validity criteria, and 3 were declared invalid. The validity of the content of the instrument is determined through expert judgment (*Member Ratings*) to assess the suitability of the question items with the indicators, editorial clarity, and suitability with the level of students' cognitive development, revisions are made based on the input provided. The instrument was then tested on students with characteristics similar to the research subjects to obtain empirical data. Validity analysis is done using item-total correlation, while differential power analysis is used to determine the ability of the question to differentiate students according to ability level, as well as difficulty analysis to ensure that the distribution of the difficulty level of the question is in the appropriate category. The results of the analysis showed that the majority of the question items that were maintained had differences in the fair to good category and the level of difficulty in the medium category. The reliability test using Cronbach's Alpha showed that the mathematical representation ability instrument had a reliability of 0.717 in the high category, while the mathematical communication ability instrument had a value of 0.684 in the medium category. Overall, the results of the analysis were stated to meet adequate psychometric criteria and were suitable for use in the research.

Based on Table 1, the analysis of the mathematical representation ability instruments indicates that the quality of each item varies. The empirical validity test shows that five question items, namely numbers 1, 2, 3, 5, and 8, have met the validity criteria, while the other three items have not met the validity requirements. A reliability coefficient value of 0.717 indicates that the instrument has a high level of internal consistency. In addition, the question difficulty index is distributed across the medium-to-hard categories, with one item in the easy category, ensuring the instrument's difficulty level remains balanced. The results of the differentiating power analysis showed that most questions distinguished high-ability and low-skilled students in the fair to good category, with one item in the bad category. In general, these findings suggest that instruments of mathematical representation ability exhibit adequate psychometric qualities for use. Question items that have met the standards are then selected for use at the data collection stage.

Table 1. Item Validity, Reliability, Difficulty Index, and Differentiating Power of Instruments: Mathematical Representation Ability

| Number Questions | Validity Score | Criteria | Power Difference Score | Criteria | Difficulty Score | Criteria | Remarks |
|---|---|---|---|---|---|---|---|
| 1. | 0,564 | Applicable | 0,472 | Good | 0,818 | Easy | Worth Using |
| 2. | 0,723 | Applicable | 0,597 | Good | 0,314 | Difficult | Worth Using |
| 3. | 0,485 | Applicable | 0,395 | Enough | 0,743 | Medium | Worth Using |
| 4. | 0,306 | Invalid | 0,201 | Enough | 0,493 | Medium | Not Suitable for Use |
| 5. | 0,854 | Applicable | 0,649 | Good | 0,646 | Medium | Worth Using |
| 6. | 0,372 | Invalid | 0,210 | Enough | 0,493 | Medium | Not Suitable for Use |
| 7. | 0,360 | Invalid | 0,182 | Ugly | 0,268 | Difficult | Not Suitable for Use |
| 8. | 0,563 | Applicable | 0,247 | Enough | 0,796 | Medium | Worth Using |
| Instrument Reliability, Mathematical Representation Ability<br>Alpha Cronbach = 0.717<br>Category = Height | | | | | | | |

Table 2. Item Validity, Reliability, Difficulty Index, and Differentiating Power of Mathematical Communication Ability Instruments

| Number Questions | Validity Score | Criteria | Power Difference Score | Criteria | Difficulty Score | Criteria | Remarks |
|---|---|---|---|---|---|---|---|
| 1. | 0,234 | Invalid | 0,162 | Ugly | 0,775 | Medium | Not Suitable for Use |
| 2. | 0,288 | Invalid | 0,244 | Enough | 0,571 | Medium | Not Suitable for Use |
| 3. | 0,449 | Applicable | 0,326 | Enough | 0,614 | Medium | Worth Using |
| 4. | 0,841 | Applicable | 0,836 | Very good | 0,593 | Medium | Worth Using |
| 5. | 0,663 | Applicable | 0,524 | Good | 0,543 | Medium | Worth Using |
| 6. | 0,213 | Invalid | -0,135 | Very ugly | 0,807 | Medium | Not Suitable for Use |
| 7. | 0,611 | Applicable | 0,515 | Good | 0,579 | Medium | Worth Using |
| 8. | 0,684 | Applicable | 0,375 | Enough | 0,629 | Medium | Worth Using |
| Instrument Reliability, Mathematical Communication Ability<br>Alpha Cronbach = 0.684<br>Category = Medium | | | | | | | |

Based on Table 2, the results of the mathematical communication ability instrument test indicate that five items (3, 4, 5, 7, and 8) meet the validity requirements, while the other three do not. The reliability coefficient of 0.684 indicates the consistency of the instrument internally in the medium category, making it quite feasible to apply it in the study. All questions are in the medium difficulty category, meaning they are not too easy or too difficult. The differentiating power analysis showed that most questions distinguished between high-ability and low-skilled students in the fair to very good categories, although two questions remained in the bad and very bad categories. In general, mathematical communication ability instruments have adequate quality and are suitable for implementation in research after the selection of question items.

