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The Effect of Mathematical Connection and Critical Thinking Skills on Mathematical ProblemSolving Skills of Vocational School Students

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Abstract. Mathematical problem-solving skills are an essential competency for vocational school students because they relate to the demands of the world of work that require analysis, reasoning, and proper decision-making. However, the results of observations show that students' problem-solving skills are still low, so a study of the factors that affect them is needed. This research aims to analyze the influence of mathematical connection skills and critical thinking skills on the mathematical problem-solving ability of vocational school students. The study uses a quantitative approach with a correlational ex-post facto type. The research sample amounted to 93 grade XI students of SMK Negeri 1 Doloksanggul who were selected through purposive sampling techniques. The research instruments include mathematical connection tests, critical thinking tests, and problem-solving tests that have been validated and declared reliable. The data were analyzed through simple regression tests and multiple linear regression. The results of the study showed that there was a positive and significant influence of mathematical connection ability on problem-solving ability; there was a positive and significant influence of critical thinking skills on problem-solving skills; and these two variables simultaneously had a significant effect on problem-solving ability. The greatest contribution comes from the ability to think critically. These findings confirm the importance of strengthening mathematical connections and critical thinking in mathematics learning in vocational schools.

Keywords: mathematical connection skills; critical thinking; problem solving; vocational mathematics; *ex-post facto*.

INTRODUCTION

Problems are something that must be solved and thought about deeply (*KBBI*, 2016). In daily life, humans are always faced with various problems, even since infancy. Piaget's theory of cognitive development shows that the process of trial and error at the sensorimotor stage is the initial form of problem-solving activities (Bormanaki & Khoshhal, 2017; Jiang, 2025; Kharitonov, 2023; Sudbery & Whittaker, 2018). Polya (1973) states that problems arise when there is a gap between the actual condition and the expected condition, while the way to solve them is not known directly. Therefore, problem-solving is seen as one of the basic human competencies that develops gradually with age (Amalia et al., 2024; Amalina & Vidákovich, 2023a, 2023b; Ukobizaba et al., 2021).

In the world of education, especially mathematics, problem-solving has a central role in the formation of higher-level thinking skills. Mathematics is not only understood as the science of numbers but as a means for students to develop logical, systematic, and analytical ways of thinking (Aswin et al., 2022; Dhianti Haeruman et al., 2024; Irham et al., 2022; Nurhasanah et al., 2025). NCTM (2000) views problem-solving as an important pillar of mathematics learning because, through this activity, students learn to build conceptual understanding, develop strategies, and evaluate solutions reflectively. Problem-solving is not only a learning goal but also a means to understand mathematical concepts in a more meaningful way.

However, the achievement of students' mathematical problem-solving skills is still far from optimal. Based on the results of initial observations and documentation analysis of the odd-semester final exam scores for the 2024/2025 school year at *SMK Negeri 1 Doloksanggul*, it was found that out of 313 Class X students, as many as 139 students (44.41%) obtained scores below the *KKM* of 60. This incompleteness varies between departments, ranging from 30% to 58%. The diagnostic test instruments used—based on Polya's steps: understanding the problem, planning strategies, executing plans, and re-checking—showed that students were particularly weak in identifying important information, understanding what was being asked, and devising appropriate resolution strategies.

This indicates the weak ability of students' mathematical connections. Mathematical connections refer to the ability to relate mathematical concepts within a topic, between topics, or with real-life contexts (Asfar et al., 2022; Hidayati et al., 2020; Putri et al., 2024; Risdayati et al., 2022). NCTM (2000) emphasizes that connection is one of the five process standards that are essential to creating meaningful mathematics learning. Silver (1997) states that connection skills help students see problems from different perspectives, while Kilpatrick, Swafford, and Findell (2001) assert that connections between concepts support logical reasoning and decision-making. Thus, mathematical connections become an important foundation for students to understand and process information in a problem.

Observations in the classroom show that students who have good mathematical connections are better able to relate concepts to other representations, such as graphs, tables, or mathematical models. On the other hand, students who only rely on memorization tend to stutter when facing contextual problems. In *SPLDV* material, for example, many students simply copy numbers without compiling a proper mathematical model. This condition is in line with the findings of Aszahra and Rosyadi (2024), who reported that students with high connection skills met 58.5% of the problem-solving indicators, while students in the medium category met 41.6% and those in the low category only 25%. These results reinforce the hypothesis that mathematical connections are an important element in predicting successful problem-solving.

Research by Rahmawati and Widodo (2021) shows that critical thinking enables students to interpret problems accurately, analyze relationships between concepts, and draw logical conclusions based on available evidence. Furthermore, Sari, Putra, and Yulianti (2022) argue that critical thinking skills contribute to students' ability to organize mathematical ideas and evaluate problem-solving strategies systematically. Similar findings were also reported by Hidayat et al. (2023), who stated that students with high levels of critical thinking tend to be able to make rational and evidence-based decisions in solving non-routine mathematical problems. In addition, Lestari and Prasetyo (2024) emphasize that mastery of critical thinking indicators such as analysis, evaluation, inference, and self-regulation is positively correlated with student success in problem solving, especially on questions that require high-level reasoning.

Empirical research supports the importance of critical thinking skills in mathematical problem-solving. Nst et al. (2023) show that critical thinking has a significant influence on problem-solving ability with a determination coefficient of 83.7%. Maryam and Pasaribu (2023) found that high levels of critical thinking were positively correlated with problem-solving abilities in the context of physics, which is also relevant to mathematics. Thus, critical thinking is a crucial component for students to understand problems, analyze information, and choose logical solution strategies.

However, field findings show that the critical thinking skills of *SMK Negeri 1 Doloksanggul* students are still low. Students have difficulty interpreting the information in the question, are unable to identify the relationships between variables, and are not used to evaluating the completion process themselves. Many students immediately perform calculations without ensuring whether the calculations are relevant to the context of the problem. This weak evaluative ability causes many answers to be illogical even though the calculations are correct.

