Journal of General Education and Humanities
Vol. 5, No. 4, August 2026, pp. 5135 – 5152, https://doi.org/10.58421/gehu.v5i4.1684
ISSN 2963-7147

The Relationship between Mathematical Reasoning, Mathematical Communication, and Students' Mathematical Problem-Solving Abilities

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Article Info

Article history:

Received 2026-05-31
Revised 2026-08-02
Accepted 2026-08-04

Keywords:

Mathematical communication
Mathematical problem-solving
Mathematical reasoning
Mathematics learning

ABSTRACT

Mathematical problem-solving ability is a fundamental competency in mathematics education that is influenced by various cognitive factors, including mathematical reasoning and communication. However, the individual and simultaneous contributions of these abilities to students' mathematical problem-solving performance remain insufficiently understood. This study aimed to examine the influence of mathematical reasoning and communication abilities on students' problem-solving. A quantitative study employing an ex post facto design was conducted with 23 eighth-grade students from a junior high school in Cirebon, Indonesia. Data were collected using validated essay-based instruments measuring mathematical reasoning, mathematical communication, and mathematical problem-solving abilities. The data were analysed using descriptive statistics, classical assumption tests, and multiple linear regression. The findings revealed that the regression model satisfied the assumptions of normality, multicollinearity, and heteroscedasticity. The regression analysis indicated that both mathematical reasoning and mathematical communication abilities significantly affected students' problem-solving performance ($p < 0.001$), explaining 85.6% of the variance in problem-solving performance. Partial regression analysis showed that mathematical reasoning ability did not have a statistically significant effect ($\beta = 0.147$, $p = 0.352$), whereas mathematical communication ability had a significant positive effect ($\beta = 1.378$, $p < 0.001$). These findings indicate that mathematical communication ability is a stronger predictor of students' problem-solving than mathematical reasoning. Therefore, mathematics instruction should emphasise learning activities that foster students' mathematical communication and reasoning, thereby enhancing their problem-solving performance.

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1. INTRODUCTION

Mathematics education plays a fundamental role in equipping students with the competencies needed to address the increasingly complex challenges of the twenty-first century. Beyond developing computational proficiency, mathematics learning is expected to cultivate higher-order thinking skills that enable students to analyse information critically, construct logical arguments, and make appropriate decisions in various contexts [1]. Contemporary mathematics education therefore emphasises the development of mathematical proficiency through interconnected competencies, including reasoning, communication, representation, and problem-solving, because these competencies support students in applying mathematical knowledge meaningfully both inside and outside the classroom [2]. Consequently, mathematics instruction should provide learning experiences that strengthen students' ability to interpret situations, formulate mathematical models, and develop effective solution strategies for authentic problems [3].

Among these competencies, mathematical problem-solving ability occupies a central position because it reflects students' capacity to understand problems, integrate relevant mathematical concepts, implement appropriate solution procedures, and evaluate the validity of obtained results [2]. This ability has become one of the principal indicators of successful mathematics learning because it demonstrates how students transform conceptual knowledge into practical solutions for unfamiliar situations [4]. Furthermore, recent research has highlighted that mathematical problem-solving ability contributes to students' mathematical literacy, adaptive reasoning, and long-term academic achievement, making its development a major objective of mathematics education worldwide [1], [5].

Despite its recognised importance, developing students' mathematical problem-solving ability remains a persistent challenge in mathematics classrooms. Numerous studies have reported that many students experience difficulties in interpreting mathematical information, identifying relationships among concepts, selecting appropriate solution strategies, and justifying their answers when confronted with non-routine mathematical tasks [5]. These difficulties often encourage procedural learning, in which students rely on memorised algorithms rather than conceptual understanding, thereby limiting their ability to transfer mathematical knowledge to unfamiliar contexts [2]. Such conditions indicate that many students have not yet developed the cognitive competencies required to solve mathematical problems effectively, even after completing formal mathematics instruction [3].

The persistence of these difficulties suggests that mathematical problem-solving ability is influenced by multiple cognitive competencies that interact throughout the learning process. Understanding the factors that contribute to students' mathematical problem-solving ability is therefore essential for designing instructional strategies that improve learning outcomes. Recent studies increasingly recommend examining cognitive variables that directly support students' mathematical thinking because such evidence can provide a stronger empirical foundation for developing more effective mathematics instruction [1], [2]. Guided by this perspective, the present study investigates the cognitive factors associated with students' mathematical problem-solving ability, with particular attention to mathematical reasoning and communication abilities, as discussed in the following section.