In general, the test results showed that the instruments used had sufficient psychometric quality to support the application of simple regression analysis to the study sample. Because this study aims to determine the influence of one independent variable on one bound variable, the level of reliability obtained has been assessed to be sufficient to meet the needs of inferential analysis. After reviewing the empirical validity of each item, reliability, level of difficulty, and differentiating power, a systematic selection and refinement process was carried out to improve the instrument's measurement accuracy. Question items that do not meet the psychometric criteria are determined to be revised or eliminated to improve the consistency of the construction and statistical strength of the instrument. Thus, only items that meet the requirements of validity, have sufficient differentiating power, and a proportionate level of difficulty are used at the next stage of analysis.

Table 3. Item Level Validity Results and Final Item Selection

| Variable | Items Defended | Revised Items | Deleted Items |
|---|---|---|---|
| Math Communication Skills | 3, 4, 5, 7, 8 | 6 | 1, 2 |
| Mathematical Representation Ability | 1, 2, 3, 5, 8 | 6 | 4, 7 |

Remarks: Revised items are questions that can still be corrected based on the analysis results, while deleted items are questions that don't meet the instrument's eligibility criteria.

## 3. RESULTS AND DISCUSSION

### 3.1. Results

The results of the research on the influence of mathematical representation skills on the mathematical communication skills of grade VII C SMP Al Washliyah Sumber are presented systematically through a table containing descriptive statistics, regression prerequisite tests, correlation tests, and simple linear regression tests, making it easier for readers to understand the flow of data analysis carried out.

Statistical descriptive analysis aims to provide a preliminary picture of the distribution of students' scores, their mathematical representation abilities, and their mathematical communication.

Table 4. Descriptive Statistics of Research Variables

| Variable | N | Minutes | Max | Red | Std. Deviation | Variance |
|---|---|---|---|---|---|---|
| Mathematical Representation | 31 | 54 | 61 | 57,48 | 2,19 | 4,79 |
| Mathematical Communication | 31 | 45 | 55 | 50,58 | 2,98 | 8,85 |

Based on Table 4, students' mathematical representation ability scores are in the range of 54 to 61, with an average of 57.48 and a standard deviation of 2.19. Meanwhile, math communication skills have a score range of 45 to 55 with an average of 50.58 and a standard deviation of 2.98. The relatively small standard deviation values in the two variables show that the data distribution is quite even, and students' abilities tend to be homogeneous.

To assess the feasibility of parametric analysis, data normality was tested. The test results used the Kolmogorov-Smirnov and Shapiro-Wilk tests.

Table 5. Normality Test Results (Shapiro-Wilk)

| Variable | Statistics | df | Sig. | Verdict |
|---|---|---|---|---|
| Mathematical Representation | 0,938 | 31 | 0,057 | Normal |
| Mathematical Communication | 0,949 | 31 | 0,140 | Normal |

Based on Table 5, the significance value of the mathematical representation variable is 0.057, and the mathematical communication is 0.140. Both values are greater than 0.05, so the data are considered normally distributed. After that, the Levene test was used to assess variance homogeneity.

Table 6. Homogeneity Test Results (Levene)

| Live Statistics | df1 | DF2 | Sig. | Verdict |
|---|---|---|---|---|
| 0,215 | 7 | 23 | 0,978 | Homogeneous |

A significance value of 0.978 (>0.05) indicates that the data have homogeneous variance, so that the assumption of variance similarity is fulfilled [13].
The linear relationship between mathematical representation ability and mathematical communication ability was tested through a linearity test.

Table 7. Linearity Test Results

| Source of Variation | Number of Squares | df | Square Average | F | Sig. |
|---|---|---|---|---|---|
| (Combined) | 275,051 | 7 | 39,293 | 114,157 | 0,000 |
| Linearity | 274,783 | 1 | 274,783 | 798,317 | 0,000 |
| Deviations from Linearity | 0,268 | 6 | 0,045 | 0,130 | 0,991 |
| In a Group | 7,917 | 23 | 0,344 | | |
| Quantity | 282,968 | 30 | | | |

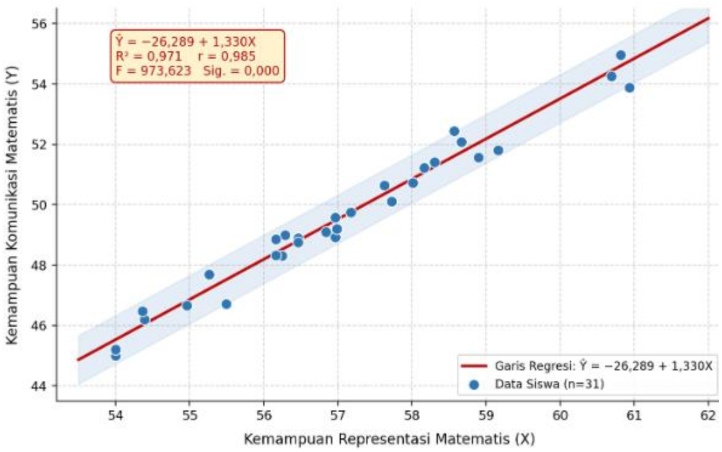


Figure 2. Graph of the Influence of Mathematical Representation Ability on Students' Mathematical Communication Skills