The inability of students to make mathematical connections and think critically has a direct impact on the low quality of the problem-solving strategies they use. In contextual problems, students tend to stop at an early stage without proceeding to the steps of planning and reflection. Too procedural learning habits, lack of habituation to face non-routine problems, and limited use of contextual approaches in learning further worsen this condition. Teachers often place more emphasis on procedural completion than on conceptual understanding that connects various mathematical ideas.

In the context of education in vocational schools, problem-solving skills, mathematical connections, and critical thinking are essential. Vocational school students are prepared to face the world of work that requires analytical and adaptive skills. They must be able to connect mathematical concepts with practical applications in the field of expertise, such as accounting, fashion, beauty, tourism, and computer engineering. When connection and critical thinking skills are low, students are unable to solve practical problems such as calculating production costs, analyzing efficiency, or interpreting data. This has the potential to hinder their readiness to enter the world of industry and technology.

The *Kurikulum Merdeka* emphasizes the importance of strengthening high-level thinking competencies, including problem-solving, critical thinking, and mathematical connections. However, the gap between the demands of the curriculum and the reality that occurs at *SMK Negeri 1 Doloksanggul* shows the need for a more effective learning strategy. Problem-based learning, contextual learning, and mathematical discussion are approaches that can help students develop both competencies in an ongoing manner.

Based on the above description, it can be concluded that problem-solving abilities cannot stand alone. The ability to make mathematical connections and the ability to think critically are the two main components that affect the effectiveness of student problem-solving. Students who have good mathematical connection skills can relate concepts, formulate mathematical models, and communicate solution strategies in a more meaningful way. Meanwhile, students with high critical thinking skills are able to analyze information, evaluate strategies, and draw conclusions rationally. These two abilities complement each other in helping students achieve effective and comprehensive problem-solving.

Considering the condition of students and the demands of modern mathematics learning, this study aims to analyze the influence of mathematical connection skills and critical thinking skills on the mathematical problem-solving ability of students at *SMK Negeri 1 Doloksanggul*. Based on the background above, this study aims to analyze the influence of mathematical connection skills and critical thinking skills on the mathematical problem-solving ability of vocational students at *SMK Negeri 1 Doloksanggul*, both partially and simultaneously. This research is expected to make an empirical contribution to the development of more relevant learning models, as well as the basis for efforts to improve the quality of mathematics learning in vocational schools.

MATERIALS AND METHOD

This research used a quantitative approach with a correlational *ex-post facto* research type. This approach was chosen because the research was conducted after the phenomenon occurred without any manipulation or treatment of the free variables, so the researcher only observed the cause-and-effect relationship that had been formed naturally. According to Darmadi (2013), *ex-post facto* research aims to find the possible cause of a change in behavior or symptoms based on the conditions that have occurred. Sappaile (2010) explained that *ex-post facto* research examines cause-and-effect relationships without intervention because the observed program or event has already taken place. This study is correlational because it aims to find out the relationship between mathematical connection skills, mathematical critical thinking skills, and students' mathematical problem-solving skills without giving specific treatment. Thus, this study is included in the non-experimental design.

The research was carried out in the odd semester of the 2025/2026 school year at SMK Negeri 1 Doloksanggul which is located at Jalan Bonan Dolok KM 2.5, Doloksanggul District, Humbang Hasundutan Regency. The population of this study is all XI grade students as many as 313 students from seven majors. The sampling technique uses purposive sampling, selected based on certain criteria relevant to the research objectives, considering that the academic ability of students between classes cannot be ensured to be equal. According to Arikunto (2010), purposive sampling is carried out when the subject is selected based on certain considerations so that the data obtained is more relevant. The number of samples is set at 30% of the total population, which is 93 students, in accordance with Arikunto's (2010) recommendation that for a population of more than 100, the sample of 20–30% is representative. The sample is proportionally divided from each department to accurately reflect population conditions.

The validity of the content was tested through expert assessments that assessed the suitability of the material, language, and question indicators (Masganti & Sitorus, 2011). All instruments are fixed as per the validator's suggestions. The empirical validity was calculated using product moment correlation at a significant level of 5%, and all question items were declared valid because of r_hitung > r_tabel. Reliability was calculated using the Cronbach Alpha formula, resulting in a value of 0.812 for the mathematical connection test, 0.947 for the critical thinking test, and 0.951 for problem solving, all of which fall into the high to very high category (Arikunto, 2013). The differentiating power was calculated using the formula of Arikunto (2013), and all question items were classified as good to very good. The difficulty level of the question is in the medium and difficult category so that the instrument is considered balanced and suitable for use.

Data analysis was carried out using SPSS through several stages. First, a prerequisite test for analysis was carried out including a normality test using Kolmogorov-Smirnov, a linearity test to ensure a linear relationship between variables, a multicollinearity test using tolerance values and VIF to ensure that there is no high correlation between independent variables, as well as homocedasticity test to ensure the similarity of residual variance. After the prerequisites were met, a correlation analysis was carried out to see the simultaneous relationship between X_1 and X_2 to Y using the formula and partial correlation using product moment correlation. The interpretation of correlation coefficients refers to the category.

Furthermore, a simple linear regression analysis was carried out to determine the influence of X_1 on Y and X_2 on Y separately. Multiple linear regression analysis was used to determine the simultaneous influence of X_1 and X_2 on Y by estimating parameters based on the least squared method. The significance of the model was tested using a simultaneous F test to see if the two independent variables together had an effect on Y. A partial t-test was used to determine whether each independent variable had a significant effect on Y after accounting for the other independent variables. Finally, the determination coefficient (R^2) is used to see the magnitude of the contribution of X_1 and X_2 in explaining the variation of Y, where the value of R^2 close to 1 indicates that the model is getting better.

