

Analyzing The Relationship Between Mathematical Communication Skills, Learning Quality and Mathematics Learning Outcomes in Vocational High Schools

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ABSTRACT

Mathematics learning outcomes are essential indicators of educational goal achievement. However, many students, particularly in Grade X at SMK Tunas Harapan Bunobogu, Buol Regency, demonstrate low performance. Observations show that nearly 40% of students fall below the expected competency level, potentially due to limited interaction between internal and external learning factors. This study investigates the relationship between mathematical communication skills, learning quality, and mathematics learning outcomes. A quantitative correlational design was employed, involving 50 Grade X students selected through simple random sampling. Data were collected using validated questionnaires and mathematics achievement tests. Partial and multiple correlation analyses were conducted using IBM SPSS Statistics 27. Findings revealed a significant positive correlation between mathematical communication skills and mathematics learning outcomes, contributing 69.8% to the variance. Learning quality also showed a significant positive correlation, contributing 20.7%. When both variables were analyzed simultaneously, their combined influence on learning outcomes increased to 77.9%. These results suggest that both mathematical communication skills and learning quality play substantial roles in improving students' mathematics performance. Enhancing students' ability to express mathematical ideas, alongside improving instructional quality, could lead to better academic achievement. Future interventions should target both internal competencies and external instructional practices to optimize learning outcomes in vocational education contexts.

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1. INTRODUCTION

Mathematics education in Indonesia remains a critical component of the national curriculum, aiming not only to develop students' cognitive understanding of mathematical concepts but also to foster essential skills such as logical reasoning, analytical thinking, and effective problem-solving. These competencies are pivotal for addressing real-world challenges and for promoting a more scientifically literate society (Permatasari & Hadi, 2022). Despite the centrality of mathematics in educational policy and practice, many Indonesian students continue to face significant difficulties in mastering mathematical concepts and demonstrating proficiency in mathematical problem-solving.

One crucial aspect that underpins successful mathematics learning is mathematical communication. This refers to a student's ability to articulate mathematical ideas clearly, both orally and in written form. According to the National Council of Teachers of Mathematics (NCTM, 2000), mathematical communication is instrumental in helping students clarify their understanding, justify their reasoning, and engage in meaningful interactions around mathematical ideas. Through communication, students not only express their thought processes but also construct and refine their mathematical understanding by engaging with others' perspectives. Unfortunately, in the context of Indonesian classrooms, many students exhibit limited ability to communicate mathematical concepts effectively, leading to misunderstandings and underperformance in assessments (Rohman & Hidayat, 2021).

The quality of instruction is another factor that significantly influences students' academic outcomes. Slavin (2006) emphasizes that high-quality instruction is characterized by clear and systematic content delivery, teaching strategies tailored to students' cognitive levels, and active student engagement in the learning process. However, classroom observations in Indonesia reveal that instructional approaches often remain teacher-centered and procedural, with minimal opportunities for students to engage in discussion or collaborative problem-solving. This conventional approach, while offering structure, may fail to nurture the deeper conceptual understanding and communication skills necessary for long-term mathematical competence (Yaniawati et al., 2020).

Preliminary findings from a local study conducted at SMK Tunas Harapan Bunobogu in Buol Regency provide insight into these challenges. In a sample of 50 vocational high school students, approximately 63% met or exceeded the Minimum Competency Criteria (MCC) for the final mathematics examination, indicating moderate success. However, 36% of the students did not reach the competency threshold, suggesting that a substantial proportion of learners continue to struggle with the subject. These statistics highlight a performance gap that warrants closer examination, particularly concerning the instructional methods and student capabilities that might influence these outcomes.

To address issues of engagement and effectiveness in mathematics learning, several scholars have explored the role of technology and motivation in educational settings. For example, Lin et al. (2017) found that digital learning environments significantly enhanced both learning motivation and academic outcomes compared to traditional teaching methods. Their research also demonstrated a positive relationship between students' motivation levels and their academic achievements, suggesting that motivated learners are more likely to succeed. Although the independent variables in Lin et al.'s study focused on digital learning and motivation, the underlying principle—that pedagogical strategies and learner dispositions influence outcomes—aligns with the current study's interest in communication skills and instructional quality.

