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The Influence of Mathematical Comprehension and Connection Abilities on Students' Mathematical Representation Ability

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ABSTRACT

This study aims to identify the influence of mathematical understanding and mathematical connection skills on students' mathematical representation skills. This study is motivated by the low level of students' mathematical representation skills, which is thought to be influenced by limited conceptual understanding and by difficulties connecting mathematical ideas. This study uses a quantitative, correlational design with a sample of class X-1 students at SMA Negeri 1 Arjawinangun. A total of 30 students were selected through cluster random sampling. Data were collected using a validated essay test to measure mathematical understanding, mathematical connection, and mathematical representation skills, and analyzed using multiple linear regression after meeting the classical assumption tests, including normality, multicollinearity, and heteroscedasticity. The results show that mathematical understanding and mathematical connection skills have a positive and significant influence on students' mathematical representation skills, both partially and simultaneously, where mathematical understanding ($\beta = 0.484$, $p < 0.05$) and mathematical connection ($\beta = 0.298$, $p < 0.05$) significantly contribute to the dependent variable. Furthermore, the two variables simultaneously explained 99.6% of the variance in students' mathematical representation skills ($R^2 = 0.996$), indicating a very strong predictive relationship. This finding highlights the importance of strengthening students' conceptual understanding and their ability to connect mathematical ideas to improve mathematical representation skills.

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1. INTRODUCTION

Mathematics is a discipline that plays a crucial role in developing students' logical, analytical, critical, and creative thinking skills. In the context of 21st-century learning, mathematics learning not only focuses on calculation skills but also emphasizes the ability to understand concepts, make connections between concepts, and represent mathematical ideas in various forms [1]. Therefore, mathematics learning in schools should develop a range of interrelated mathematical skills, including mathematical understanding, connections, and representations.

Mathematical comprehension ability is the ability to understand the meaning of a concept, re-explain the concept, and use it in different situations [2]. According to Putra et al. [3], mathematical comprehension ability is one of the important aspects measured in international assessments such as TIMSS. In addition, mathematical connection ability is the ability to connect mathematical concepts within a single topic, between topics, and with real-life contexts [4]. Meanwhile, mathematical representation ability is the ability of students to present mathematical ideas in the form of symbols, images, tables, graphs, or mathematical models to facilitate understanding and problem solving [5]. According to Izzati and Farizi [6], mathematical representation ability is the ability to reinterpret mathematical ideas in various meaningful forms.

The importance of mastering these skills is also evident in international assessments, which show that Indonesian students' mathematical abilities remain relatively low. Data from the Program for International Student Assessment (PISA) shows that Indonesian students' mathematical literacy is below the OECD average. In PISA 2022, Indonesia ranked 69th out of 81 countries with an average score of 379, compared to the OECD average of 472 [7]. These results indicate that most students still struggle to understand concepts, connect ideas, and represent mathematical problems accurately. This finding aligns with research by Prastyo [8], which found that Indonesian students are generally only able to solve routine problems and still struggle with problems that require conceptual understanding and reasoning.

Empirically, low mathematical representation skills were also reported in Afri [9], which showed that students' average representation score was only 10.31 out of a maximum of 28 (36.82%). This indicates that students' ability to communicate and interpret mathematical ideas is still suboptimal. This low mathematical representation ability is suspected to be related to students' low mathematical understanding and connection skills.

Theoretically, mathematical representation skills do not develop in isolation but are influenced by mathematical understanding and connection skills. According to Adliani et al. [10], students with a good conceptual understanding will more easily connect various mathematical ideas and express them in different representations. Komala and Suryadi [11] also stated that mathematical connection skills play a crucial role in building strong internal representations for solving mathematical problems. Siagian [12] emphasized that mathematical connection skills need to be developed because they help students understand the relationships between concepts in mathematics and in everyday life.

From the perspective of 21st-century mathematical literacy, representational skills are also closely related to mathematical modeling and higher-order thinking skills (HOTS). The OECD emphasizes that mathematical literacy involves the ability to formulate, apply, and interpret mathematics through various forms of representation. Heinze et al. [13] demonstrated that the flexible use of various strategies and representations can improve students' ability to understand and solve mathematical problems. Furthermore, Mandur et al. [14] found that mathematical connection skills and mathematical representation skills develop simultaneously during the learning process.

