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Structural Model Between Mathematical Reasoning and Mathematics Problem-Solving Abilities of Junior High School Students

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Abstract

Based on the preliminary survey, it is known that the scores of junior high school students' math problem-solving abilities are low. One of the causes of the low ability to solve mathematical problems is the low ability of students' mathematical reasoning. The purpose of this study was to examine the suitability of the structural equation model for the relationship between mathematical reasoning abilities and mathematical problem-solving abilities. This research design is ex post facto. The population of this study was students of SMP N 1 Bengkulu City, as many as 296 students. A simple sample randomly selected as many as 100 people. The research instrument was a test of mathematical problem-solving ability and a test of mathematical reasoning ability. The data were analyzed through a structural equation model with the help of the Lisrel 8.8 and SPSS programs. The result of this research is that the path efficiency is very significant, meaning that the ability of mathematical reasoning is directly related to the ability of solving mathematical problems. This means that an increase in mathematical reasoning ability leads to an increase in mathematical problem-solving ability. The conclusion of this study is that mathematical reasoning ability is directly related to mathematical problem-solving ability, with the contribution of mathematical reasoning ability to increasing mathematical problem-solving ability of 15.13%. The implication is that in the process of learning to solve mathematical problems, mathematical reasoning abilities are a necessary condition for students before learning to solve mathematical problems.

Keywords: Mathematical Reasoning, Problem-Solving Ability, Structural Mode

Introduction

Mathematics is a compulsory subject for junior high school students, but most students have difficulty learning it. Based on an initial survey conducted by researchers in April-May 2022 at SMP N 1 Bengkulu City, it was found that the score for the math problem-solving ability of these junior high school students was low. The data shows that only 24.24% of students are able to understand problems and only 16.67% of students are able to make mathematical models (see Figure 1).

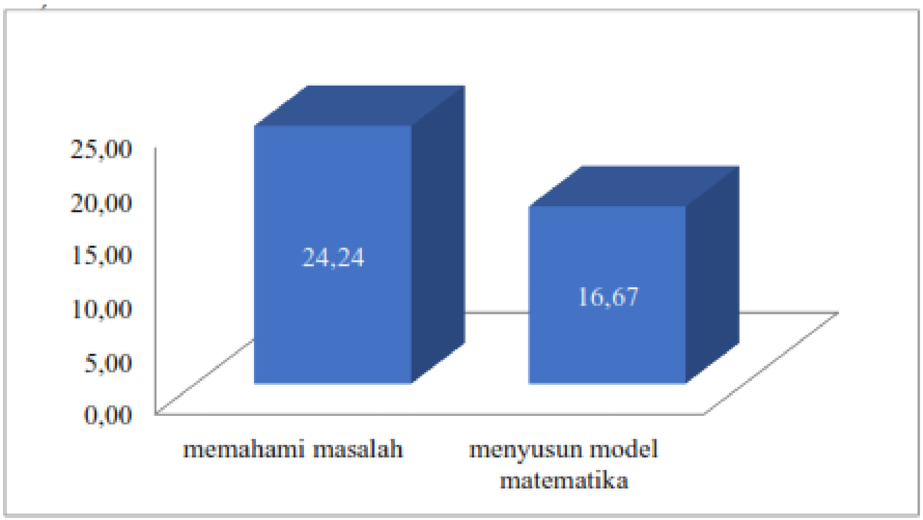

Figure 1. Facts about Mathematics Problem-solving Ability of SMP N 1 Students in Bengkulu City

Based on Figure 1, only 24.24% of students were able to understand the math problems given, one of the proofs was that students did not write down what they knew and what was asked of the questions. Also, only 16.67% of students can make mathematical models correctly, these students solve problems without making mathematical models. One of the causes of low mathematical problem-solving abilities is low students' mathematical reasoning abilities. Problem-solving ability is one of the higher-order thinking skills (HOTS). It is a difficult skill for students (Tanujaya & Mumu, 2020)

A math problem becomes a problem depending on the readiness and situation of the student's prior knowledge and the mathematical content. The situation in a problem is a barrier that is clearly realized or not limited by the subject/student and to overcome it he needs a creative search for new knowledge, ways, and new activities. The barrier is not the only element of the problematic situation, there are other factors as well (Dostál, 2015). Problem-solving is a skill in mathematics that although always relevant has been prioritized due to changes in new mathematics (Bradshaw & Hazell, 2017; Yu, Fan, & Lin, 2015). In a problem-centered curriculum, the types of problems students are asked to solve are important (Lappan et al., 2002). According to him, problems must embody critical concepts and skills and have the potential to engage students in understanding mathematics. Students build understanding by reflecting and communicating, problems need to encourage them to use this process. Therefore, to be able to solve mathematical problems, sufficient mathematical thinking skills are needed. Solving a problem means finding a way out of a predicament, a way around obstacles, and reaching a goal that cannot be achieved immediately (Polya, 1981). Polya further explained that solving problems is a special achievement of intelligence, and intelligence is a special gift of humanity. Solving problems can be considered the most typical human activity.