Further reinforcing the importance of internal student factors, Nugraha et al. (2021) investigated the correlation between learning motivation and mathematics achievement. Their findings revealed that higher levels of student motivation were associated with improved performance in mathematics. However, while motivation is a well-established predictor of learning success, this study adopts a different focus by examining how students' mathematical communication skills and the quality of instruction affect learning outcomes in mathematics.

Learning outcomes are multidimensional and can be shaped by a combination of cognitive, psychological, social, and environmental factors (Ormrod, 2020). However, this study narrows its scope to two key variables: mathematical communication skills and the quality of mathematics instruction.

These factors are selected based on their direct impact on how students interact with mathematical content and their teachers, which in turn influences their understanding and achievement. By exploring these variables, the study aims to provide a more targeted understanding of how teaching practices and student competencies contribute to educational success in the mathematics classroom, particularly within the vocational school context.

Therefore, the purpose of this research is twofold: (1) to examine the relationship between students' mathematical communication skills and their learning outcomes in mathematics, and (2) to analyze how the quality of mathematics instruction contributes to students' academic performance. Special emphasis is placed on understanding how well students can express mathematical ideas both orally and in written form and how this capacity interacts with the effectiveness of instructional strategies used by educators. The findings of this research are expected to contribute valuable insights into improving teaching practices, designing curriculum interventions, and enhancing students' academic outcomes in mathematics within Indonesia's vocational education sector.

2. METHODS

This study employed a descriptive quantitative approach using a survey method with a correlational design to examine the relationships between three key variables: mathematical communication skills (X_1), learning quality (X_2), and mathematics learning outcomes (Y). The goal of the study was to analyze the extent to which students' abilities to communicate mathematical ideas and the quality of instructional delivery contribute to their academic performance in mathematics.

The research was conducted at SMK Tunas Harapan Bunobogu, located in the Tunas Harapan Sub-district, Buol Regency, Central Sulawesi Province, over a six-month period from February to July 2024. The study population comprised students enrolled in the 2023/2024 academic year. A total of 50 students actively participating in the learning process during this academic year were selected as the research sample.

To ensure representativeness, a probability sampling technique was employed, specifically the simple random sampling method. This approach provides every member of the population with an equal chance of being selected, thereby minimizing sampling bias and enhancing the generalizability of the findings.

Data collection relied primarily on the survey method, utilizing a structured questionnaire as the main research instrument. In addition to the questionnaire, interviews were conducted as a supplementary tool to support and validate the data obtained. The questionnaire consisted of two major sections:

1. Demographic Information: This section gathered basic data about respondents, including their name, age, gender, and grade level.
2. Closed-ended Items: This section included a series of items aligned with the study variables. Respondents answered using a **numerical scale** determined by the researcher. These items were designed to measure students' mathematical communication skills and perceptions of learning quality.

The instruments used in this study were developed based on a grid derived from the theoretical framework and defined research variables. Instrument development followed a systematic process to ensure validity and reliability.

Before the instruments were administered, they underwent theoretical and empirical validation:

1. Theoretical validity was assessed through expert judgment, involving lecturers and colleagues with expertise in educational research and mathematics education. Their feedback was used to refine the content, structure, and relevance of the items.
2. For content validity, subject-matter experts reviewed the instruments to ensure that all relevant dimensions of the constructs were adequately represented.

3. The instruments were further examined for construct validity, with the expectation that expert input would enhance the instruments' ability to measure the intended variables accurately.

The data collected from the questionnaires and interviews were analyzed using two types of analysis:

1. Descriptive analysis: This provided summaries of the data, including measures such as means, percentages, and standard deviations, to describe the distribution and characteristics of each variable.
2. Inferential analysis: This was used to examine the relationships between the independent variables (mathematical communication skills and learning quality) and the dependent variable (mathematics learning outcomes). Correlational statistical techniques were employed to determine the strength and direction of these relationships.

This methodological design was chosen to provide both a snapshot of the current state of students' mathematical communication and learning quality, as well as an in-depth understanding of how these factors interact to influence learning outcomes in vocational education settings.