Among the cognitive competencies associated with mathematical problem-solving, mathematical reasoning has received considerable attention because it enables students to construct logical arguments, identify mathematical relationships, evaluate evidence, and justify solution strategies throughout the problem-solving process [6]. Rather than relying solely on memorised procedures, students with well-developed reasoning abilities analyse mathematical situations conceptually and determine appropriate strategies with logical justification [7]. This competency supports students in interpreting mathematical information, recognising patterns, and drawing valid conclusions, all of which are essential for solving non-routine mathematical problems [8]. Recent empirical evidence has consistently demonstrated that reasoning-oriented learning environments improve students' ability to solve mathematical problems by strengthening conceptual understanding and promoting higher-order thinking processes [9].

Although mathematical reasoning provides the logical foundation for problem-solving, students must also be able to communicate their mathematical thinking effectively throughout the solution process. Mathematical communication enables students to organise ideas systematically, represent mathematical relationships through symbols, diagrams, tables, or written explanations, and justify every solution step using appropriate mathematical language [10]. Clear mathematical communication facilitates students in translating contextual problems into mathematical models, explaining solution procedures, and evaluating the validity of obtained results [11]. Consequently, mathematical communication functions not only as a means of expressing mathematical ideas but also as a cognitive process that reinforces conceptual understanding and supports students in constructing coherent mathematical arguments [12].

Recent studies increasingly indicate that mathematical reasoning and communication are closely interconnected rather than independent competencies. During mathematical problem solving, reasoning enables students to formulate logical solutions, whereas communication allows these solutions to be represented, justified, and evaluated systematically [13]. Students who demonstrate strong reasoning but struggle to communicate their mathematical ideas often find it difficult to present complete and coherent solutions. Conversely, effective communication without adequate reasoning may produce well-organised explanations that lack logical validity [14]. These findings suggest that both competencies complement one another throughout the mathematical problem-solving process and should therefore be examined simultaneously when investigating factors influencing students' mathematical problem-solving ability.

Furthermore, recent empirical research has consistently reported positive associations between mathematical reasoning, mathematical communication, and mathematical problem-solving ability across various educational settings. For example, Aljura et al. demonstrated that reasoning and communication jointly contribute to students' success in solving mathematical word problems [15]. Similarly, several recent studies have reported that students with stronger reasoning and communication abilities generally achieve higher performance in mathematical problem-solving because they are better able to interpret problems, formulate mathematical representations, justify solution strategies, and evaluate their final answers [7], [11], [13]. Collectively, these findings provide a strong

 https://doi.org/10.58421/gehu.v5i4.1684

theoretical foundation for examining the simultaneous contributions of mathematical reasoning and communication to students' problem-solving ability.

Despite the growing body of research on mathematical reasoning, communication, and problem-solving, previous studies have predominantly examined these variables from separate perspectives. Several recent studies have reported that mathematical reasoning significantly enhances students' ability to analyse mathematical situations, formulate logical arguments, and develop effective solution strategies [16]. Other investigations have demonstrated that mathematical communication facilitates students' expression of mathematical ideas, construction of mathematical representations, and systematic explanation of solution procedures [17]. In addition, several studies have confirmed that each of these competencies is positively associated with students' mathematical problem-solving performance across different educational contexts [18], [19]. Although these findings provide valuable evidence regarding the individual contribution of each competency, they offer only a partial understanding of the cognitive processes underlying mathematical problem solving.

Recent investigations have also examined the relationship among multiple mathematical competencies. For instance, Aljura et al. reported that mathematical reasoning and mathematical communication jointly contribute to students' success in solving mathematical problems by strengthening conceptual understanding and supporting logical argumentation [15]. Similarly, several studies in secondary mathematics education have emphasised that integrating reasoning and communication within classroom instruction improves students' mathematical performance more effectively than emphasising either competency independently [20], [21]. Nevertheless, most previous studies have primarily focused on instructional interventions, descriptive analyses, or correlational relationships. At the same time, relatively limited attention has been devoted to quantitatively examining the simultaneous predictive contributions of mathematical reasoning and mathematical communication abilities to students' mathematical problem-solving ability through multiple regression analysis.