RESULTS AND DISCUSSION

Description of Research Results Data

In collecting research data, several instruments in the form of tests are used to collect data from each research variable. The data described in this study includes mathematical connection ability test data (X_1), mathematical critical thinking ability test (X_2), and a mathematical problem-solving ability test (Y) obtained from 95 students at SMK Negeri 1 Doloksanggul. The results of the calculation can be seen in the following table 1:

Table 1. Summary of Research Variable Value Results

Statistics	X1	X2	Y
Highest Score	92	92	73
Lowest Score	25	4	0
Mean	63,63	47,33	38,64
Standard Deviation	14,623	20,200	20,160

Source: Primary data, processed with SPSS 26 (2025)

1. Mathematical connection capability (X_1)

Based on table 1, the data obtained from the results of the study with a sample number of 95 with the highest value of 92 and the lowest of 25 with an average (M) = 63.63 with a standard deviation (SD) = 14.623 Data frequency distribution of mathematical connection ability variables (X_1) can be seen in the following table 2:

Table 2. Variable Frequency Distribution of Connection Capability (X_1)

No	Interval Classes	Frequency	Cumulative Frequency	Relative Frequency (%)	Cumulative Relative Frequency (%)
1	25 - 33	2	2	2,1	2,1
2	34 – 42	8	10	8,4	10,5
3	43 – 51	16	26	16,8	27,4
4	52 – 60	16	42	16,8	44,2
5	61 – 69	10	52	10,6	54,7
6	70 – 78	34	86	35,8	90,5
7	79 – 87	7	93	7,4	97,9
8	88 - 96	2	95	2,1	100
	Total	95		100	

Source: Mathematical connection ability test results, primary data (2025)

In table 2 above, the mean value of 63.63 is in the interval of 61 – 69, this means that the mathematical connection ability is 10 (10.6%) students are at the average score of the interval class, as many as 42 (44.2%) students are below the average of the interval class, and as many as 43 (45.3%) students are above the average of the interval class. From the results of the frequency distribution variable, the mathematical connection ability (X_1) can be depicted on the histogram of the distribution of values based on frequency as shown in the following figure 1.

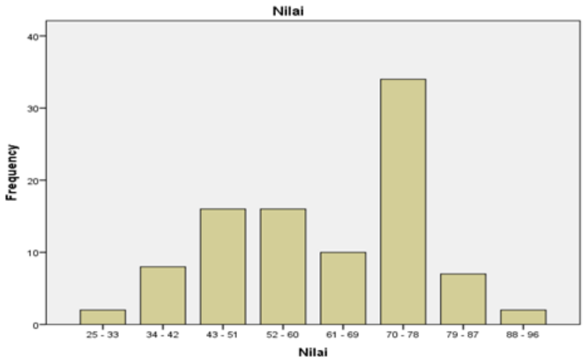

Figure 1 Connection Capability Distribution Diagram

Source: Processed primary data using SPSS 26 (2025)

2. Critical thinking skills (X_2)

Based on the data obtained from the results of the study with a sample of 95, there was the highest score of 92 and the lowest score of 4 with an average (M) = 47.33 and a standard deviation (SD) = 20.200. Data frequency distribution of critical thinking proficiency variable (X_2) can be seen in the following table 3:

Table 3. Frequency Distribution of Critical Thinking Ability Variables (X_2)

No	Interval Classes	Frequency	Cumulative Frequency	Relative Frequency (%)	Cumulative Relative Frequency (%)
1	4 – 15	6	6	6,3	6,3
2	16 - 27	7	13	7,4	13,7
3	28 – 39	22	35	23,2	36,8
4	40 - 51	21	56	22,1	58,9
5	52 - 63	15	71	15,8	74,7
6	64 - 75	18	89	18,9	93,7
7	76 - 87	5	94	5,3	98,9
8	88 - 99	1	95	1,1	100
Total		95		100	

Source: Critical thinking ability test results, primary data (2025)

In table 3 above, the mean value of 47.33 is in the interval of 40 - 51, this means that the mathematical critical thinking ability is 21 (22.1%) students are at the average score of the interval class, as many as 35 (36.8%) students are below the average of the interval class, and as many as 39 (41.1%) students are above the average of the interval class. From the results of the frequency distribution of the critical thinking ability variable (X_2) can be depicted on the histogram of the distribution of values based on frequency as shown in the following figure 2

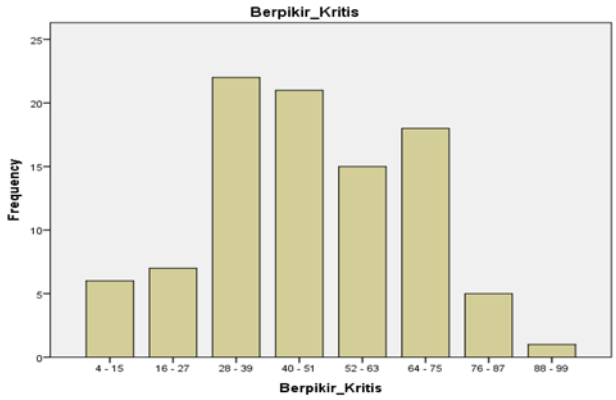

Figure 2 Critical Thinking Ability Distribution Diagram

Source: Processed primary data using SPSS 26 (2025)

3. Problem-solving ability (Y)

Based on the data obtained from the results of the study with a total of 95 samples, there was a high score of 73 and the lowest score of 0 with an average (M) = 38.64 and a standard deviation (SD) = 20.160. The data frequency distribution of the solver (Y) variable can be seen in the following table 4:

Table 4. Frequency Distribution of Troubleshooting Variables (Y)