The Pearson product-moment correlation formula was used to determine the item validity for the instruments on learning quality and learning motivation, correlating the item score with the total score using Cronbach's alpha formula. The criteria for testing item validity were as follows, where the critical value or r_{table} at a significance level of $\alpha = 0.05$:

- a. If $r_{item} = r_{table}$, therefore the item is considered valid or accepted.
- b. If $r_{item} > r_{table}$, therefore the item is considered invalid or rejected.

Pearson's product-moment correlation was also used in determining the validity of the questionnaire as an instrument in this study, correlating the item score with the total score using the following formula:

$$r_{xy} = \frac{N \sum XY - [\sum X] [\sum Y]}{[\sum X^2 - (\sum X)^2] [\sum Y^2 - (\sum Y)^2]}$$

If $r_{xy} > r_{table}$ with $\alpha=0.05$, then the instrument is considered valid.

The interpretation of the correlation coefficient r_{xy} was based on the following criteria:

- a. $0.80 < r_{xy} \leq 1.00$: very high item validity
- b. $0.60 < r_{xy} \leq 0.80$: high item validity
- c. $0.40 < r_{xy} \leq 0.60$: moderate item validity
- d. $0.20 < r_{xy} \leq 0.40$: low item validity
- e. $0.00 < r_{xy} \leq 0.20$: invalid item

Meanwhile, Cronbach's Alpha formula was used in calculating the instrument's reliability since the instrument scores were not binary (1 and 0), with the following formula:

$$r_{xy} = \left(\frac{k}{k-1} \right) \left(1 - \frac{\sum \sigma_b^2}{\sigma_1^2} \right)$$

In addition, we used a Likert scale with an interval range of 1 to 5 to measure respondents' attitudes, views, and perceptions regarding specific social aspects. The Likert scale with an interval range of 1 to 5 is a type of rating scale commonly used in quantitative research to measure respondents' preferences, attitudes, opinions, or perceptions of a particular statement or variable.

Regression and multiple correlation statistical tests with two predictors were used to test the four proposed research hypotheses.

3. FINDINGS AND DISCUSSION

3.1 Descriptive Statistical Analysis

3.1.1 Mathematics Learning Outcomes (MLO) (Y)

The analysis of the mathematics learning outcomes test instrument found that out of 50 students in the Xth grade at SMK Tunas Harapan Bunobogu Buol, 50% had low mathematics learning outcomes,

42% had moderate learning outcomes, and 8% had high learning outcomes. Additionally, the average score obtained was 54, indicating that the 10th-grade students of SMK Tunas Harapan Bunobogu Buol had moderate mathematics learning outcomes.

3.1.2 Mathematical Communication Skills (MCS) (X_1):

The analysis of the mathematical communication skills non-test instrument involving 50 students in the Xth grade at SMK Tunas Harapan Bunobogu Buol revealed that 52% of the students were categorized as having low skills, 40% had moderate skills, and only 8% were categorized as having high skills. The average mathematical communication skills score was 57, putting it in the moderate mathematical communication skills category.

3.1.3 Learning Quality (X_2):

The analysis of the learning quality non-test instrument found that out of 50 students in the Xth grade at SMK Tunas Harapan Bunobogu Buol, 66% of the students rated the learning quality as adequate, 20% rated it as good, and 14% rated it as poor. The average learning quality score obtained was 65, categorizing it as adequate.

3.2 Inferential Statistical Analysis

Normality tests were conducted on the variables of mathematical communication skills (X_1) and learning quality (X_2) on mathematics learning outcomes (Y), both partially and simultaneously, using the Kolmogorov-Smirnov test with the following statistical hypotheses:

H_0 : MCS does not follow a normal distribution

H_1 : The regression estimate of MCS follows a normal distribution

Table 1. Normality Test Results

Test	Sig.	Statistical Test
MCS on MLO	.200d	.102
Learning Quality on MLO	.200d	.126
MCS and Learning Quality on MLO	.200d	.069

Table 1 showed that the significance values (Asymp. Sig. (2-tailed)) were greater than 0.05, which means that H_0 was rejected and H_1 was confirmed, indicating that the data were normally distributed. Hypothesis testing was performed afterward, specifically the significance testing of multiple correlation analysis.