A linearity value of 0.000 (<0.05) indicates a significant linear relationship. Meanwhile, the value of Sig. Deviation from Linearity 0.991 (>0.05) indicates that there is no deviation from the linear line, so the linearity assumption is met.

### 3.2. Discussion

The study found that mathematical representation skills had a positive and significant influence on students' mathematical communication skills in grade VII C at SMP Al Washliyah Sumber. This is shown by the value of F = 973.623, with a significance of 0.000, and the influence contribution of $R^2 = 0.971$, or 97.1%. These findings confirm that mathematical representations provide a cognitive foundation for the development of effective mathematical communication skills [10]. Mathematical representation skills are related to a variety of other math skills, especially communication and problem-solving [17]. Through representations, students can convey ideas and mathematical concepts to facilitate the problem-solving process [18]. Thus, mathematical representations naturally contain communicative elements that make them strong predictors of students' mathematical communication skills [19].

The very strong relationship between the two variables, as indicated by the correlation coefficient r = 0.985, further underscores that mathematical representations are an integral part of mathematical communication. The process of mathematical communication requires the use of various forms of representation, such as diagrams, graphs, tables, and mathematical symbols. When students can present math ideas visually, their comprehension will be easier to understand, and the problem-solving process will be more effective [20]. In addition, results from other studies show that perceptions of mathematical thinking can predict students' disposition toward mathematical communication, both explicitly and implicitly, suggesting that internal cognitive processes play a role in shaping students' communication abilities [21]. Therefore, students who can combine visual, symbolic, verbal, and numerical representations demonstrate more precise and systematic mathematical communication skills [22].

A positive regression coefficient value of 1.330 indicates that every one-unit increase in mathematical representation ability will be followed by an increase in mathematical communication ability by 1.330 units. These findings show that good verbal, symbolic, and numerical representation skills make a real contribution to students' ability to express mathematical ideas [23]. Conversely, weaknesses in visual representation can decrease the overall effectiveness of mathematical communication [24]. Strengthening visual representation is important to help students' mathematical communication skills develop optimally [25].

The magnitude of the determination coefficient of 97.1% indicates that, in the context of statistical learning among grade VII students, mathematical representation ability is the dominant factor affecting mathematical communication skills [15]. Mathematical representation includes one of the main mathematical thinking skills that positively correlates with other mathematical abilities, including mathematical communication [26]. Therefore, improving representation skills will directly strengthen students' mathematical communication [27]. However, another 2.9% of the variance was influenced by factors outside the study, such as reasoning ability, mathematical connections, confidence, and student learning motivation [28], [29].

These findings also reinforce and expand on previous research that generally examined the capabilities of mathematical representation and mathematical communication separately. This study specifically shows that within the framework of simple linear regression analysis, mathematical representation ability can play a very strong role as a predictor of mathematical communication skills, particularly in junior high school students. The practical implication of these results is the need for teachers to design learning that structurally encourages students to apply different types of mathematical representations.

## 4. CONCLUSION

This study shows that mathematical representation ability positively influences the mathematical communication ability of grade VII students at Al-Washliyah Sumber Junior High School. Students' ability to present mathematical ideas through various forms of representation, such as visual, verbal, symbolic, and numeric, helps students in communicating mathematical ideas in a more systematic and easy-to-understand manner. These findings reinforce the idea that mathematical representation and mathematical communication are interrelated abilities in the mathematics learning process.

The results of this study provide practical implications for teachers and education practitioners to facilitate the use of various forms of mathematical representation in the learning process. Learning that provides opportunities for students to use and develop mathematical representations can help improve students' mathematical communication skills. In addition, this research also makes a theoretical contribution in strengthening the study of the relationship between mathematical representation skills and mathematical communication skills in junior high school students.

However, this study still has limitations because it was conducted in only one class, with limited sample coverage, and used a quantitative approach. Therefore, further research is recommended to involve a wider sample and examine different levels of education, as well as other variables that may affect students' mathematical communication skills. Follow-up research can also use a mixed methods approach to gain a more comprehensive understanding of the relationship between mathematical abilities. The results of this research are expected to be a reference in the development of more effective mathematics learning to improve the quality of students' mathematical abilities in the educational environment and society in general.

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