Theoretical Framework

Problem-solving is a cognitive process that involves physical activity (if needed) to find a solution to the problem at hand. There are four activities carried out in problem-solving, namely understanding the problem, compiling a solution plan through a mathematical model, solving problems according to the mathematical model, and returning the completion of the mathematical model to the initial problem (Polya, 1973). In mathematics, a model is a mathematical formulation obtained through abstraction from a real situation. Making this model aims to facilitate problem-solving. After making a mathematical model using the rules in mathematics, a solution is obtained from the model. This process is a particular difficulty for students in understanding mathematical concepts and principles.

The process of solving problems requires critical thinking and higher-order thinking. Critical thinking is the ability of students to analyze information and ideas carefully and logically from various perspectives. This skill is shown by the ability of students with indicators:

1. Analyze complex issues and make the right decisions
2. Synthesize information to arrive at reasonable conclusions
3. Evaluate the logic, validity, and relevance of the data
4. Use knowledge and understanding to generate and explore new questions

Ability is the ability or ability of an individual to master a skill that is used to do various tasks in a job (Anggo, 2011). Problem-solving ability is a person's ability through a cognitive process to find a way out of difficulties, a way out of obstacles, or achieve goals that cannot be achieved immediately (Polya, 1973). According to him, indicators of problem-solving ability are:

1. Identify the problem (write down what is known and asked from math problems)
2. Planning to problem-solve, writing sketches/drawings/models/formulas/ algorithms to solve problems
3. Solve the problem according to the plan that has been made
4. Interpret the solution to the initial problem

Based on these descriptions can be synthesized as follows. Mathematical problem-solving ability (Ypm) is a cognitive process that can involve physical activity to find a solution to a problem which is measured based on the following indicators:

1. Understanding the problem (Y7)
2. Constructing a mathematical model (Y8)
3. Applying mathematical models to solve problems (Y9)
4. Explain the results according to the original problem (Y10)

Therefore, the relationship between the latent variable Mathematical Solving Ability and the indicator variables, see Figure 2.

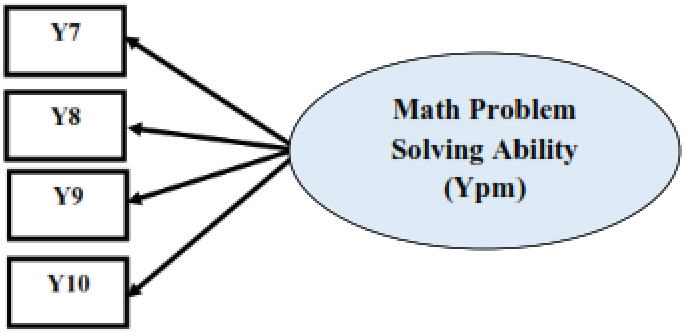

Figure 2. Relationship of Problem-solving Ability and Its Indicators

Mathematical reasoning ability is an important ability in learning mathematics because using reasoning can make sense of mathematics (Lestari, 2019). Mathematical reasoning is a very important cognitive process for students and teachers of mathematics in various conceptualizations of reasoning (Hjelte, Schindler, & Nilsson, 2020). According to him, mathematical reasoning is used in a general-domain way, without restrictions on certain mathematical sub-domains. Reasoning is a process of drawing conclusions and using hierarchical interactionism to look at internal and external factors in mathematical reasoning and learning.

According to NCTM (2000), indicators of mathematical reasoning are (1) making conjectures, performing mathematical manipulations, drawing conclusions; (2) compiling evidence; (3) providing reasons or evidence for the correctness of solutions, drawing conclusions from statements, check the validity of an argument, and find patterns or properties of mathematical phenomena to make generalizations. Thus, mathematical reasoning ability can be measured based on indicators: making conjectures, compiling evidence, and giving reasons from the steps of the proof.

In learning mathematics, mathematical reasoning ability is an important ability in solving problems/problems, also in the process of understanding mathematical objects. Mathematical reasoning is a mathematical cognitive process both inductive and deductive. According to Mhlolo (2012), inductive and deductive reasoning is a series of activities that consciously apply logic to reach a conclusion. The conclusion is obtained from one or more statements that are known so that a decision/conclusion can be made.

These activities start from examples that can be classified and eliminated through an abstraction process into a concept that is obtained through a generalization process.

Reasoning is a mathematical ability that has very complex implications. This complexity causes reasoning to include abilities that are not easily achieved by students (Sukirwan, Darhim, & Herman, 2018). According to Sukiwan et al., that a mathematician must have a very good level of reasoning. Mathematical reasoning abilities play an important role in solving mathematical problems through mathematical reasoning. The results of Hasanah et al. (2019) show that students with high mathematical abilities have good mathematical reasoning abilities. Whereas Sukirwan et al. (2018) state that students generally still have problems with reasoning. Student reasoning tends to be imitative, namely through a routine procedure. The mathematical reasoning abilities of junior high school students can be improved through a problem-solving approach because the increase in the mathematical reasoning abilities of students who use the problem-solving approach is better than students who use conventional learning (Lestari, 2019). This also means that students' mathematical reasoning abilities influence students' ability to solve mathematical problem-solving in geometry (Sandy, Inganah, & Jamil, 2019). Students with a high level of mathematical reasoning are able to fulfill all indicators of reflective thinking processes (Tisngati & Genarsih, 2021). The thinking process includes identifying facts and questions, explaining the operations to be selected, carrying out plans, and providing logical conclusions with indicators students write down the correct final answer based on the sequence of the previous problem-solving process.