Table 2. Correlation Coefficients

Model	R	R Square	Adjusted R Square
MCS (X_1) on MLO (Y)	.836a	.698	.692
Learning Quality (X_2) on MLO (Y)	.456a	.207	.191
MCS (X_1) on Learning Quality (X_2)	.402a	.161	.023
MCS (X_1) and Learning Quality (X_2) on MLO (Y)	.883a	.779	.770

Table 2 demonstrated that the R value indicates a positive correlation coefficient on mathematics learning outcomes, which means H_0 was rejected, and H_1 was confirmed. The significance of the correlation was then tested using the T-Test at a significance level of $\alpha = 0.05$, with the statistical hypotheses formulated as follows:

H_0 : The correlation is not significant

H_1 : The correlation is significant

The decision-making criterion was that if the significance value is greater than α , H_0 is confirmed; otherwise, H_0 is rejected. This analysis was conducted using IBM SPSS Statistics 27, obtaining the following results:

Table 3. T-Test

Coefficients ^a			
Model		t	Sig.
1 (Constant)		-.501	.619
MCS (X ₁) on MLO (Y)		10.539	.000
2 (Constant)		2.743	.009
Learning Quality (X ₂) on MLO (Y)		3.545	.001
3 (Constant)		5.344	.009
MCS (X ₁) on Learning Quality (X ₂)		1.475	.037

Table 3 demonstrated that the significance values obtained were less than $\alpha = 0.05$, which means that H_0 was rejected, and H_1 was confirmed. The significance of the multiple correlation analysis was then tested using the F-Test at a significance level of $\alpha = 0.05$. The results revealed that the significance value obtained was 0.000, meaning that H_0 was rejected and H_1 was confirmed, indicating that mathematical communication skills and learning quality simultaneously had a strong and significant positive relationship with mathematics learning outcomes.

The results of the first research hypothesis test indicated a positive and significant relationship between students' mathematical communication skills and the mathematics learning outcomes of class X students at SMK Tunas Harapan Bunobogu Buol, with a contribution of 69.8%, as shown in the R-Square table below. This shows that the higher the mathematical communication skills possessed by students, the higher the achievement of student learning outcomes, and vice versa, the lower the students' mathematical communication skills, the lower the students' learning outcomes.

Table 4. Correlation Coefficient of KKM (X₁) Against HBM (Y)

Model Summary ^b				
Adjusted R				
Model	R	R Square	Square	Std. Error of the Estimate
1	.836a	.698	.692	7.228

a. Predictors: (Constant), Mathematical Communication Skills
 b. Dependent Variable: HBM

The results of the second research hypothesis test indicated a positive and significant influence of Learning Quality on the Mathematics Learning Outcomes of class X students at SMK Tunas Harapan Bunobogu Buol, with a contribution of 20.7%, as shown in the R-Square table below. This indicates that the higher the students' assessment of Learning Quality towards their teachers, the higher the achievement of student learning outcomes, and vice versa. The lower the students' assessment of Learning Quality towards their teachers, the lower the student learning outcomes will be.

Table 5. Correlation Coefficient of KP (X₂) Against HBM (Y)

Model Summary ^b					
Adjusted R					
Model	R	R Square	Square	Std. Error of the Estimate	
1	.456 ^a	.207	.191	11.713	

a. Predictors: (Constant), Learning quality
 b. Dependent Variable: HBM

The results of the third research hypothesis test indicated a positive and significant influence of Mathematical Communication Ability on the Quality of Learning among class X students of SMK Tunas Harapan Bunobogu Buol towards their mathematics teachers, with a contribution of 16.1%, as shown in the R-Square table below. This indicates that the higher the students' Mathematical Communication Ability, the higher the assessment of the Quality of Learning by students towards teachers, and vice versa.

versa. The lower the students' Mathematical Communication Ability, the lower the assessment of the Quality of Learning by students towards teachers.

Table 6. Correlation Coefficient of KKM (X_1) Against KP (X_2)

Model Summary ^b				
	R	Adjusted R		
Model	R	Square	Square	Std. Error of the Estimate
1	.402 ^a	.161	.023	12.636

a. Predictors: (Constant), Mathematical Communication Skills

b. Dependent Variable: Learning quality

The results of the fourth research hypothesis test stated that there was a positive and significant influence between Mathematical Communication Ability and Learning Quality on the mathematics learning outcomes of class X students of SMK Tunas Harapan Bunobogu Buol with a contribution of 77.9% as seen from the R Square table below. This shows that the higher the Mathematical Communication Ability and the assessment of Learning Quality by students, the higher the achievement of student learning outcomes, and vice versa, the lower the Mathematical Communication Ability and the assessment of Learning Quality by students, the lower the student learning outcomes will be.