This limitation indicates a clear research gap in the existing literature. Although mathematical reasoning and mathematical communication have each been recognised as important determinants of mathematical problem-solving, empirical evidence explaining their simultaneous contribution within a single predictive model remains limited, particularly in the context of junior secondary school mathematics education. Furthermore, previous studies have rarely quantified the relative contribution of each cognitive competency in explaining variations in students' mathematical problem-solving ability. Addressing this gap is essential because understanding the relative influence of these competencies may provide stronger empirical evidence for designing instructional strategies that effectively improve students' mathematical problem-solving performance.

The present study addresses this gap by simultaneously examining the contributions of mathematical reasoning and mathematical communication to students' mathematical problem-solving using a multiple linear regression model. Unlike previous studies that primarily investigated these variables independently or focused on instructional effectiveness, this study evaluates the predictive strength of both competencies within a unified statistical framework. This analytical approach provides a more comprehensive understanding of how mathematical reasoning and communication together explain students' performance in mathematical problem-solving.

Accordingly, this study aims to (1) analyse the contribution of mathematical reasoning ability to students' mathematical problem-solving ability, (2) examine the contribution of mathematical communication ability to students' mathematical problem-solving ability, and (3) determine the simultaneous contribution of mathematical reasoning ability and mathematical communication ability to students' mathematical problem-solving ability. The findings are expected to enrich theoretical understanding of the cognitive competencies underlying mathematical problem-solving while providing empirical evidence to support mathematics teachers in designing instructional practices that strengthen students' reasoning, communication, and problem-solving abilities.

2. METHOD

This study employed a quantitative, correlational research design to examine the contributions of mathematical reasoning and mathematical communication to students' mathematical problem-solving. A correlational design was considered appropriate because the study sought to investigate the predictive relationships among variables without manipulating the learning environment or implementing an experimental treatment. The research focused on determining both the individual and simultaneous contributions of the independent variables to the dependent variable using multiple linear regression.

Mathematical reasoning and communication abilities served as independent variables, and students' mathematical problem-solving ability was the dependent variable. The proposed regression model enabled the researchers to estimate the relative contribution of each predictor and to evaluate the model's overall explanatory power in predicting students' mathematical problem-solving ability. This analytical approach provides empirical evidence on the extent to which each cognitive competency contributes to mathematical problem-solving within the investigated population.

The study was conducted at SMP Negeri 1 Sindangwangi, Majalengka, West Java, Indonesia, during the 2024/2025 academic year. The research involved students who had completed mathematics instruction on the instructional topics assessed by the research instruments, ensuring that all participants had comparable learning experiences before data collection.

The target population consisted of all Grade VIII students enrolled at the school. A total of 72 students participated in the study, selected through purposive sampling. This sampling technique was employed because the selected participants satisfied the predetermined research criteria, including completion of the relevant mathematics topics and willingness to participate in the research. Furthermore, purposive sampling ensured that the collected data appropriately represented students who possessed sufficient learning experiences to complete the mathematical reasoning, mathematical communication, and mathematical problem-solving assessments.

Prior to data collection, permission to conduct the study was obtained from the principal and the mathematics teacher of the participating school. The data collection process was conducted during regular mathematics instruction. Students completed all research instruments under the supervision of the researcher and the classroom teacher. The collected data were used solely for research purposes, and participants' identities were kept confidential throughout the analysis and reporting process.

Three research instruments were employed to measure the variables investigated in this study, namely a Mathematical Reasoning Ability Test, a Mathematical Communication Ability Test, and a Mathematical Problem-Solving Ability Test. All instruments were developed in accordance with the research objectives and relevant indicators of each construct. The instruments consisted of essay-type questions that allowed students to demonstrate their mathematical thinking processes, reasoning, and written explanations, rather than merely selecting predetermined answers.

The Mathematical Reasoning Ability Test was designed to measure students' capacity to analyse mathematical situations, identify relationships among mathematical concepts, formulate logical arguments, and draw valid conclusions when solving mathematical problems. The test items were constructed based on established indicators of mathematical reasoning and were aligned with the mathematics learning objectives implemented in the participating school. Essay-format items were selected because they provide richer information about students' reasoning processes and allow researchers to evaluate the quality of the mathematical arguments produced by participants.

The Mathematical Communication Ability Test assessed students' ability to express mathematical ideas through written explanations, mathematical symbols, representations, and logical arguments. The instrument evaluated students' competence in translating contextual situations into mathematical models, communicating solution procedures systematically, and interpreting mathematical results appropriately. These indicators reflect essential aspects of mathematical communication that support students in explaining and justifying their problem-solving processes.