Based on the quote above, mathematical reasoning ability (X) is a mathematical cognitive process for connecting existing data or facts so that it arrives at a conclusion that is measured based on the following indicators:

1. Submit an allegation (X1)
2. Compiling evidence (X2)
3. Provide reasons for the steps of proof (X3)

Thus, the relationship between the latent variable Mathematical Reasoning ability and the indicator variables, see Figure 3.

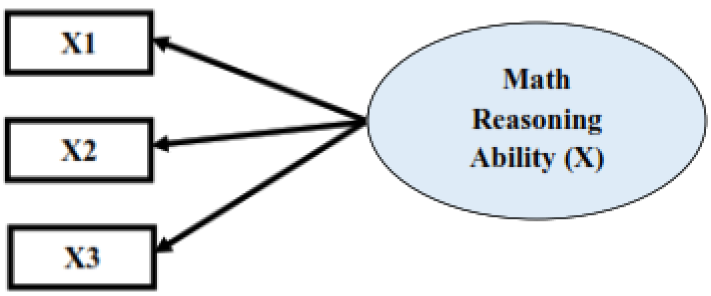

Figure 3. Relationship between Mathematical Reasoning Variables and their Indicators

Results of Tisngati & Genarsih (2021) states that there is a relationship between problem-solving abilities and mathematical reasoning, also with students' reflective thinking abilities. These results mean that mathematical reasoning ability is directly related to problem-solving ability. Similar results were also obtained from other studies. Study of Sandy, Inganah, & Jamil (2019) concluded that students who have a high level of mathematical reasoning ability can solve problems about geometric shapes. Masfingatin, Murtafiah, & Maharani (2020) stated that out of thirty-two students, only one student was identified as having creative mathematical reasoning in solving geometric problems. Students who have low creative mathematical reasoning have difficulty solving problems related to novelty indicators, so they need scaffolding to guide them in solving problems. Hasanah, Tafrilyanto, & Aini (2019) states that students with high mathematical reasoning abilities can solve math problems. Whereas students with low mathematical reasoning abilities are only able to understand the problem. Research results of Inayah (2016) show that students who have high mathematical reasoning abilities have different mathematical communication abilities from students who have low mathematical reasoning abilities. Also, students who have high mathematical reasoning abilities have different mathematical connection abilities from students who have low mathematical reasoning abilities. Therefore, mathematical communication skills affect the ability to solve mathematical problems.

Lestari (2019) concluded that the mathematical reasoning abilities of junior high school students increased if they studied through a problem-solving approach. This means that there is a relationship between reasoning abilities and problem-solving approaches. Research results of Zakir (2015) state that students' mathematical logical reasoning with different thinking styles has an effect on solving mathematical problems Helviyana, Susanti, Indaryanti, Sari, & Simarmata (2020) show that there are students who have inductive reasoning only on generality perceptions and generality expressions where logical analysis gathers facts, assesses or proposes assumptions, and establishes conclusions. Other students are capable of inductive reasoning and only partial logical analysis. Also, there are students who have inductive reasoning and are able to do logical analysis well, namely proposing assumptions, assessing or testing assumptions, and establishing conclusions, so that students are able to solve the problems they face. The results of these studies consistently conclude that mathematical reasoning abilities are directly related to mathematical problem-solving abilities.

Research of Jailani, Retnawati, Apino, & Santoso (2020) resulted in the conclusion that the ability of mathematical connections is directly related to the ability to solve mathematical problems. Similar research results of Kadir, Rochmad, & Junaedi (2020) that students who have high mathematical connection abilities can make it easier to solve math problems. The research of Pambudi, Budayasa, & Lukito (2020) states that students who have good mathematical connection abilities succeed in solving mathematical problems well, on the other hand, students who have low mathematical connection abilities fail in solving mathematical problems. This statement means that there is a positive correlation between the ability of mathematical connections with the ability of students to solve mathematical problems. Research of Mueller, Yankelewitz, & Maher, (2014) states that mathematical reasoning encourages student justification and/or explanation to provide more detailed arguments about strategies, generalize solutions, and/or make mathematical connections. This means that mathematical reasoning abilities encourage students to be able to make mathematical connections.

The results show that there is a direct relationship between mathematical reasoning ability and mathematical problem-solving ability. Therefore, there is a causal relationship between mathematical reasoning abilities and mathematical problem-solving abilities. Look at Figure 4.

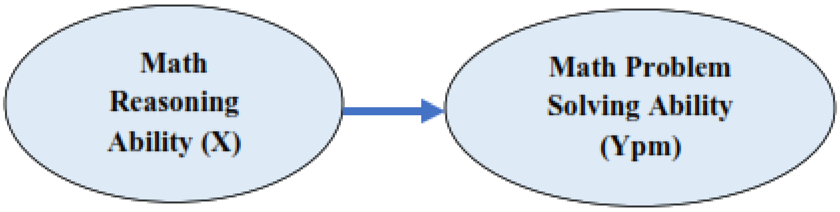

Figure 4. Direct Relationship between Reasoning and Problem-solving

Based on Figures 2, 3 and 4, the theoretical equation model of the relationship between mathematical problem-solving ability and its relation to mathematical reasoning can be seen in Figure 5.