No	Interval Classes	Frequency	Cumulative Frequency	Relative Frequency (%)	Cumulative Relative Frequency (%)
1	0 – 10	6	6	6,3	6,3
2	11 – 20	13	19	13,7	20,0
3	21 – 30	18	37	18,9	38,9
4	31 – 40	19	56	20,0	58,9
5	41 - 50	10	66	10,5	69,5
6	51 - 60	9	75	9,5	78,9
7	61 - 70	16	91	16,8	95,8
8	71 - 80	4	95	4,2	100
	Total	95		100	

Source: Problem-solving ability test results, primary data (2025)

In table 4 above, the mean value of 38.64 is in the range of 31 – 40, this means that in problem solving skills, there are 19 (20%) students who are in the average score of the interval class, as many as 37 (18.9%) students are below the average of the interval class, and as many as 39 (41%) students are above the average of the interval class. From the results of the frequency distribution variable, the problem-solving ability (Y) can be depicted on the histogram of the distribution of values based on frequency as shown in the following figure 3:

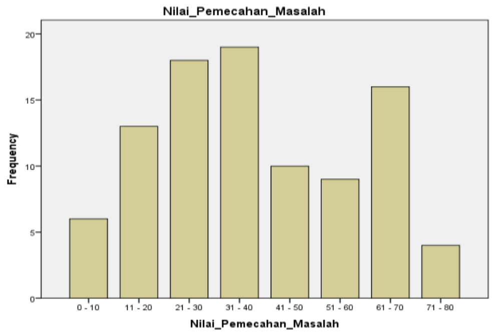

Figure 3. Problem-Solving Ability Distribution Diagram

Source: Processed primary data using SPSS 26 (2025)

4. Results of the analysis prerequisite test

The analysis prerequisite test or classical assumption test is carried out before the hypothesis test using linear regression, there are several prerequisite tests that must be met so that the conclusion of the regression is not biased, namely by the normality test, linearity test, multicollinearity test, homoscedasticity test.

a) Normality Test

The normality test aims to see whether the residual value is normally distributed or not. A good regression model is that it has a normally distributed residual. The hypotheses used are as follows:

H0 : normal distributed residual value

Ha : residual values are not normally distributed

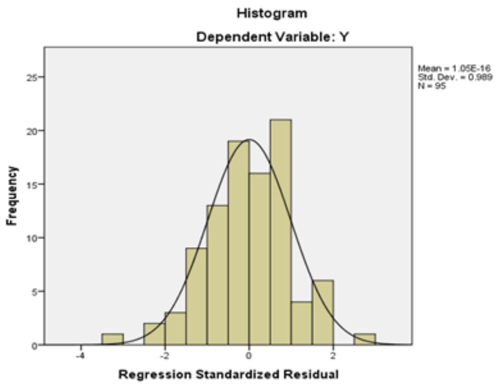

Figure 4. Histogram Chart Normality Test

Source: SPSS 26 output, normality test (2025)

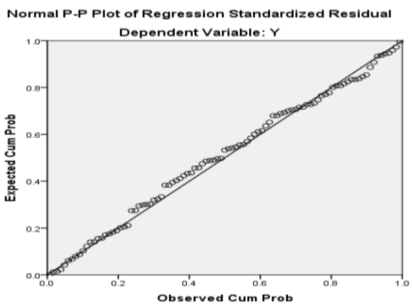

Figure 5. P-Plot Normality Test
Source: SPSS 26 output, P-Plot normality test (2025)

In Figure 4, the normality test based on the histogram graph shows that the distribution pattern is in the middle of the bell-shaped and the points are pressed to the right and left while Figure 5 shows that the points follow and approach the diagonal line so that from the graph and the normality of the P-Plot thus accept H_0 that residual values are normally distributed. Then the normality test is statistically using the Kolmogorov-Smirnov test with the criterion that if the probability > 0.05, then H_0 accepted, which means that the residual value is normally distributed and if the probability is 0.05 then $H\leq_0$ rejected, which means the residual value is not normally distributed. So the results are obtained in table 5 which is calculated using SPSS:

Table 5. Data Normality Test Results

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		95
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	12.97388370
Most Extreme Differences	Absolute	.055
	Positive	.049
	Negative	-.055
Test Statistic		.055
Asymp. Sig. (2-tailed)		.200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

Source: SPSS 26 output, processed from primary data (2025)

From table 5 above, it is obtained that the statistical value of the Kolmogorov Smirnov test is 0.055. In the Asmp line. Sig. (2-tailed) with a significant level = 0.05 then Sig. (p-value) = 0.200 > 0.05 or $H\alpha_0$ is accepted. Thus, the residual value (error) is normally distributed.

b) Linearity Test

The linearity test is a test that aims to find out whether each independent variable has a linear relationship to the bound variable or not. A good regression model is that it has a linear relationship between independent variables and bound variables. The linearity test in this study uses Deviation from linearity on Anova Table at SPSS. The results of the linearity test of this research data are as follows:

1) The results of the linearity test of connection ability, critical thinking ability, and problem-solving ability

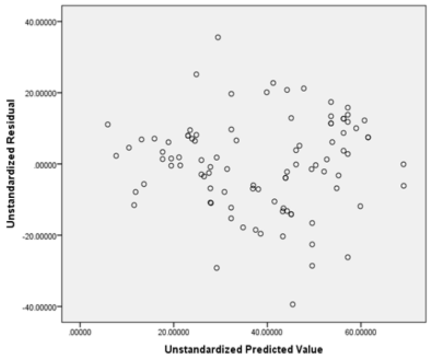

Figure 6. Results of Linearity Test X_1, X2, against Y
Source: Linearity test results, SPSS 26 (2025)