Cognitively, representational ability is related to the semiotic representation theory proposed by Duval [15], which states that mathematical understanding occurs through transformations between various forms of representation. This is reinforced by Cai and Hwang [16], who showed that students with strong mathematical connection skills are better able to transform symbolic representations into visual and verbal ones. Research by Azmidar and Husan [17] also shows that strong conceptual understanding significantly influences students' ability to construct mathematical representations in problem-solving situations.

Several previous studies have examined mathematical understanding, connection, and representation skills separately and within specific learning contexts. Widada et al. [18] found that a realistic learning approach can improve students' mathematical connection and representation skills. Fajriah et al. [19] stated that strong representation skills are essential for students to understand concepts more deeply. Prayitno et al. [20] showed that prospective teachers with a strong conceptual understanding tend to have higher representation skills. Utomo and Syarifah [21] also found that students' difficulties in solving PISA problems are related to their weak ability to connect mathematical information and represent problems.

Although various studies have shown a relationship between mathematical understanding, connection, and representation abilities, most of these studies were conducted in specific learning contexts or using experimental approaches, so there are not many studies that specifically examine the influence of mathematical understanding and mathematical connection abilities on students' mathematical representation abilities simultaneously using a quantitative correlational approach in the context of high school students. Therefore, there is still a research gap that needs further study, especially regarding the extent to which mathematical understanding and connection abilities contribute in predicting students' mathematical representation abilities.

40 Based on these problems, the author plans a problem-solving effort using quantitative research and multiple linear regression to determine the effects of mathematical understanding and mathematical connection abilities on students' mathematical representation abilities. This study aims to analyze the effect of mathematical understanding and mathematical connection abilities on students' mathematical representation abilities both partially and simultaneously.

1 The results of this study are expected to make theoretical contributions to strengthen the study of the relationship between mathematical abilities, as well as practical benefits for teachers in designing learning that emphasizes conceptual understanding and the relationships between concepts, thereby enabling students' mathematical representation 25 abilities to develop optimally. Furthermore, this study is expected to serve as a reference for future research examining the comprehensive development of students' mathematical abilities.

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2. METHOD

41 This study used a quantitative correlational research design to determine the influence of mathematical understanding and connection skills on students' mathematical representation skills. Quantitative research encompasses several research methods in this field [22]. This study did not involve specific learning treatments or experiments, but rather focused on measuring students' abilities through test instruments to obtain empirical data that objectively represent the relationships between variables and analyze the influence between variables using inferential statistics.

The location of this research is SMA Negeri 1 Arjawinangun, Arjawinangun District, Cirebon Regency. This school is registered with the Ministry of Education and Culture as a public school under NPNS 20214971, with A accreditation, using the Merdeka curriculum. The population of this research is all grade X students at SMAN 1 Arjawinangun, totaling 360 students. The research sample consisted of 30 students selected
19 via cluster random sampling, and the selected class was X-1. The research was conducted in the odd semester of the 2025/2026 academic year.

This research examined three main variables: students' mathematical comprehension as the first independent variable (X1), students' mathematical connection
35 ability as the second independent variable (X2), and students' mathematical representation ability as the dependent variable (Y). To analyze the relationships among these variables, a multiple linear regression approach was employed to determine the extent to which mathematical comprehension and mathematical connection abilities contribute to students' mathematical representation ability. From a conceptual perspective, the regression framework used in this study is illustrated in Figure 1, where mathematical comprehension and mathematical connection abilities function as predictor variables influencing students' mathematical representation ability.

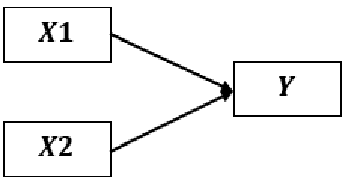

Figure 1. Conceptual Research Model

47 Mathematically, the relationship between variables in this study is formulated through the multiple linear regression equation as follows:

$$\gamma = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \quad (1)$$

With γ representing students' mathematical representation ability, X_1 representing students' mathematical comprehension ability, X_2 representing students' mathematical connection ability, β_0 the constant, β_1 and β_2 the regression coefficients, and ε the error.