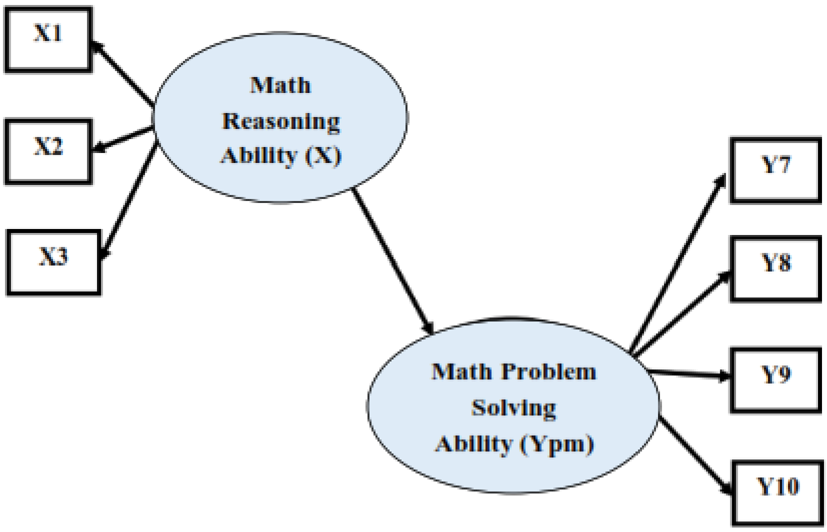

Figure 5. Theoretical Structural Equation Model

Based on Figure 5, the process of solving mathematical problems can be done if students have mathematical reasoning abilities. This is a direct line of mathematical reasoning abilities to mathematical problem-solving abilities. Mathematical reasoning ability (X) is measured based on the indicators: making conjectures (X1); compiling evidence (X2); and provide reasons for the steps of proof (X3). Mathematical problem-solving ability (Ypm) is measured based on the following indicators: understanding the problem (Y7); construct a mathematical model (Y8); applying mathematical models to solve problems (Y9); and 4) explain the results according to the original problem (Y10). Theoretically, an increase in mathematical reasoning ability leads to an increase in mathematical problem-solving ability.

Based on this description, the purpose of this study was to test whether the theoretical structural equation model of the relationship between mathematical reasoning ability and mathematical problem-solving ability is compatible with the empirical model. Also, testing whether mathematical reasoning ability is directly related to mathematical problem-solving ability.

Methods

Based on the facts at SMP N 1 Bengkulu City regarding the ability to solve mathematical problems and this research problem, this research design is ex post facto. The target population in this study was all 296 Grade 8 students of SMP Negeri 1 in Bengkulu City. The composition of Class VIII students at the SMP consists of nine parallel classes with each class containing students with a heterogeneous composition of mathematical abilities. This gives a good probability because every member of the population has the same chance of being a member of the sample. Thus, sample selection can be easily carried out using simple random sampling techniques. The number of samples in this study was 100 people. The sample selection begins by giving a number to each member of the population from 001 to 296, then a series of random numbers are selected using random numbers with the help of the SPSS Application Program.

The implementation of this research will be carried out from August 2022 to December 2022. There are two research instruments, namely: a problem-solving ability test, and a mathematical reasoning test. The two research instruments are valid and reliable. The results of expert validation will be analyzed using panelist tests, namely 1) Test Item Validity with Aiken Test, and 2) reliability test using Anova Hoyt. The expert test that validated the research instrument was 7 (seven) experts, namely 6 Mathematics Education lecturers and 1 mathematics supervisor. Based on Cochran's reference (Cochran, 2005) that each problem-solving ability test item with an average of 0.85 has a high level of validity. In detail, the level of validity of test items 1a, 2a, and 2b is 0.85; while the validity of test items 1b, 1c, 1d, 2c, and 2d were 0.84 each. Overall, the average of Aiken's Validation Index is 0.85. Thus, the Mathematical Problem-solving Ability Test Instrument has eight valid test items through expert validation, namely 1a, 1b, 1c, 1d, 2a, 2b, 2c, and 2d. To determine the reliability level of the instrument's ability to solve mathematical problems, a panel of seven mathematics education experts was tested through the ICC (Intraclass Correlation Coefficients) using Anova Hoyt. The results of the expert assessment of the mathematical problem-solving ability instrument obtained R11 (ICC) = 0.83273 = 0.833. Based on the ICC statistical criteria, that: if $ICC < 0.4$ then the instrument is not reliable; $0.4 \le ICC < 0.75$ the instrument is quite reliable; and if ICC

≥ 0.75, then the instrument is very reliable (Ismunarti, Zainuri, Sugianto, & Saputra, 2020). Thus, it can be concluded that based on the panelist test, the instrument of mathematical problem-solving ability is valid and reliable.