Table 7. Correlation Coefficient of KKM (X_1) and KP (X_2) Against HBM (Y)

Model Summary ^b				
	R	Adjusted R		
Model	R	R Square	Square	Std. Error of the Estimate
1	.883 ^a	.779	.770	6.246

a. Predictors: (Constant), KP, KKM

b. Dependent Variable: HBM

The findings of this study demonstrate that mathematical communication skills and learning quality are significantly related to students' mathematics learning outcomes. These results align with prior research emphasizing the critical role of student-related and instructional factors in academic achievement. For instance, Ricardo and Meilani (2017) found that learning interest and motivation have both simultaneous and partial positive effects on students' academic performance. Their research underscores the importance of engaging students actively in the learning process, as motivation serves as a driving force behind students' effort and persistence, which in turn affects their learning outcomes. Similarly, the current study reinforces that students' active engagement—reflected in their ability to communicate mathematical ideas clearly and effectively—is a vital contributor to their performance in mathematics.

Although both studies focus on predictors of learning success, the variables investigated differ. Ricardo and Meilani (2017) concentrated on students' learning interest and motivation in the context of office equipment management at a private vocational high school in Bandung Regency. In contrast, this study explored mathematical communication skills and learning quality in the context of mathematics education at SMK Tunas Harapan Bunobogu, Buol Regency. While the subject matter and focus differ, both studies converge on the conclusion that internal student factors and instructional quality play key roles in shaping learning outcomes.

Another relevant dimension is the influence of gender on written mathematical communication, as discussed by Majid (2022). His research identified gender-based differences in students' abilities to express mathematical solutions in written form, with male students outperforming female students in terms of completeness, clarity, and concreteness. While gender was not a primary focus in the current

study, the findings suggest that individual differences—including communication ability—can significantly influence how students perform in mathematics. These results point to the necessity of differentiated instruction and assessment practices that consider such variations to support equitable learning experiences.

Furthermore, the study's findings support the argument that learning quality—defined by effective teaching strategies, clarity in instructional delivery, and student engagement—has a significant impact on learning outcomes. This is consistent with the views of Slavin (2006), who emphasized that high-quality instruction is characterized by structured content, responsiveness to student needs, and opportunities for active participation. When students are taught in environments where learning is interactive and responsive, they are more likely to develop deeper conceptual understanding and better problem-solving skills.

In summary, the study contributes to the growing body of literature indicating that both student competencies (such as communication skills) and instructional quality are key determinants of student success in mathematics. Future research may consider integrating additional variables such as gender, learning motivation, or technological tools to explore a more comprehensive model of mathematics achievement.

4. CONCLUSION

In conclusion, this study found a significant positive relationship between students' mathematical communication skills and their mathematics learning outcomes at SMK Tunas Harapan Bunobogu Buol, with an effect contribution of 69.8%, indicating that stronger communication skills are associated with higher academic achievement in mathematics. Additionally, students' perceptions of learning quality also showed a significant positive relationship with learning outcomes, contributing 20.7% to the variance, while the interaction between mathematical communication skills and perceived learning quality explained 77.9% of the variance in mathematics learning outcomes. A further significant relationship was observed between mathematical communication skills and students' assessment of learning quality, contributing 16.1%, suggesting that students with higher communication skills tend to perceive their learning environment more positively. These findings emphasize the critical role of both student competencies and instructional quality in supporting academic success. However, this study is limited by its focus on a single vocational high school, a relatively small sample size, and reliance on self-reported data, which may not capture the full complexity of classroom interactions or student abilities. Future research should explore additional factors influencing mathematical communication skills, such as teaching methods, mathematical literacy, and technology integration, as well as investigate how teacher feedback, instructional style, and learning environments affect both communication development and academic outcomes. These insights can guide educators and policymakers in designing more effective and inclusive mathematics instruction.

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