Students' Mathematical Problem-Solving Ability was measured using an essay test designed to evaluate four stages of mathematical problem-solving: understanding the problem, planning an appropriate solution strategy, implementing the selected strategy, and evaluating the obtained solution. These stages were incorporated into the scoring rubric to ensure that the assessment captured both the problem-solving process and the accuracy of students' final answers.

Prior to administration, all research instruments underwent content validity evaluation conducted by experts in mathematics education to ensure the relevance, clarity, and representativeness of each item with respect to the intended construct. Suggestions provided during the validation process were incorporated into the revision of the instruments before they were administered to the research participants.

As presented in Table 1, eight mathematical reasoning items, four mathematical communication items, and all five mathematical problem-solving items satisfied the validity criteria and were retained for the main study. The retained items were subsequently subjected to reliability analysis using Cronbach's Alpha coefficient to determine the internal consistency of each instrument. The results of the reliability analysis are presented in Table 2.

Table 1. Summary of Instrument Validity Test Results

Variables	**Initial Items**	**Valid Items**	**Invalid Items**
Mathematical Reasoning Ability	14	8	6
Mathematical Communication Ability	8	4	4
Mathematical Problem-Solving Ability	5	5	0

Table 2. Reliability Test Results

Variables	**Valid Items**	**Category Alpha**	**Category**
Mathematical Reasoning Ability	8	0.660	Moderate
Mathematical Communication Ability	4	0.637	Moderate
Mathematical Problem-Solving Ability	5	0.821	High

The internal consistency of each instrument was subsequently examined using Cronbach's Alpha. The obtained reliability coefficients indicated that all research instruments satisfied the acceptable reliability criteria for educational measurement, demonstrating that each instrument consistently measured the intended construct and was therefore appropriate for data collection and subsequent statistical analysis.

To ensure objective assessment, students' responses were scored using predetermined scoring rubrics developed for each instrument. The scoring process emphasised both procedural accuracy and the quality of students' mathematical reasoning and written communication. This scoring procedure enabled the collected data to represent students' actual cognitive performance across the investigated variables.

Data collection was conducted after obtaining formal approval from the school administration and coordinating with the mathematics teacher responsible for the participating classes. Before administering the research instruments, students were informed of the study's objectives, the voluntary nature of their participation, and the confidentiality of their responses. The researcher also provided instructions regarding the procedures for completing each instrument to ensure that all participants clearly understood the testing process.

The three essay-based instruments, namely the Mathematical Reasoning Ability Test, the Mathematical Communication Ability Test, and the Mathematical Problem-Solving Ability Test, were administered during regular mathematics learning sessions. Students completed the tests individually under the supervision of the researcher and the classroom teacher. Upon completion, all answer sheets were collected, scored according to predetermined scoring rubrics, and tabulated into a database for statistical analysis. Prior to hypothesis testing, the collected data were checked for completeness, consistency, and scoring accuracy to ensure the dataset's quality.

The collected data were analysed using IBM SPSS Statistics. Descriptive statistical analysis was first conducted to summarise the characteristics of each research variable, including the mean, standard deviation, minimum, and maximum scores. These descriptive statistics provided an overview of students' mathematical reasoning, communication, and problem-solving abilities before inferential analysis was performed.

Before testing the research hypotheses, several classical assumption tests were conducted to assess the suitability of the regression model. The normality test was performed to determine whether the data were normally distributed. The linearity test was employed to examine the linear relationship between each independent variable and the dependent variable. In addition, the multicollinearity test was conducted using the Tolerance and Variance Inflation Factor (VIF) values to identify potential correlations among the independent variables. A heteroscedasticity test was also performed to verify the homogeneity of residual variance across the regression model.

Following confirmation that the regression assumptions were satisfied, multiple linear regression was conducted to examine the individual and simultaneous contributions of mathematical reasoning and mathematical communication to students' mathematical problem-solving. The significance of each independent variable was evaluated using the t-test, whereas the overall significance of the regression model was examined using the F-test. Furthermore, the coefficient of determination (R^2) was calculated to estimate the proportion of variance in students' mathematical problem-solving ability explained by both mathematical reasoning and mathematical communication. Statistical significance was determined at the 0.05 significance level.

This study adhered to the ethical principles governing educational research. Participation was entirely voluntary, and students were informed that their responses would be used solely for academic research. The identities of all participants were kept confidential throughout the research process by anonymising the collected data prior to statistical analysis. The study did not involve any interventions that could negatively affect participants' learning activities, and all research procedures were conducted with the participating school's permission.