The results of testing the instrument of mathematical problem-solving ability, it can be that the validity of the test items of mathematical problem-solving ability is obtained that all item correlation is significant at the 0.01 level (2-tailed) with sig. 0.000, which means that all of the test items are valid. In detail, the validity level of item 1a = 0.667; item 1b = 0.823; item 1c = 0.789; item 1d = 0.821; item 2a = 0.673; item 2b = 0.754; item 2c = 0.743; and item 2d = 0.676. Thus, it can be concluded that all problem-solving ability test items are valid. Also, the reliability level of Cronbach's Alpha is 0.780. The results show that the reliability level of the test instrument for mathematical problem-solving ability is high.

Experts also agree that each item on the mathematical reasoning ability test has a high level of validity with an average of 0.99. In detail, the validity level of test items 1a, 1b, 1e, 1f, and 2b is 0.99; while the validity of test items 1c, 1d, 1g, and 2c were 0.98 each; and the validity of test item 2a is 0.97. Overall, the average Aiken's Validation Index is 0.99. Thus, the Mathematical Reasoning Ability Test Instrument has eight valid test items through expert validation, namely 1a, 1b, 1c, 1d, 1e, 1f, 1g, 2a, 2b, and 2c. While R11 (ICC) = 0.833. Based on the ICC statistical criteria, that: if ICC <0.4 then the instrument is not reliable; 0.4 ≤ ICC < 0.75 the instrument is quite reliable; and if ICC ≥ 0.75, then the instrument is very reliable (Ismunarti et al., 2020). Thus, it can be concluded that based on the panelist test, the instrument of mathematical reasoning ability is valid and reliable.

The results of testing on 30 students, the validity of the test items for mathematical reasoning ability showed that all items had a significant correlation at the 0.01 level (2-tailed) with sig. 0.000, which means that all of the test items are valid. In detail, the validity level of item 1a = 0.824; item 1b = 0.925; item 1c = 0.835; item 1d = 0.770; item 1e = 0.758; item 1f = 0.900; item 1g = 0.823; item 2a = 0.883; item 2b = 0.877; and item 2c = 0.817. Thus, it can be concluded that all the test items of mathematical reasoning ability are valid. Also, it was found that the reliability level of Cronbach's Alpha was 0.783. The results show that the level of reliability of the test instrument for mathematical reasoning ability is high.

Based on this research problem, the research data is analyzed using inferential statistics. The analysis was preceded by descriptive statistical analysis. Descriptive analysis in the form of data presentation (in the form of frequency distribution tables and histograms), measures of central tendency (in the form of mean, median and mode) and measures of spread (in the form of variance and standard deviation). Inferential statistical analysis is used to test statistical hypotheses in the form of path analysis in a structured equation model, which begins with normality and linearity tests.

Testing the path diagram fit model in a complete structural equation was analyzed using the help of the Lisrel 8.8 application program. The test requirements are, a theoretical model structural equation is said to match the empirical model if:

1. $\chi^2_{hitung}\chi^2_{hitung}$ is small, and P-value ≥ 0,05;
2. The Root Mean Square Error of Approximation (RMSEA) ≤ 0,08; NFI ≥ 0,90; NNFI ≥ 0,90, CFI ≥ 0,90; IFI ≥ 0,90; RFI ≥ 0,90;
3. Root Mean Square Residual (RMR) ≤ 0,05;
4. Standardized Root Mean Square Residual (SRMR) ≤ 0,05;
5. Goods of Fit Index (GFI) ≥ 0,90; dan
6. Adjusted Goodness of Fit Index (AGFI) ≥ 0,9 (or AGFI meets marginal fit).

The above requirements are to test the overall empirical structural equation model. Theoretical structural equation model as a relationship between the latent variables X (Mathematical Reasoning), Mathematical problem-solving (Ypm) with the indicator variables is as follows:

$$Ypm = P_{ypmx}X + P_{y\varepsilon y}\,\varepsilon_y.$$

Tests about the relationship between Mathematical Reasoning Ability (X) and Mathematical problem-solving Ability (Ypm) are tested using the following pairs of hypotheses:

$$H_0: \beta_{ypmx} = 0;$$
$$H_1: \beta_{ypmx} > 0.$$

Based on the structural equation model test, if the path coefficient is obtained X to Ypm (ρypmx), with tcount and sig. < 0,05, Ho rejected, and H1 accepted.

Results and Discussion

The research data is in the form of test scores for the three abilities arranged in a tabulation. Based on the data tabulation of each ability test, it is described using inferential statistical analysis. The statistical test is path analysis in structural equations. In order to be able to perform the inferential statistical test, the analysis prerequisites are first tested, namely the Normality Test and the Linearity Test.

Normality Test

Based on the mathematical reasoning ability (X) score data, the normality was analyzed using the SPSS application to obtain the output as Table 1.

Table 1. Data Normality Test for Variable X

Variable	Kolmogorov-Smirnov[a]

	Statistic	df	Sig.
Math Reasoning Ability (X)	1.149	100	.157

Based on Table 1, it can be seen that the statistical value of the Kolmogorov-Smirnov test for data on mathematical reasoning ability is 1.149 with a Sig. on the Kolmogorov-Smirnova column is 0.157. Based on the normality test criteria, that if the Sig. more than 0.05 then H0 is accepted. This means that data with mathematical reasoning ability (X) comes from a normally distributed population.