In the figure above, it can be seen that the observation points are evenly distributed around the horizontal line and do not form a specific pattern, while table 6 on the line Deviation from linearity value Sig. 0.060 >0.05 then accept H_0 This means that the regression model is linear Where the error does not have a certain pattern so that the regression model is correct.
2) The results of the linearity test of mathematical connection ability to problem solving ability

Table 6. Results of the Linearity Test X_1 to Y
ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
Y * X1	Between Groups	(Combined)	19430.399	15	1295.360	5.450	.000
		Linearity	17979.911	1	17979.911	75.653	.000
		Deviation from Linearity	1450.488	14	103.606	0.436	.958
	Within Groups		18775.433	79	237.664		
	Total		38205.832	94			

Source: Linearity test results, SPSS 26 (2025)

Based on table 6, the results of the linearity test of connection ability (X_1) to problem-solving ability (Y) can be seen with a value of Sig.>0.05, which is 0.958 >0.05, so it can be stated that connection ability and problem-solving ability have a linear relationship.
3) The results of the linearity test of critical thinking ability on problem-solving ability

Table 7. Results of the Linearity Test X_2 to Y
ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
Y * X2	Between Groups	(Combined)	25121.991	34	738.882	3.388	.000
		Linearity	18992.763	1	18992.763	87.097	.000
		Deviation from Linearity	6129.228	33	185.743	.852	.687
	Within Groups		13083.840	60	218.064		
	Total		38205.832	94			

Source: Linearity test results, SPSS 26 (2025)

Based on table 7 the results of the linearity test of critical thinking ability (X_2) to the problem-solving ability (Y) can be seen as a Sig. > value of 0.05, which is 0.687 > 0.05 so that it can be stated that critical thinking skills and problem-solving skills have a linear relationship.

c. Multicollinearity Test

The multicollarity or double collinearity test is the relationship between independent variables in a double regression model. A good regression model is that there are no symptoms of multicollinearity between independent variables. The multicollinearity test in this study is by looking at the value of Value Inflation Factors (VIF) and Tolerance value using SPSS with the following hypothesis:

H_0 : no multicollinearity

Ha : there is multicollinearity

The testing criteria are as follows:

- If VIF is 10 and the Tolerance value is 0.10, it is concluded that there is no symptom of multicollinearity between independent variables≤≥
- If VIF is 10 and the Tolerance value is 0.10, it is concluded that there are symptoms of multicollinearity between free variables≥≤

From the calculations carried out using SPSS, the results in table 8 are obtained as follows:

Table 8. Multicollinearity Test Results

coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-17.036	6.103		-2.792	.006		
	X1	.542	.122	.393	4.440	.000	.574	1.743
	X2	.447	.088	.448	5.060	.000	.574	1.743

a. Dependent Variable: Y

Source: SPSS 26 output, multicollinearity test (2025)

From table 8, it can be seen that the VIF values are 1.743 and 1.743 respectively less than 10 and the tolerance values are 0.574 and 0.574 which means greater than 0.10, so that H_0 It is accepted that there is no multicollinearity in this study. This means that between the independent variables of connection ability (X_1) and critical thinking skills (X_2) do not interfere with each other's contributions.

d) Homoskedasticity test

The homoskedasticity test is used to determine whether or not the variants of the residual observations are the same or not. A good regression model is that the condition for homocedasticity is met. This test uses SPSS with the following hypothesis:

H_0 : the variance of the error is homoskedasticity or var () = $\hat{\varepsilon_i}\hat{\sigma}^2$

Ha : the variance of the error is homoskedasticity or var() $\hat{\varepsilon_i} \neq \hat{\sigma}^2$

Table 9. Homoskedasticity Test Results

coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.646	3.746		1.507	.135
	X2	.046	.054	.115	.846	.400
	X1	.036	.075	.065	.479	.633

a. Dependent Variable: ABS_res

Source: SPSS 26 output, homoskedasticity test (2025)

From table 9, the value $t_{count} < t_{table}$ namely 0.846; 0.479 < 1.986 and significance value (Sig.) > 0.05 i.e. 0.400 and 0.633 so that H_0 accepted, this means that there is a homocedasticity symptom that indicates that the error of different independent variable values has the same variant value.

5. Simple Linear Regression Analysis

Simple regression analysis is shown to test hypotheses, namely: the influence of mathematical connection ability on mathematical problem-solving ability, and the influence of mathematical critical thinking ability on mathematical problem-solving ability. This simple regression test was used to find out how much each independent variable (mathematical connection ability and mathematical critical thinking ability) separately contributed to the bound variable (mathematical problem-solving ability). The results of this analysis will show whether the relationship that occurs is significant or not, by looking at the value of the regression coefficient, the value of the *t count* Compared *t table*, as well as its significance. Thus, it can be concluded whether the proposed research hypothesis can be accepted or rejected.

Table 10. Test Results of the Influence of Mathematical Connection Ability on Mathematical Problem-Solving Ability

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	17979.911	1	17979.911	82.673	.000[b]
	Residual	20225.920	93	217.483		
	Total	38205.832	94			

a. Dependent Variable: Y
b. Predictors: (Constant), X1

Source: Simple linear regression results, primary data (2025)

From Table 10 it can be seen that the value of F_{count} = 82.673 with a significance of 0.000 < 0.05. This shows that a simple regression model is formed between the ability of mathematical connections (X_1) on mathematical problem-solving ability (Y) is significant. Thus, it can be concluded that there is a positive and significant influence between mathematical connection ability and mathematical problem-solving ability. This means that the better the student's mathematical connection skills, the higher their mathematical problem-solving skills.