Data were gathered using a written test designed in accordance with the theoretical indicators of each research variable. The development of the research instrument began with the construction of a test blueprint to ensure balanced coverage of indicators for the mathematical comprehension, mathematical connection, and mathematical representation ability tests. The mathematical comprehension test was based on indicators such as the ability to restate concepts, classify objects according to given concepts, provide examples and non-examples, apply concepts through various forms of representation, transform representations, and use concepts in problem-solving situations. The mathematical connection test comprised indicators related to linking mathematical ideas across different topics, integrating mathematics with other fields of study, and relating mathematical concepts to real-life situations. Meanwhile, the mathematical representation test was developed using indicators that assess students' ability to generate and use representations to organize, document, and communicate mathematical ideas; convert between different representational forms; and model and interpret physical, social, and mathematical phenomena. Each indicator was assessed using three randomly ordered items.

The mathematical comprehension ability test instrument grid, the mathematical connection ability test, and the mathematical representation ability test are designed to measure students' abilities comprehensively. The mathematical comprehension ability test instrument grid aims to assess conceptual and procedural mastery through questions at cognitive levels C2 to C5, thereby describing comprehension from basic to higher-order thinking. The mathematical connection ability test instrument grid is designed to measure students' ability to link concepts across mathematical topics, other disciplines, and everyday life contexts, and is also designed for cognitive levels C2 to C5. Meanwhile, the mathematical representation ability test instrument grid aims to reveal students' ability to represent mathematical ideas and concepts in various forms, with variations in cognitive levels C2 to C5, so that it can describe students' ability to use and interpret mathematical representations meaningfully.

After developing the test instrument outline, the research instruments used were a mathematical comprehension test, a mathematical connection test, and a mathematical representation test in essay form. The instruments were developed using indicators of each mathematical ability, informed by relevant theoretical studies. Before being used in the research, the instruments underwent expert validation and a pilot test to ensure their suitability.

Instrument validation was conducted through expert judgment involving two mathematics education lecturers from the Syekh Nurjati Islamic State University (Syria) in Cirebon and one mathematics teacher from SMAN 1 Arjawinangun. The experts were asked to assess the suitability of the test items to the ability indicators being measured, the clarity of the language, the appropriateness of the difficulty level to the student's level, and the accuracy of the mathematical concepts. The validation results indicated that the instrument was valid, with several improvements to the question wording and the suitability of the indicators. These improvements were made in accordance with the validator's suggestions.

After expert validation, the instrument was piloted on a limited basis through a preliminary trial on students outside the research sample who shared similar characteristics. The trial was conducted on 30 Tenth-grade students at the same school, but in different classes. The pilot test data were analyzed to determine the validity, reliability, difficulty level, and discriminatory power of the items. The results of the preliminary trial analysis of the three instruments are presented in detail below.

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Table 1. Item Validity, Reliability, Difficulty Index, and Discrimination Power of the Mathematical Comprehension Ability Instrument

Number Questions	Validity		Discrimination Indeks		Difficulty Level		Remarks
	Score	Criteria	Score	Criteria	Score	Criteria	
1	0.154	Invalid	0.100	Bad	0.100	Difficult	Not Used
2	0.138	Invalid	0.025	Bad	0.080	Difficult	Not Used
3	0.470	Valid	0.025	Bad	0.080	Difficult	Used
4	0.575	Valid	0.400	Enough	0.100	Difficult	Used
5	0.505	Valid	0.300	Enough	0.090	Difficult	Used
6	0.437	Valid	0.275	Enough	0.060	Difficult	Used
7	0.688	Valid	0.350	Enough	0.100	Difficult	Used
8	0.808	Valid	0.525	Good	0.100	Difficult	Used
9	0.767	Valid	0.700	Good	0.120	Difficult	Used
10	0.470	Valid	0.550	Good	0.110	Difficult	Used
11	0.844	Valid	0.575	Good	0.080	Difficult	Used
12	0.683	Valid	0.325	Enough	0.070	Difficult	Used
13	0.801	Valid	0.350	Enough	0.070	Difficult	Used
14	0.785	Valid	0.350	Enough	0.070	Difficult	Used
15	0.785	Valid	0.350	Enough	0.070	Difficult	Used
16	0.676	Valid	0.350	Enough	0.080	Difficult	Used
17	0.737	Valid	0.325	Enough	0.080	Difficult	Used
18	0.858	Valid	0.325	Enough	0.080	Difficult	Used
Reliability of the Mathematical Comprehension Ability Instrument Alpha Cronbach = 0.890 Criteria = High							

Based on Table 1 of the mathematical comprehension ability instrument trial, 16 of the 18 questions were declared valid, and 2 were invalid (questions 1 and 2), which were not used in the study. The discriminatory power of the questions was generally in the category of sufficient to good, although some questions had low discriminatory power. In terms of difficulty level, all questions were classified as difficult, indicating a relatively high level of difficulty. Meanwhile, the reliability test results showed a Cronbach's Alpha of 0.89 in the high category, indicating that this instrument is reliable and suitable for use, although it needs improvement in the variation in the difficulty of the questions.