Table 2. Ypm Variable Data Normality Test

Variable	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Mathematical Problem-solving Ability (Ypm)	1.084	100	.275

Based on Table 2, the normal distribution test, it can be seen that the statistical value is 1.084 with a Sig. On the Kolmogorov-Smirnova column, it is 0.275. Based on the normality test criteria, if the Sig. more than 0.05 then H0 is accepted. This means that data for mathematical problem-solving ability (Ypm) comes from a normally distributed population.

Linearity Test

The research data was also tested by prerequisites in the form of a linearity test between mathematical reasoning ability (X) and mathematical problem-solving ability (Ypm). The results of the linearity analysis can be summarized in Table 3.

Table 3. Anava Relationship between X and Ypm

			Sum of Squares	df	Mean Square	F	Sig.
Problem-solving Ability * Math Reasoning Ability	Between Groups	(Combined)	1322.049	5	264.410	173.093	.000
		Linearity	1292.773	1	1292.773	846.298	.000
		Deviation from Linearity	9.276	4	2.319	1.517	.231
	Within Groups		143.591	94	1.528		
	Total		1465.640	99			

Based on Table 4, the significance value (sig.) of anava is obtained by the value of Deviation from Linearity F = 1.517 with sig. 0.231 is more than 0.05. Thus, there is a linear relationship between Mathematical Reasoning Ability (X) and Mathematical Problem-solving Ability (Ypm). This can also be described using the F table (Ft), which is based on the F value from the anava table is $F = 1.517$, and F table (4, 94) for a significance level of 5% is $Ft = 2.31$ which means that $F < Ft$, it can be concluded that there is a linear relationship between Mathematical Reasoning Ability (X) and Mathematical Problem-solving Ability (Ypm).

Based on the prerequisite tests (normality and linearity) all met the requirements for statistical hypothesis testing to be able to do this research. However, in the structural equation model, it is necessary to test the suitability of the structural equation model, the validity of the indicator variables, and the reliability of the latent variables.

The research data were analyzed using the Lisrel 8.8 application, a complete structural model was obtained with the observed variables and their outputs. Based on Lisrel's output, the equation model fit test obtained $\chi 2\_count = 14.85$, P-value = $0.127 \geq 0.05$ means good fit. RMSEA = $0.021 \leq 0.08$; means good fit. NFI = $0.93 \geq 0.90$ means a good fit. NNFI = $0.98 \geq 0.90$ good Fft. CFI = $0.95 \geq 0.90$ good fit. IFI = $0.95 \geq 0.90$ good fit. RFI = $0.97 \geq 0.90$ good fit. RMR = $0.032 \leq 0.05$ good fit. SRMR = $0.045 \leq 0.05$ good fit. GFI = $0.45 \geq 0.90$ good fits. Finally, $0.8 \leq AGFI = 0.83 \leq 0.9$ which means marginal fit. This shows that the fit test of the complete structural equation model is suitable. It also means that the theoretical structural equation model is compatible with the empirical structural equation model. Thus, the overall fit test of the model shows the fit model, and it can be concluded that the empirical structural equation model can be used as a basis for data analysis in answering the research problems.

Research data from the measurement results of three latent variables, namely the ability to solve mathematical problems (PMASALAH), and mathematical reasoning abilities (NALAR). Each of these latent variables has several observed variables as measurable indicator variables. The ability to solve mathematical problems is measured through four variable indicators, namely: 1) understanding the problem (Y7), 2) constructing a mathematical model (Y8), 3) applying a mathematical model to solve problems (Y9), and 4) explaining the results according to the original problem (Y10). Meanwhile, mathematical reasoning ability is measured through three indicators as follows: (1) making conjectures (X1); (2) compiling evidence (X2); (3) providing reasons for the steps of proof (X3). Based on the results of data analysis using Lisrel 8.8, presented in the Basic Model Standard Solution Flowchart of the structural equation model (see Figure 6).