Table 11. Results of the Calculation of the Coefficient of Mathematical Connection Ability to Mathematical Problem-Solving Ability

coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-21.540	6.790		-3.172	.002
	X1	.946	.104	.686	9.092	.000

a. Dependent Variable: Y

Source: SPSS 26 output, regression coefficients (2025)

From Table 11, a simple regression model equation can be obtained, namely:
Y= −21.540 + 0.946 X1. From this equation it is shown that every 1-point increase in mathematical connection ability (X1) will increase mathematical problem-solving ability (Y) by 0.946 points, assuming the other variables are fixed. A constant value of -21,540 indicates

that if the mathematical connection ability is zero, then the mathematical problem-solving ability is predicted to be negative, which can practically be interpreted as a very low problem-solving ability. Furthermore, the t-value of calculation = 9.092 with a significance of 0.000 < 0.05, so it can be concluded that the ability of mathematical connections has a positive and significant effect on mathematical problem-solving ability.

Table 12. Test Results of the Influence of Mathematical Critical Thinking Skills on Mathematical Problem-Solving Abilities

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18992.763	1	18992.763	91.934	.000[b]
	Residual	19213.069	93	206.592		
	Total	38205.832	94			

a. Dependent Variable: Y

b. Predictors: (Constant), X2

Source: Simple linear regression results, primary data (2025)

Based on Table 12, the value of F_{count} = 91.934 with a significance (Sig.) of 0.000 < 0.05. This shows that the regression model constructed is significant, so it can be concluded that there is a significant influence between mathematical critical thinking skills (X_2) on mathematical problem-solving skills (Y).

Table 13. Results of the Calculation of the Coefficient of Mathematical Critical Thinking Ability on Mathematical Problem-Solving Ability

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.339	3.773		1.415	.160
	X2	.704	.073	.705	9.588	.000

a. Dependent Variable: Y

Source: SPSS 26 output, regression coefficients (2025)

From Table 13, a simple regression equation is obtained, namely $Y = 5.339 + 0.704 X_2$. This equation shows that every 1-point increase in mathematical critical thinking ability (X_2) will increase mathematical problem-solving ability (Y) by 0.704 points, assuming other variables are fixed. The constant value of 5.339 indicates that if the mathematical critical thinking ability is zero, then the mathematical problem-solving ability is predicted to be worth 5.339. Furthermore, the$_{\text{t-value of calculation}}$ = 9.588 with a significance of 0.000 < 0.05, so it can be concluded that mathematical critical thinking skills have a positive and significant effect on mathematical problem-solving skills.

6. Multiple Linear Regression Analysis

Linear Regression Analysis is shown to test hypotheses, namely: the influence of connection skills, critical thinking skills and mathematical problem-solving abilities of students partially or simultaneously. Statistically, to test the hypothesis, a multiple linear regression model was used, then the significance of the coefficients was tested. From the results of the connection ability, critical thinking ability, and problem-solving ability, the results of the calculation using SPSS were obtained in the following table:

Table 14. Multiple Linear Regression Coefficient Calculation Results

coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-17.036	6.103		-2.792	.006
	X2	.447	.088	.448	5.060	.000
	X1	.542	.122	.393	4.440	.000

a. Dependent Variable: Y

Source: SPSS 26 output, multiple linear regression (2025)

From Table 14, we can see the equation of the multiple linear regression model, namely: Y = -17.036 + 0.542 X_1 + 0.447X2. From this equation, it is interpreted that if the mathematical connection ability (X_1) increases by one unit and the critical thinking ability is constant, then the mathematical problem-solving ability of students (Y) will increase by 0.542 units. Likewise, the students' mathematical critical thinking skills (X_2) will increase by one unit and the mathematical connection ability (X_1) will be constant, so the students' mathematical problem-solving ability (Y) will increase by 0.447 units. The constant value of -17.036 means that if the mathematical connection ability (X_1) and the mathematical critical thinking ability (X_2) are equal to zero, then the student's mathematical problem-solving ability (Y) is predicted to be -17.036. It can be interpreted that without the ability to connect and think critically, students' mathematical problem-solving skills are very low.

By value Standardized Coefficients (Beta) obtained $\beta X_1 = 0.393$ and βX2 = 0.448. This suggests that although both have a positive and significant effect, mathematical critical thinking skills contribute more to mathematical problem-solving skills than mathematical connection skills.

A. Simultaneous F Test

Simultaneous F tests were performed to determine whether the independent variables (X_1 and X_2) together had a significant effect on the bound variable (Y). The hypotheses tested are:

H0 : = 0 β_i the regression model is insignificant)

H1 : 0, i = 1.2 (significant regression model)$\exists_i \ni \beta_i \neq$

The test criteria are: accept Ho if the Sig. value is > 0.05 and minus H_0 if Sig. 0.05. From the calculations carried out using SPSS, the results in table 15 are obtained as follows: ≤

Table 15. Simultaneous Effect Test Results

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22383.596	2	11191.798	65.076	.000[b]
	Residual	15822.236	92	171.981		
	Total	38205.832	94			

a. Dependent Variable: Y

b. Predictors: (Constant), X1, X2

Source: Simultaneous F-test results, SPSS 26 (2025)

From Table 15, it can be seen that the significance value (Sig.) is 0.000 < 0.05. Thus H_0 is rejected and H_1 is accepted, which means that multiple linear regression models involving mathematical connection abilities (X_1) and critical thinking abilities (X_2) together have a significant effect on problem-solving abilities (Y). In other words, the regression equation obtained is a model that is suitable to be used to explain the relationship between X_1 and X_2 with Y. To determine the influence of each independent variable individually, a partial test (t-test) will be carried out.

Partial t-test

T test Partial was conducted to see if there was a significant influence between variable X on variable Y partially. The test is to receive H_0 if the value of Sig. > 0.005. From the previous calculation in Table 14 which was carried out using SPSS, the following results were obtained:

1) The influence of mathematical connection ability on students' mathematical problem-solving ability

The regression coefficient of the variable X_1 is 0.542 with a value of t_{count} = 0.440 and significance 0.000 < 0.05. This shows that the ability to connect mathematical has a positive and significant effect on students' mathematical problem-solving ability. Thus, the better the student's mathematical connection ability, the higher the mathematical problem-solving ability.