3. RESULTS AND DISCUSSION

3.1 Result

Descriptive statistical analysis was conducted to provide an overview of students' performance on the three research variables before inferential statistical analyses were performed. The descriptive statistics included the number of participants, minimum, maximum, mean, and standard deviation for mathematical reasoning ability, mathematical communication ability, and mathematical problem-solving ability. The results are presented in Table 3.

As shown in Table 3, students obtained the highest mean score in mathematical reasoning ability (M = 83.48, SD = 4.09), followed by mathematical communication ability (M = 78.91, SD = 3.55). In contrast, mathematical problem-solving ability yielded the lowest mean score (M = 63.83, SD = 5.71). Moreover, the larger standard deviation for mathematical problem-solving ability indicates greater variability in students' performance than for the other two variables. Overall, these descriptive statistics demonstrate that the dataset exhibits sufficient variation across all research variables, providing an appropriate basis for the subsequent assumption tests and multiple linear regression analysis.

Table 3. Descriptive Statistics of Research Variables

Variable	N	Minimum	Maximum	Mean	SD
Mathematical Reasoning Ability	23	76.00	90.00	83.48	4.09
Mathematical Communication Ability	23	71.00	87.00	78.91	3.55
Mathematical Problem-Solving Ability	23	53.00	77.00	63.83	5.71

Prior to conducting the multiple linear regression analysis, a series of classical assumption tests was performed to assess whether the collected data met the statistical assumptions required for regression. These tests comprised the normality, multicollinearity, and heteroscedasticity tests. Satisfying these assumptions is essential to ensure that the regression model produces valid, reliable, and unbiased parameter estimates. The results of each assumption test are presented as follows.

The normality test was performed using the Kolmogorov–Smirnov test, supported by a visual examination of the Normal Probability-Probability (P–P) Plot of standardised residuals. This procedure was conducted to determine whether the research data followed a normal distribution, a fundamental assumption underlying multiple linear regression analysis. The results of the statistical normality test are presented in Figure 1.

		Unstandardized Residual
N		23
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	2.06890948
Most Extreme Differences	Absolute	.160
	Positive	.124
	Negative	-.160
Test Statistic		.160
Asymp. Sig. (2-tailed)		.131[c]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Figure 1. Results of the Normality Test

As presented in Figure 1, the One-Sample Kolmogorov–Smirnov test produced an Asymp. Sig. (2-tailed) value of 0.131, which is greater than the significance level of **0.05**. Therefore, the null hypothesis stating that the residuals are normally distributed cannot be rejected. This result indicates that the residuals of the multiple linear regression model follow a normal distribution and satisfy the normality assumption required for regression analysis.

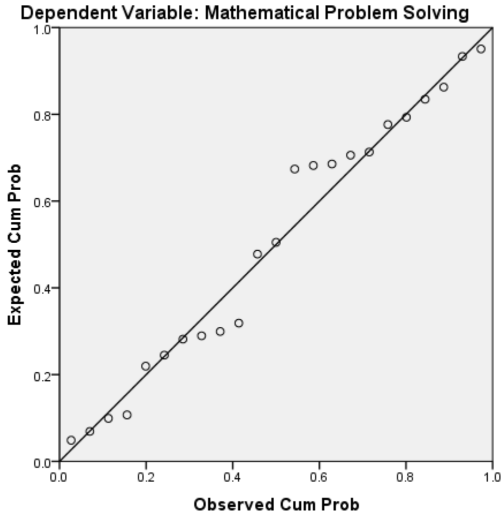

Figure 2. Normal P–P Plot of Standardised Regression Residuals

Having confirmed that the residuals are normally distributed, the next assumption examined was the absence of multicollinearity among the independent variables. This test was necessary to ensure that mathematical reasoning ability and mathematical communication ability provide independent information when predicting students' mathematical problem-solving ability.

The multicollinearity test was conducted using the Tolerance and Variance Inflation Factor (VIF) statistics. These indicators were used to assess whether a high degree of correlation existed among the independent variables, as excessive multicollinearity can distort regression coefficients and reduce the stability of the regression model. The results are presented in Figure 3.