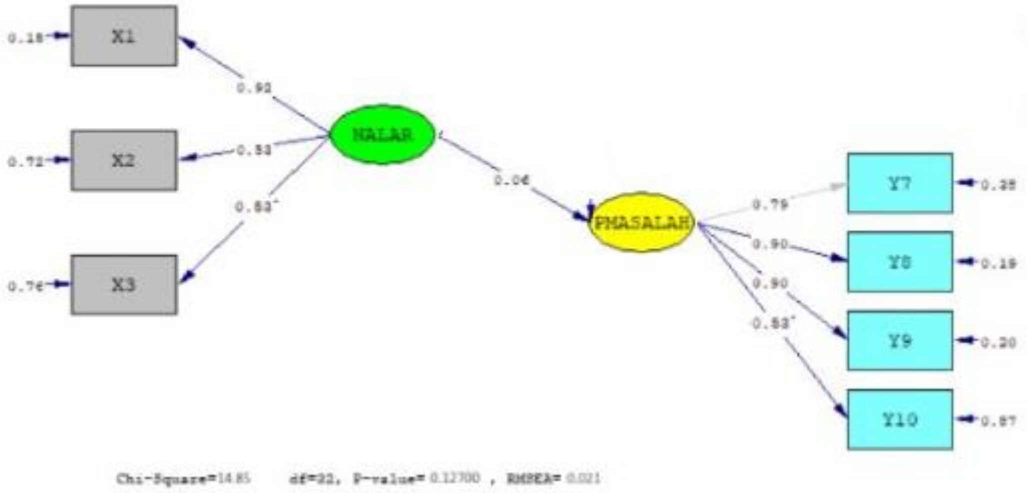

Figure 6. Basic Model Standard Solution

The output of data analysis using the Lisrel 8.8 application also obtained a diagram of the Basic T-Value Model from the structural equation model (see Figure 7). This diagram is a complement to the standard solution diagram used to determine the level of validity of each indicator of latent variables, and the reliability of latent variable measuring instruments. For the standard solution model, each indicator variable is said to be valid if the loading factor value is ≥ 0.50 and the t-value is ≥ 1.96 (based on the T-value diagram of the basic model). Whereas to determine the level of reliability of the latent variable measuring instrument provided that the reliability of the latent variable measuring instrument is reliable if construct reliability (CR) ≥ 0.70 and the value of variance extracted (VE) ≥ 0.50 (Wijayanto, 2008).

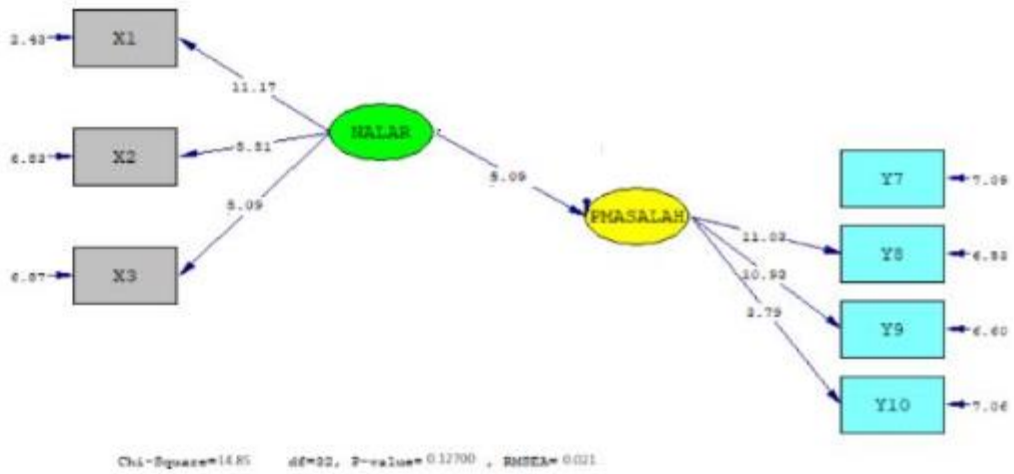

Figure 7. Basic Model T-Score

There are three variables observed from the latent variable of mathematical reasoning ability X1, X2, and X3, each of which has a good level of validity. The validity test for each indicator is fulfilled because the loading factor value is ≥ 0.50 and the t-value is ≥ 1.96. As for the reliability level of the measuring instrument for the variable mathematical reasoning ability, CR = 0.71 > 0.70 and VE = 0.56 > 0.50 which means that the level of reliability for the variable mathematical reasoning ability is very good. So, the instrument of mathematical reasoning ability has a good consistency. For the variable mathematical problem-solving ability, all of the indicator variables (Y7-Y10) have a loading factor value of ≥ 0.50 and each of these indicator variables has a t-value > 1.96. Thus, each indicator variable of mathematical problem-solving ability has a good level of validity. For the reliability value construct (CR) of the latent variable mathematical problem-solving ability is 0.80 > 0.70 and VE = 0.51 > 0.50. It shows that the reliability test of the mathematical problem-solving ability variable is good. So, the latent variable measuring instrument of mathematical problem-solving ability has a good consistency.

Based on the results of prerequisite testing and the suitability of the structural equation model with empirical data that has been fulfilled, the data analysis can proceed to hypothesis testing. Based on the results of calculations and analysis with the help of SPSS, it is possible to present the path coefficient between variables involving the variable's Mathematical Problem-solving Ability (Ypm) and Mathematical Reasoning Ability (X). The data from the research results can be tested individually through the structural equation path coefficients. This was analyzed using SPSS assistance, and the results can be seen in Table 5.

Table 5. Substructural Path Coefficient-1

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	35.754	2.029		17.623	.000
	Math Reasoning Ability (X)	1.128	.171	.389	6.589	.000

Dependent Variable: Mathematical Problem-solving Ability (Ypm)

Mathematical Problem-solving Ability (Ypm) was tested using the following pair of hypotheses:

$$H_0: \beta_{ypmx} = 0$$
$$H_1: \beta_{ypmx} > 0$$

Based on Table 3.5, the path coefficient X to Ypm (ρypmx) is 0.389; with tcount = 6.589; with sig. = 0.000 < 0.05. Because of sig. = 0.000 < 0.05 means that reject Ho, and accept H1. Thus, it can be concluded that the path coefficient is very significant, which means that mathematical reasoning ability is directly related to mathematical problem-solving ability. This means that an increase in mathematical reasoning ability leads to an increase in mathematical problem-solving abilities. To determine the magnitude of ρyεy, R2 is used to obtain ρyεy = 0.238. Thus, the structural equation for Substructure-1 is:

$$Ypm = 0{,}389X + 0{,}238\varepsilon_{ypn}.$$

Based on the structural equation for Substructure-1, an empirical path diagram of the usual relationship between variables can be seen as shown in Figure 8.