Table 2. Item Validity, Reliability, Difficulty Index, and Discrimination Power of the Mathematical Representation Ability Instrument

Number Questions	Validity		Discrimination Indeks		Difficulty Level		Remarks
	Score	Criteria	Score	Criteria	Score	Criteria	
1	-0.151	Invalid	-0.100	Very Bad	0.410	Medium	Not Used
2	0.681	Valid	0.600	Good	0.320	Medium	Used
3	0.417	Valid	0.300	Enough	0.190	Difficult	Used
4	0.720	Valid	0.500	Good	0.140	Difficult	Used
5	0.663	Valid	0.500	Good	0.120	Difficult	Used
6	0.660	Valid	0.400	Good	0.100	Difficult	Used
7	0.462	Valid	0.200	Enough	0.150	Difficult	Used
8	0.705	Valid	0.500	Good	0.110	Difficult	Used
9	0.584	Valid	0.500	Good	0.120	Difficult	Used
Reliability of the Mathematical Representation Ability Instrument Alpha Cronbach = 0.688 Criteria = Medium							

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Based on Table 2 of the mathematical representation ability instrument, of the 9 items tested, 8 were valid, and 1 was invalid: question 1. The discriminatory power of the questions was dominated by the sufficient and good categories, indicating that the questions' ability to differentiate students' ability levels was adequate. The questions varied in difficulty from moderate to difficult, providing a more diverse distribution of difficulty levels than the previous instrument. The reliability test yielded a Cronbach's Alpha of 0.688, indicating moderate reliability and suggesting the instrument could be improved to increase consistency.

Table 3. Item Validity, Reliability, Difficulty Index, and Discrimination Power of the Mathematical Connection Ability Instrument

Number Questions	Validity		Discrimination Indeks		Difficulty Level		Remarks
	Score	Criteria	Score	Criteria	Score	Criteria	
1	0.615	valid	0.500	Good	0.200	Difficult	Not Used
2	0.533	Valid	0.330	Enough	0.120	Difficult	Used
3	0.679	Valid	0.280	Enough	0.110	Difficult	Used
4	0.844	Valid	0.520	Good	0.140	Difficult	Used
5	0.676	Valid	0.330	Enough	0.110	Difficult	Used
6	0.727	Valid	0.500	Good	0.150	Difficult	Used
7	0.731	Valid	0.300	Enough	0.150	Difficult	Used
8	0.731	Valid	0.340	Enough	0.140	Difficult	Used
9	0.752	Valid	0.550	Good	0.130	Difficult	Used
Reliability of the Mathematical Connection Ability Instrument Alpha Cronbach = 0.866 Criteria = High							

Based on Table 3 of the mathematical connection ability instrument, all 9 questions were deemed valid. The discriminatory power of the questions was in the fair to good category, effectively differentiating student abilities. However, all questions were difficult, indicating a need to adjust to provide greater variation. The reliability test results showed a Cronbach's Alpha value of 0.866, which is in the high category, indicating that this instrument has a good level of consistency and is suitable for use in research.

Data analysis employed a multiple linear regression technique to examine the effect of mathematical comprehension and mathematical connection abilities on students' mathematical representation skills. Prior to performing the regression analysis, several prerequisite assumption tests were carried out, including a normality assessment using the Kolmogorov–Smirnov test and Normal P–P Plot, a multicollinearity evaluation based on Tolerance and Variance Inflation Factor (VIF) criteria, as well as heteroscedasticity detection through scatterplot inspection and the Glejser test. All statistical procedures were implemented at the 5% significance level to confirm the adequacy and robustness of the regression model.

Based on the research conceptual framework and the multiple linear regression model, the relationship among mathematical comprehension ability, mathematical connection ability, and mathematical representation ability was analyzed quantitatively to test the influence of the variables. A statistical hypothesis was formulated to provide direction for empirical testing of the partial and simultaneous influences of independent variables on the dependent variable. Therefore, the research hypothesis is formulated as follows:

1. H0 = Mathematical comprehension and connection skills simultaneously have a significant effect on students' mathematical representation abilities.
2. H1 = Mathematical comprehension and connection skills do not affect students' mathematical representation skills.