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	-57.158	10.820		-5.282	.000		
	Mathematical Reasoning Ability	.147	.154	.105	.953	.352	.539	1.854
	Mathematical Communication Ability	1.378	.177	.858	7.773	.000	.539	1.854

a. Dependent Variable: Mathematical Problem Solving

Figure 3. Results of the Multicollinearity Test

As shown in Figure 3, both independent variables yielded Tolerance values of 0.539, which are substantially above the minimum acceptable threshold of 0.10. Likewise, the VIF value of 1.854 is considerably lower than the commonly accepted maximum of 10.00. These findings indicate that mathematical reasoning and mathematical communication abilities do not exhibit multicollinearity and can therefore be included simultaneously in the regression model.

Since the independent variables satisfy the multicollinearity assumption, the next step was to examine whether the residual variance remained constant across the predicted values. This evaluation used heteroscedasticity tests, both graphical and statistical.

The heteroscedasticity assumption was evaluated through visual inspection of the residual scatterplot and verified statistically using the Glejser test. The scatterplot provides an initial assessment of whether the residuals exhibit a systematic pattern, whereas the Glejser test provides statistical evidence of heteroscedasticity.

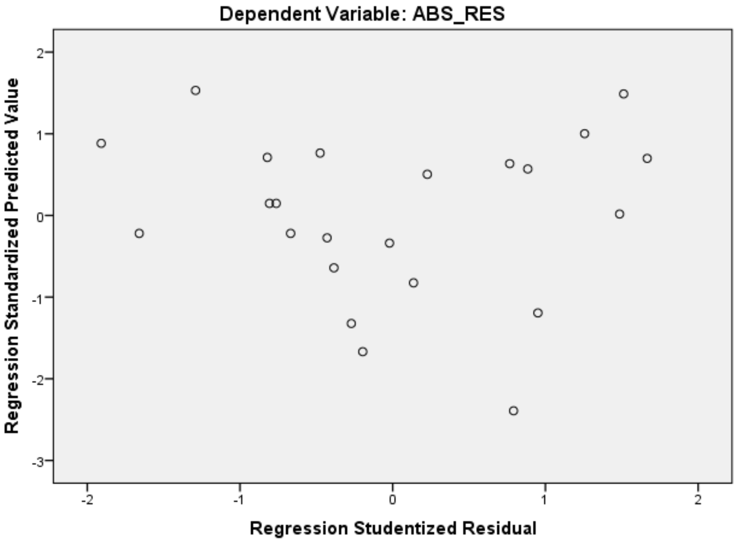

Figure 4. Scatterplot of Standardised Residuals

As illustrated in Figure 4, the residuals are randomly dispersed around the horizontal axis without forming a distinct pattern, funnel shape, or other systematic distribution. This random dispersion indicates that the residual variance remains relatively constant throughout the regression model.

The graphical findings are supported by the Glejser test results, presented in Figure 5.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-2.377	5.178		-.459	.651		
	Mathematical Reasoning Ability	.079	.074	.315	1.068	.298	.539	1.854
	Mathematical Communication Ability	-.031	.085	-.107	-.364	.719	.539	1.854

a. Dependent Variable: ABS_RES

Figure 5. Results of the Glejser Test

The significance values for mathematical reasoning ability (0.298) and mathematical communication ability (0.719) both exceed the 0.05 significance level. Consequently, the regression model does not exhibit heteroscedasticity, indicating that the residual variance is homogeneous across the predicted values.

Taken together, the results of the normality, multicollinearity, and heteroscedasticity tests indicate that all classical assumptions for multiple linear regression have been met.

Therefore, the regression model is considered statistically appropriate for examining the individual and simultaneous contributions of mathematical reasoning and mathematical communication to students' mathematical problem-solving.

The coefficient of determination was calculated to evaluate the explanatory power of the proposed regression model. The results are presented in Figure 6.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.932[a]	.869	.856	2.16989

a. Predictors: (Constant), Mathematical Communication Ability, Mathematical Reasoning Ability

b. Dependent Variable: Mathematical Problem Solving

Figure 6. Coefficient of Determination

As shown in Figure 6, the regression model produced an adjusted R-square of 0.856. This result indicates that 85.6% of the variation in students' mathematical problem-solving ability can be jointly explained by mathematical reasoning and mathematical communication abilities. The remaining 14.4% of the variance is associated with variables not included in the present study. These findings demonstrate that the proposed regression model possesses strong explanatory power in predicting students' mathematical problem-solving ability.