2) The effect of mathematical corrective skills on students' mathematical problem-solving ability

The regression coefficient of the variable X_2 is 0.447 with a value of t_{count}= 5.060 and significance 0.000 < 0.05. This shows that critical thinking skills also have a positive and significant effect on students' mathematical problem-solving skills. Thus, improving students' critical thinking skills will contribute to improving mathematical problem-solving skills.

Coefficient of Determination (R^2)

The determination coefficient is a measure in regression analysis that shows how much independent variables are able to explain the variation of dependent variables. In other words, the determination coefficient is used to find out how well the established regression model can describe the relationship between independent variables and bound variables.

The value of the determination coefficient is expressed in the form of R^2 which ranges from 0 to 1. The closer it is to 1, the greater the proportion of variation of the bound variable that can be explained by the free variable. In contrast, a small R^2 value indicates that the independent variable is only able to explain a small fraction of the variation of the bound variable, while the rest is influenced by other factors outside the model.

Table 16. Determinant Coefficients

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.765**	.586	.577	13.114

a. Predictors: (Constant), X1, X2

Source: SPSS 26 output, coefficient of determination (2025)

Based on Table 16, the value of R = 0.765 was obtained. This R-value indicates the degree of tightness of the relationship between the free variable (mathematical connection ability and critical thinking ability) and the bound variable (problem-solving ability). The number 0.765 indicates that there is a strong and positive relationship between the two independent variables and the bound variables.

Furthermore, a determinant coefficient value (R^2) of 0.586 was obtained. This means that 58.6% of the variation in mathematical problem-solving ability can be explained by the variables of mathematical connection ability (X_1) and critical thinking ability (X_2). Meanwhile, the remaining 41.4% was influenced by other factors that were not included in this regression model.

In addition, the *Adjusted R Square value* of 0.577 indicates a determination coefficient that has been adjusted for the number of independent variables and sample size. This value is slightly lower than R^2, but it is more accurate to use as a measure of how well the model can be applied to the population.

Thus, it can be concluded that the multiple linear regression model obtained has a fairly good ability to explain the relationship between mathematical connection ability and critical thinking ability to students' mathematical problem-solving ability.

Correlational Analysis

Correlation analysis is used to determine the degree of closeness of the relationship between two variables using the Pearson correlation coefficient (r) whose values range from –1 to +1. If the value of r is close to +1, then the relationship between variables can be said to be very strong and positive, which means that an increase in variable X is followed by an increase in variable Y. Conversely, if the value of r is close to –1, then the relationship that occurs is very strong and negative, meaning that an increase in variable X is followed by a decrease in variable Y. Meanwhile, a value of r that is close to 0 indicates that there is no significant relationship between the two variables. To strengthen the interpretation, this correlation value is complemented by a significance value (Sig.) so that if the Sig. value < 0.05, the relationship between variables is statistically significant.

Table 17. Correlation Test Results of Mathematical Connection Ability, Critical Thinking Ability and Problem-Solving Ability

		Y	X1	X2
Y	Pearson Correlation	1	.686**	.705**
	Sig. (2-tailed)		.000	.000
	N	95	95	95
X1	Pearson Correlation	.686**	1	.653**
	Sig. (2-tailed)	.000		.000
	N	95	95	95
X2	Pearson Correlation	.705**	.653**	1
	Sig. (2-tailed)	.000	.000	
	N	95	95	95

**. Correlation is significant at the 0.01 level (2-tailed)

Source: SPSS 26 output, Pearson correlation analysis (2025)

From Table 17 above, it can be stated that:

a. Correlation between the student's mathematical connection ability (X_1) and the student's mathematical problem-solving ability (Y)
b. The value of the Pearson correlation coefficient is 0.686 with a significance value (Sig. 2-tailed) of 0.000 < 0.01. This shows that there is a strong and significant relationship between the ability to make mathematical connections and the mathematical problem-solving ability of students. This means that the higher the mathematical connection ability that students have, the higher their ability to solve mathematical problems

c. Correlation between mathematical critical thinking skills (X_2) and students' mathematical problem-solving skills (Y)
d. The value of the Pearson correlation coefficient is 0.705 with a significance value (Sig. 2-tailed) of 0.000 < 0.01. These results show a strong and significant relationship between critical thinking skills and students' mathematical problem-solving abilities. This can be interpreted that the better the students' critical thinking skills, the better their ability to solve mathematical problems.
e. Correlation between mathematical connection ability (X_1) and mathematical critical thinking ability (X_2)
f. The value of the Pearson correlation coefficient was 0.653 with a significance value (Sig. 2-tailed) of 0.000 < 0.01. These results show a strong and significant relationship between mathematical connection skills and students' critical thinking skills. Thus, students who have good mathematical connection skills tend to also have good critical thinking skills.

In this section, the discussion of research results related to the influence of mathematical connection skills and mathematical critical thinking skills on the mathematical problem-solving ability of vocational school students is described.

1) The effect of mathematical connection ability on students' mathematical problem-solving ability.