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3. RESULTS AND DISCUSSION

Following the analysis of data obtained from the tests measuring students' mathematical comprehension, mathematical connection, and mathematical representation abilities, the subsequent results were identified as follows:

3.1. Data Description of Students' Mathematical Comprehension Ability, Students' Mathematical Connection Ability, Students' Mathematical Representation Ability

Data on the mathematical comprehension ability test, mathematical connection ability test, and mathematical representation test were collected through an essay test comprising 16 questions administered to the sample class, namely class X-1, comprising 30 students. The test results were then processed in SPSS 21. A description of students' perceptions of the three ability tests is presented in Table 4 below. 24

Table 4. Statistical Description of the Results of the Mathematical Comprehension Ability Test, Mathematical Connection Ability Test, and Mathematical Representation Ability Test

	N	Min	Max	Mean	Sum	Std. Deviation
Mathematical Comprehension Ability	30	31	93	69.300	2079	20.849
Mathematical Connection Ability	30	31	100	59.500	1785	22.669
Mathematical Representation Ability	30	31	79	57.800	1734	14.042

Based on the descriptive statistics generated through SPSS, each research variable, mathematical comprehension ability, mathematical connection ability, and mathematical representation ability, comprised 30 respondents. The mathematical comprehension ability variable ranged from 31 to 93, with a mean of 69.300 and a standard deviation of 20.849, 3 indicating relatively wide dispersion in students' abilities. The mathematical connection ability variable ranged from 31 to 100, yielding a 69-point range, with an average score of 39 59.500 and a standard deviation of 22.669, indicating a fairly heterogeneous distribution. In contrast, the mathematical representation ability variable had a minimum score of 31 30 and a maximum score of 79, yielding a range of 48, a mean of 57.800, and a standard deviation of 14.042, suggesting lower variability than the other two variables. Overall, the descriptive statistics indicate that the data across all variables are adequately distributed and suitable for subsequent inferential analysis.

3.2. The Influence of Mathematical Comprehension and Connection Ability on Students' Representation Ability

After obtaining a general overview of the data characteristics through descriptive statistical analysis, the next stage focused on testing the prerequisites for multiple linear regression analysis to ensure that the data met the necessary assumptions before testing the relationships between variables. Testing the assumptions for multiple linear regression begins with a normality test to assess whether the data distribution meets the normality assumptions underlying the parametric analysis.

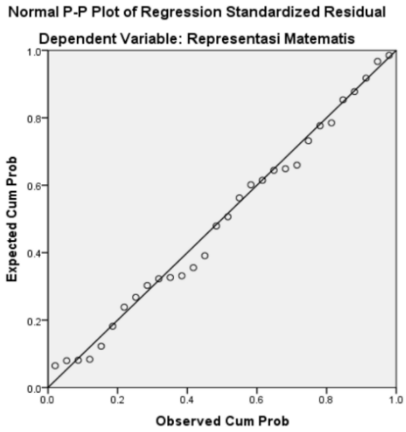

Figure 2. P-P Plot Normality Test

Based on the figure, the residual points appear to be distributed along a diagonal line extending from the lower left to the upper right, with no noticeable extreme deviations. This pattern indicates that the residuals tend to follow a normal distribution, as the discrepancies between the observed and expected cumulative probabilities remain relatively small and within acceptable limits. Therefore, it can be inferred that the normality assumption of the regression residuals has been satisfied, indicating that the regression model is appropriate for subsequent statistical analysis. To further support the visual evidence obtained from the P–P Plot, a statistical normality assessment was additionally performed using the Kolmogorov–Smirnov test.

Table 5. Results of Residual Normality Testing of Regression Model

N		30
Normal Parameters[a,b]	Mean	0.000
	Std. Deviation	0.881
Most Extreme Differences	Absolute	0.083
	Positive	0.083
	Negative	-0.058
Test Statistic		0.083
Asymp. Sig.(2-tailed)		0.200[c,d]

Based on the One-Sample Kolmogorov–Smirnov test conducted on the unstandardized residuals involving 30 observations, the obtained test statistic was 0.083, with an asymptotic significance value (Asymp. Sig. [2-tailed]) of 0.200, which exceeds the predetermined significance threshold of 0.05. These results indicate that the residual distribution does not differ significantly from a normal distribution. Consequently, it can be concluded that the residuals satisfy the assumption of normality, confirming that the regression model is appropriate for further inferential analysis and for interpreting the results. The subsequent analysis, therefore, proceeds to the next prerequisite assessment: the multicollinearity test.