The overall significance of the regression model was evaluated using the F-test. The results are presented in Figure 7.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	623.136	2	311.568	66.172	.000[b]
	Residual	94.169	20	4.708		
	Total	717.304	22			

a. Dependent Variable: Mathematical Problem Solving

b. Predictors: (Constant), Mathematical Communication Ability, Mathematical Reasoning Ability

Figure 7. Result of the F-Test

As shown in Figure 7, the regression model yielded a significance value of 0.000, which is lower than the significance level of 0.05. Therefore, the regression model is statistically significant, indicating that both mathematical reasoning and mathematical communication abilities simultaneously influence students' mathematical problem-solving ability. This finding confirms that the two independent variables together explain variations in students' mathematical problem-solving performance.

The t-test was conducted to determine the individual contribution of each independent variable while controlling for the effect of the other predictor. The results are presented in Figure 8.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-57.158	10.820		-5.282	.000		
	Mathematical Reasoning Ability	.147	.154	.105	.953	.352	.539	1.854
	Mathematical Communication Ability	1.378	.177	.858	7.773	.000	.539	1.854

a. Dependent Variable: Mathematical Problem Solving

Figure 8. Result of the t-Test

Based on Figure 8, the estimated multiple linear regression equation is expressed as:

$$Y = -57.158 + 0.147X_1 + 1.378X_2$$

where Y denotes mathematical problem-solving ability, X_1 represents mathematical reasoning ability, and X_2 represents mathematical communication ability.

The regression coefficient of 0.147 for mathematical reasoning ability indicates that, assuming mathematical communication ability remains constant, each one-unit increase in mathematical reasoning ability is associated with a 0.147-unit increase in students' mathematical problem-solving ability. However, this variable yielded a p-value of 0.352, which exceeds the 0.05 significance level. Accordingly, mathematical reasoning ability does not have a statistically significant effect on students' mathematical problem-solving ability. Therefore, the first hypothesis (H_1) is rejected.

In contrast, the regression coefficient of 1.378 for mathematical communication ability indicates that, with mathematical reasoning ability held constant, each one-unit increase in mathematical communication ability is associated with a 1.378-unit increase in students' mathematical problem-solving ability. The significance value of 0.000 is lower than 0.05, demonstrating that mathematical communication ability has a statistically significant positive effect on students' mathematical problem-solving ability. Therefore, the second hypothesis (H_2) is accepted.

Overall, these findings indicate that although mathematical reasoning and mathematical communication jointly contribute to the proposed regression model, only mathematical communication demonstrates a statistically significant individual contribution to students' mathematical problem-solving ability. The implications of these findings are discussed in the following section by relating the results to relevant theories and previous empirical studies.

3.2 Discussion

The findings of this study demonstrate that mathematical reasoning and communication abilities jointly contribute significantly to students' mathematical problem-solving. The regression model explains 85.6% of the variance in students' mathematical problem-solving performance, indicating that these two cognitive competencies collectively play an important role in supporting students' success in solving mathematical problems. This finding reinforces the theoretical perspective presented in the introduction: mathematical problem solving is a multidimensional cognitive process that requires students to integrate logical reasoning with the ability to communicate mathematical ideas effectively. As argued previously, mathematical reasoning enables students to formulate logical arguments and establish relationships among mathematical concepts, whereas mathematical communication facilitates the representation, explanation, and justification of mathematical thinking throughout the problem-solving process [6]–[15], [22]. The present findings therefore support the proposition that these competencies should be viewed as complementary rather than independent components of mathematical proficiency.

Although the regression model was statistically significant, the partial analysis revealed that mathematical reasoning ability did not significantly influence students' mathematical problem-solving ability. This finding appears to differ from several previous studies that reported a positive relationship between mathematical reasoning and problem-solving [7], [9], [16], [23]. One possible explanation is that students may possess adequate reasoning skills but experience difficulty applying them effectively in complex problem-solving situations. Mathematical reasoning primarily reflects students' ability to analyse relationships, construct logical arguments, and draw conclusions. However, solving mathematical problems requires students not only to reason logically but also to interpret problem situations, organise mathematical information, communicate solution strategies, and verify the correctness of their answers. Consequently, reasoning ability alone may not be sufficient to explain variations in students' mathematical problem-solving performance within the context of this study.

Another plausible explanation concerns the overlap between mathematical reasoning and communication during the regression analysis. Because both variables were entered simultaneously into the regression model, the unique contribution of mathematical reasoning became statistically non-significant after controlling for mathematical communication ability. This finding suggests that students' reasoning processes may be expressed and evaluated primarily through their ability to communicate mathematical ideas. In other words, reasoning that is not effectively represented through mathematical language, symbols, diagrams, or written explanations may not contribute substantially to observable problem-solving performance. This interpretation is consistent with the theoretical framework presented in the introduction, which emphasises that reasoning and communication function as interconnected cognitive processes during mathematical problem solving rather than as isolated competencies [13]–[15], [24].