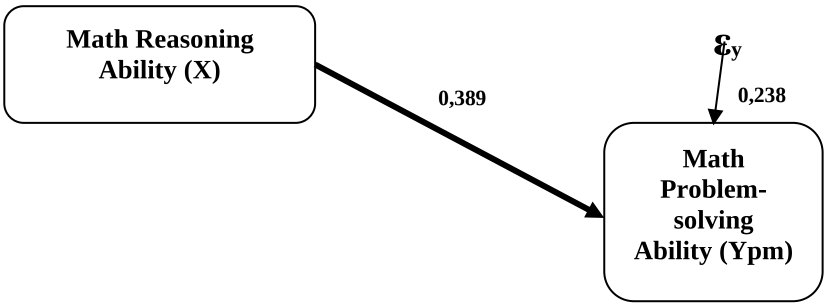

Figure 8. Empirical Model Path Diagram

Based on the hypothesis test and Figure 8, it can be concluded that mathematical reasoning ability is directly related to mathematical problem-solving ability. This means that an increase in mathematical reasoning ability leads to an increase in mathematical problem-solving abilities. The contribution of mathematical reasoning ability to improving mathematical problem-solving ability is 0.3892 = 0.1513 or 15.13%.

The results of this study indicate that students' deficiencies in solving mathematical problems can be seen from the weaknesses of students in understanding the problem, making plans to solve problems through mathematical models, applying mathematical models in solving problems, and explaining the results according to the initial problem. However, by increasing the ability of mathematical reasoning, students experience an increase in their ability to solve mathematical problems. Students can be fostered by increasing their ability to make conjectures, the ability to compile evidence, and the ability to give reasons for proof steps.

Furthermore, based on the analysis, it was found that the t-value of the direct relationship between mathematical reasoning ability and problem-solving ability was t = 5.09 > 1.96. The test is significant which is in line with the conclusion that mathematical reasoning ability has a direct effect on mathematical problem-solving abilities. These results support previous research that students with high mathematical reasoning abilities can solve mathematical problems (Anggoro, Haji, & Sumardi, 2022). Whereas students with low mathematical reasoning abilities are only able to understand the problem (Hasanah, Tafrilyanto, & Aini, 2019). Therefore, an increase in mathematical reasoning ability leads to an increase in mathematical problem-solving ability.

The results of this study indicate that mathematical reasoning skills contribute to an increase in mathematical problem-solving abilities by 15.13%. Masfingatin, Murtafiah, & Maharani (2020) that of the thirty-two students, only one student was identified as having creative mathematical reasoning in solving geometric problems. Students who have low creative mathematical reasoning have difficulty solving problems related to novelty indicators, so they need scaffolding to guide them in solving problems. This shows that mathematical reasoning skills play an important role in solving problems. Tisngati & Genarsih (2021) supports the results of this study, that there is a relationship between problem-solving abilities and mathematical reasoning, also with students' reflective thinking abilities. It means that mathematical reasoning ability is directly related to problem-solving ability. Students who have a high level of mathematical reasoning ability can solve problems about geometric shapes. This shows that mathematical reasoning ability has a direct positive relationship with the ability to solve geometric problems (Sandy, Inganah, & Jamil, 2019) (Widada, Agustina, Serlis, Dinata, & Hasari, 2019) (Herawaty et al., 2021).

The results of this study also support the research of Hasanah, Tafrilyanto, & Aini (2019) that students with high mathematical reasoning abilities can solve mathematical problems. The mathematical reasoning abilities of junior high school students increase if they learn through a problem-solving approach. This means that there is a relationship between reasoning abilities and problem-solving approaches (Lestari (2019). Zakir (2015) and Helviyana, Susanti, Indaryanti, Sari, & Simarmata (2020) also support the results of this study which states that the logical-mathematical reasoning of students with different thinking styles has an effect on solving mathematical problems.

Based on the results of this study and the discussion above, it is significant that students' weaknesses in understanding problems, constructing mathematical models, applying mathematical models to solving problems and explaining results in accordance with the initial problems can be overcome by increasing mathematical reasoning abilities. That is to improve students' abilities in making conjectures, compiling evidence, and giving reasons for proof steps. Discussion of the results of this study suggests that conclusions about mathematical reasoning abilities are directly related to mathematical problem-solving abilities.

Conclusion

Based on the results of data analysis and discussion of the results of this study, it can be concluded that mathematical reasoning abilities are directly related to mathematical problem-solving abilities. This means that an increase in mathematical reasoning ability leads to an increase in mathematical problem-solving abilities. The contribution of mathematical reasoning ability to the improvement of mathematical problem-solving ability is 15.13%. In learning mathematics, it is recommended for teachers to complete mathematical reasoning abilities first before teaching students about mathematical problem-solving abilities. This research is still limited to the qualitative relationship between construct variables, therefore further research is needed in-depth about the description of the qualitative indicators of each of these latent variables. The implication is that in the process of learning to solve mathematical problems, mathematical reasoning abilities are a necessary condition for students before learning to solve mathematical problems.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been covered completely by the authors.

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