Table 6. Multicollinearity Indicators Between Independent Variables

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	6.523	0.643		10.149	0.000		
	Mathematical Comprehension Ability	0.484	0.009	0.719	55.590	0.000	0.871	1.148
	Mathematical Connection Ability	0.298	0.008	.481	37.153	0.000	0.871	1.148

The results of the multicollinearity test indicate that the mathematical comprehension and mathematical connection ability variables have a tolerance value of 0.871 and a VIF value of 1.148. A tolerance value exceeding the 0.100 threshold indicates that the variance portion of each independent variable that stands independently is at a sufficient level. Correspondingly, a VIF value far below the 10.000 limit indicates the absence of a significant linear relationship between the independent variables in the regression model. This finding confirms that both independent variables are suitable for simultaneous analysis in multiple linear regression without affecting the accuracy of coefficient estimates. This situation reflects the stability of the regression parameters and the absence of overlapping information between predictor variables. With the multicollinearity assumption met, the contribution of each independent variable to the dependent variable can be analyzed independently and objectively. Based on these findings, the testing of the multiple linear regression prerequisites continues with a heteroscedasticity test to assess the uniformity of the residual variance as an indicator of the regression model's feasibility.

Table 7. Results of the Heteroscedasticity Test of Residual Variance (Glejser Method)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	0.355	0.355		1.001	0.326		
	Mathematical Comprehension Ability	4.820E-5	0.005	0.002	0.010	0.992	0.871	1.148
	Mathematical Connection Ability	0.006	0.004	0.266	1.337	0.192	0.871	1.148

Based on the heteroscedasticity assessment of residual variance using the Glejser procedure, the significance values obtained for the mathematical comprehension ability and mathematical connection ability variables were 0.992 and 0.192, respectively, both of which exceed the 0.050 significance level. These findings indicate that neither independent variable has a statistically significant effect on the absolute residual values. Therefore, it can be concluded that the regression model does not exhibit heteroscedasticity, indicating that the homoscedasticity assumption has been met and that the model is appropriate for subsequent statistical analysis.

After all prerequisite assumptions have been satisfied, the influence of the independent variables on the dependent variable can be examined using multiple linear regression. The analysis begins with a simultaneous significance test using the F-test to evaluate the overall significance of the regression model.

Table 8. Simultaneous Regression Model Feasibility Test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5696.290	2	2848.145	3416.266	0.000[b]
	Residual	22.510	27	0.834		
	Total	5718.800	29			

The ANOVA regression analysis yielded an F statistic of 3416.266 and a significance value (Sig.) of 0.000, which is below the 0.05 threshold, indicating that the constructed regression model is statistically significant. These findings demonstrate that, when considered simultaneously, mathematical comprehension ability and mathematical connection ability exert a significant influence on students' mathematical representation ability. This conclusion is further reinforced by the comparison of variance components, where the regression sum of squares (5696.290) substantially exceeds the residual sum of squares (22.510), suggesting that the two predictor variables account for a large proportion of the variability in mathematical representation ability. Given the regression degrees of freedom (df = 2) and residual degrees of freedom (df = 27), the model can be regarded as adequate and appropriate for predicting students' mathematical representation ability based on their levels of mathematical comprehension and connection abilities.

Table 9. Partial Influence of Independent Variables on Students' Mathematical Representation Ability

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	6.523	0.643		10.149	0.000		
	Mathematical Comprehension Ability	0.484	0.009	0.719	55.590	0.000	0.871	1.148
	Mathematical Connection Ability	0.298	0.008	0.481	37.153	0.000	0.871	1.148

Referring to the partial t-test results presented in the table, mathematical comprehension ability shows a t-value of 55.590 with a significance level of 0.000, which falls below the 0.05 criterion, indicating a positive, statistically significant effect on students' mathematical representation ability. The unstandardized regression coefficient (B = 0.484) suggests that an increase of one unit in mathematical comprehension ability is associated with an increase of 0.484 units in mathematical representation ability, assuming other variables remain constant. Similarly, mathematical connection ability also exerts a positive and significant influence, as reflected by a t-value of 37.153 and a significance value of 0.000, with a regression coefficient of B = 0.298, indicating that each one-unit improvement in mathematical connection ability contributes to a 0.298-unit increase in mathematical representation ability. Furthermore, an examination of the standardized beta coefficients reveals that mathematical comprehension ability (β = 0.719) makes a greater contribution than mathematical connection ability (β = 0.481) in accounting for the variance in students' mathematical representation ability.