In contrast, mathematical communication ability made a significant positive contribution to students' mathematical problem-solving. This result indicates that students who can express mathematical ideas clearly, construct appropriate mathematical representations, and communicate logical solution procedures tend to achieve better problem-solving performance. This finding is consistent with previous studies reporting that mathematical communication supports students in translating contextual problems into mathematical models, organising solution strategies systematically, and evaluating the validity of the solutions obtained [10]–[12], [17], [25]. Effective mathematical communication also enables students to externalise their thinking, making it easier to identify relationships among concepts, detect errors in reasoning, and refine solution strategies throughout the problem-solving process.

The significant contribution of mathematical communication further highlights its pedagogical importance in mathematics instruction. Classroom learning that encourages students to explain mathematical ideas, justify their reasoning, engage in mathematical discussions, and present multiple solution strategies may strengthen both conceptual understanding and problem-solving performance. Therefore, mathematics teachers should provide learning environments that actively promote mathematical communication alongside opportunities for reasoning, allowing students to develop these competencies simultaneously. Such instructional practices are expected to improve students' ability to solve mathematical problems across various contexts, particularly when supported by formative feedback that helps them monitor and refine their reasoning [26].

Overall, the findings of this study extend previous research by demonstrating that although mathematical reasoning and mathematical communication jointly explain students' mathematical problem-solving ability, mathematical communication is the stronger individual predictor in the proposed regression model. These findings contribute to the growing body of literature emphasising the importance of integrating multiple cognitive competencies when investigating students' mathematical problem-solving ability and provide empirical evidence that can inform the design of mathematics learning activities aimed at improving students' problem-solving performance, consistent with prior efforts emphasising teachers' role in cultivating students' reasoning skills as part of broader instructional design [27].

4. CONCLUSION

This study investigated the contributions of mathematical reasoning and mathematical communication abilities to students' mathematical problem-solving using multiple linear regression. The findings revealed that the proposed regression model was statistically significant, indicating that mathematical reasoning and communication abilities jointly contribute to students' mathematical problem-solving. Together, these variables explained 85.6% of the variance in students' mathematical problem-solving performance, demonstrating the substantial role of these cognitive competencies in supporting mathematical problem-solving.

At the individual level, the findings showed that mathematical communication ability had a significant positive effect on students' mathematical problem-solving ability, whereas mathematical reasoning ability did not demonstrate a statistically significant independent contribution after controlling for mathematical communication ability. These results suggest that students' success in mathematical problem solving is strongly associated with their ability to express mathematical ideas, construct mathematical representations, and communicate solution strategies systematically. Accordingly, mathematical communication emerges as the dominant predictor of mathematical problem-solving ability within the context of this study.

This study contributes to mathematics education research by providing empirical evidence on the simultaneous relationships among mathematical reasoning, mathematical communication, and mathematical problem-solving within a multiple regression framework. The findings extend previous studies that predominantly examined these competencies separately and highlight the importance of considering multiple cognitive competencies when investigating students' mathematical problem-solving performance, in line with evidence that targeted instructional topics can strengthen students' mathematical communication skills [28].

From a practical perspective, the findings suggest that mathematics teachers should design learning activities that actively encourage students to communicate mathematical ideas through written explanations, mathematical representations, classroom discussions, and justification of solution strategies. Such learning experiences may strengthen students' mathematical communication ability while simultaneously supporting the development of mathematical problem-solving skills, an approach shown to be effective in enhancing students' problem-solving performance in similar instructional contexts [29].

Despite these contributions, this study has several limitations. The research involved a relatively limited number of participants from a single junior secondary school, which may restrict the generalizability of the findings to broader educational contexts. In addition, the regression model included only two predictor variables, whereas students' mathematical problem-solving ability may also be influenced by other cognitive and affective factors, such as conceptual understanding, self-efficacy, metacognitive skills, or learning motivation [30], [31]. Therefore, future studies are recommended to involve larger, more diverse samples, incorporate additional predictor variables, and employ more comprehensive analytical approaches, such as structural equation modelling, to gain a broader understanding of the factors influencing students' mathematical problem-solving ability.

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