According to De Gamboa et al. (2022), mathematical connection ability is the ability of students to see the relationship between concepts, procedures, and representations in mathematics, as well as to relate them to problems or contexts outside of mathematics. For this research at SMK Negeri 1 Doloksanggul, the definition is very relevant because students in SMK not only face mathematical material in theory but also have to apply it in the context of vocational practice, so the ability to relate mathematical concepts to real situations is important

Based on the results of the simple linear regression analysis between the mathematical connection capabilities (X_1) on the mathematical problem-solving ability of students (Y), a correlation coefficient value (R) of 0.686 was obtained. This shows that there is a strong relationship between mathematical connection ability and students' mathematical problem-solving ability. Furthermore, the value of the coefficient of determination (R^2) was 0.471, which means that 47.1% of the variation in students' mathematical problem-solving ability can be explained by mathematical connection ability, while the remaining 52.9% is influenced by other factors outside of this study

The results of this study are in line with the results of research by Lumbanraja, et al. (2024) which show that the ability of mathematical connections has a positive and significant effect on students' problem-solving abilities in SPLDV material in class X of Cinta Kasih Catholic High School Tebing Tinggi FY 2023/2024. It is also in line with the research of Berlinda, et al. (2023) which found that mathematical connection skills have a positive and significant effect on students' mathematical problem-solving abilities. Thus, the two studies reinforce the finding that mathematical connection skills have an important role in improving students' problem-solving abilities.

2) The influence of students' mathematical critical thinking skills on students' mathematical problem-solving abilities.

Critical thinking is the ability to transform acquired information into deep understanding through logical analysis, evaluation, and reasoning. In the context of mathematics learning, mathematical critical thinking can be interpreted as the ability of students to use mathematical knowledge and skills in analyzing problems, evaluating arguments, and making appropriate decisions based on rational reasons. So it can be concluded that mathematical critical thinking is a high-level thinking ability that requires students to not only understand mathematical concepts, but also to study, compare, and evaluate various problem-solving strategies logically and systematically.

Based on the research that has been conducted, the effect of mathematical critical thinking skills on mathematical problem-solving ability was calculated using SPSS, obtained a Sig. value of $0.000 < 0.05$. This shows that students' mathematical critical thinking skills have a positive and significant influence on students' mathematical problem-solving skills. In addition, a correlation coefficient value (R) of 0.705 was obtained, which indicates a strong relationship between mathematical critical thinking skills and mathematical problem-solving skills. The coefficient of determination (R^2) was 0.497, which means that 49.7% of the variation in students' mathematical problem-solving abilities could be explained or influenced by mathematical critical thinking skills, while the remaining 50.3% were influenced by other factors not included in this model.

The results of this study are in line with the results of previous research which showed a relationship between critical thinking skills and problem-solving skills. Perdani, et al. (2023) in their research revealed that there is a significant correlation between critical thinking skills and junior high school students' problem-solving skills in dealing with climate change issues, which shows that the higher the students' critical thinking skills, the better their ability to solve complex problems. In line with that, research conducted by Nur'Aini, et al. (2023) also found that critical thinking skills play an important role in solving numeracy-oriented mathematics problems in algebraic content, where students with better critical thinking skills are able to develop problem-solving strategies more systematically and precisely. Thus, the results of the study strengthen the findings in this study that critical thinking skills are closely related to mathematical problem-solving skills.

3) The influence of students' mathematical connection ability and mathematical critical thinking ability on students' mathematical problem-solving ability.

The ability to make mathematical connections and the ability to think critically mathematically have an important role in students' mathematical problem-solving skills. Both abilities have the same purpose in mathematical problem-solving skills. In this case, students are required to be able to see, think and understand the context of the problem situation, so that they are able to solve problems. Problem solving in this case is not only in school learning but also in daily life in the world of work which plays an important role in the era of globalization. This shows that mathematical problem-solving skills are abilities that must be mastered by students during mathematics learning, because in the process students are able to acquire knowledge in skills that can be applied to solving non-routine problems in the world of work.

Based on the results of the study, it was concluded that there was a positive and significant influence between the variables of mathematical connection ability and mathematical critical thinking ability on the mathematical problem-solving ability of vocational school students simultaneously, which was calculated with SPSS by using a Sig. value of 0.000 < 0.05. Likewise, the correlation coefficient (r) of 0.765 with a strong relationship between the ability to connect mathematical and the ability to think critically mathematically to the ability to solve problems simultaneously and Adjusted R Square 0.577 which means that 57.5% of students' mathematical problem-solving skills are influenced by mathematical connection skills and mathematical critical thinking skills, and the remaining 43.5% are influenced by other factors in regression equations.

This research has been tried as much as possible to be able to answer the formulation of the problem in this study, to obtain the results of the contribution between bound variables to independent variables. However, this research is inseparable from the shortcomings and limitations encountered by researchers, so these limitations are expected to open opportunities for other researchers to conduct similar research that is useful for the expansion of educational science, especially at the vocational school level, including:

1. The limitations of the researcher in ensuring the laxity of the process of working on the research instrument are because there are several students who are still discussing in doing the test, so that the desired result is to describe the state of the student's true ability without treatment has not been fully achieved.
2. The researcher could not control other factors that could affect the results of the students' ability tests due to time and such as the psychological factors of the students, gender, achievement and student learning outcomes. So that this study regarding students' mathematical connection ability and mathematical critical thinking ability does not solely have an influence on students' mathematical problem-solving ability, there is a possibility that other factors contribute.

CONCLUSION

The analysis reveals significant partial influences of mathematical connection ability (correlation $r = 0.686$, $R^2 = 0.471$, explaining 47.1% of variance) and mathematical critical thinking skills (correlation $r = 0.705$, $R^2 = 0.497$, explaining 49.7% of variance) on vocational students' mathematical problem-solving ability. Simultaneously, these factors exert a strong combined effect (correlation $r = 0.765$, adjusted $R^2 = 0.577$), accounting for 57.7% of the variance in problem-solving ability, with the remaining 42.3% attributable to other factors; notably, critical thinking skills contribute more substantially ($\beta_{X2} = 0.448$) than connection ability ($\beta_{X1} = 0.393$) per standardized regression coefficients. For future research, studies could explore mediating variables like students' prior knowledge or instructional methods (e.g., problem-based learning) to explain the residual 42.3% variance and test these effects longitudinally across diverse vocational contexts.

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