Based on the results of multiple linear regression analysis, the following regression model equation was obtained:

$$Y = 6{,}523 + 0{,}484X_1 + 0{,}298X_2 \quad (2)$$

In this regression model, students' mathematical comprehension and mathematical connection abilities serve as independent variables. The constant value of 6.523 indicates that when both mathematical comprehension and mathematical connection abilities are assumed to be zero, the predicted value of students' mathematical representation ability is 6.523. The regression coefficient for mathematical comprehension ability is 0.484, with a significance value of 0.000, which is below the 0.05 level, indicating a positive, statistically significant effect on mathematical comprehension ability. This result implies that an increase of one unit in mathematical comprehension ability leads to an increase of 0.484 units in mathematical representation ability. Likewise, the regression coefficient for mathematical connection ability is 0.298 with a significance value of 0.000, indicating a positive and significant contribution to students' mathematical representation ability. Overall, these results confirm that both mathematical comprehension and mathematical connection abilities play a meaningful role in predicting students' mathematical representation ability within the multiple linear regression framework applied in this study.

Table 10. Coefficient of Determination

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	0.998[a]	0.996	0.996	0.91307

Referring to the coefficient of determination results, the correlation coefficient (R) of 0.998 indicates an exceptionally strong association between mathematical comprehension ability, mathematical connection ability and students' mathematical representation ability. The obtained R-squared value of 0.996 indicates that, collectively, the two independent variables account for 99.6% of the variance in mathematical representation ability, while the remaining 0.4% is attributable to other variables not included in the model. Furthermore, the Adjusted R Square of 0.996, which closely approximates the R Square, suggests that the regression model is highly stable and is not substantially affected by the number of predictors. Additionally, the standard error of the estimate, recorded at 0.91307, signifies a relatively low level of prediction error, thereby reinforcing the conclusion that the regression model possesses a high degree of accuracy in predicting students' mathematical representation ability.

The results of this study, which showed a simultaneous contribution of 99.6%, indicate that mathematical representation skills are highly dependent on the foundation of conceptual understanding and connections between concepts. This finding is consistent with a study by Rittle-Johnson et al. [23], which found that conceptual and procedural understanding develop interactively and, together, strengthen symbolic representation skills.

Research by Fauzan et al. [24] shows that students' mathematical representation skills across all school categories can have a positive impact when accompanied by other supporting mathematical methods and skills. Meanwhile, a study by Gravemeijer [25] in the context of Realistic Mathematics Education (RME) showed that developing contextual connections strengthens students' internal representational structures.

Thus, the results of this study strengthen the theoretical framework that mathematical understanding and connections are the main predictors in building meaningful mathematical representation competencies.

4. CONCLUSION

This research demonstrates that mathematical comprehension and mathematical connection skills play a crucial role in developing students' mathematical representation skills. The results confirm that mathematical representation develops through a strong conceptual understanding and the ability to connect various mathematical ideas, thus ensuring that these three skills are interconnected in the learning process.

Theoretically, these findings reinforce the idea that mathematical skills are an inseparable whole. Mathematical understanding forms the basis for building connections between concepts, and both skills support students in representing mathematical ideas more meaningfully. From an educational perspective, these research findings demonstrate that mathematics learning should be designed to focus not only on procedures but also on conceptual understanding, the interrelationships among materials, and the use of various forms of representation to optimally develop students' mathematical thinking skills.

This study has limitations due to its small sample size and the use of only two predictor variables, limiting the ability to generalize the results widely. Therefore, further research is recommended involving a larger sample size, in different school contexts, and incorporating other variables related to higher-order thinking skills or employing a more diverse research approach.

This research is expected to contribute to the development of mathematics learning, particularly by designing learning that integrates conceptual understanding, mathematical connections, and mathematical representations, so that students are better prepared to address various problems in life and in the development of science.

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