p-ISSN 2338 – 3216
e-ISSN 2528 – 1070

JURNAL STATISTIKA
UNIVERSITAS MUHAMMADIYAH SEMARANG
13(1) 2025: 35-44

THE APPLICATION OF THE PATH ANALYSIS MODEL IN DETERMINING THE EFFECT OF IQ AND LANGUAGE SKILLS ON MATHEMATICS LEARNING OUTCOME

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Article Info:
Received: July 29, 2024
Accepted: September 5, 2025
Available Online: September 5, 2025

Keywords:
Path analysis; IQ; Language skill; Mathematics learning outcome.
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Abstract: Mathematics learning outcome is inseparable from many factors that influence it. Intelligence Quotient (IQ) and language skills are several factors that are thought to influence learning outcomes in mathematics. This study aims to determine the path analysis model of the mathematics learning outcome with IQ and language skill as the factors. The population of this research was all the students of Kesatrian I Junior High School, Semarang (SMP Kesatrian I Semarang), and by using a random sampling technique, we took 221 students as the sample. The result shows a significant influence of IQ and language skills on mathematics learning outcomes.

1. INTRODUCTION

Path analysis is a statistical analysis technique developed from multiple regression analysis. This analysis is not used solely to find out the causes that influence a variable. Still, path analysis is used to study the relationship of causal variables (cause and effect) from formulations made by researchers based on theoretical considerations and certain knowledge [1]. In contrast to regression analysis, where the relationship pattern is used to predict the value of the dependent variable based on the value of one or several independent variables, the relationship pattern in path analysis is used to measure the magnitude of the influence of the causal variable on the effect variable. The researcher determines the relationship model between variables using a hypothesis based on previous discoveries.

The application of the path analysis model is very useful for use in various fields such as business and economics, medicine, education, and so on. However, in the field of education itself, there are still few studies that use path analysis techniques, even though this technique helps researchers to understand cases of relationships between several variables that are more complex and cannot be resolved using multiple regression analysis. Based on literature from previous studies, cases in mathematics education that can be studied using path analysis are the influence of intelligence and language skills on mathematics learning outcomes. Howard Gardner states that one form of individual intelligence is verbal/language intelligence and logical/logical-mathematical intelligence [2].

Based on this theory, it is suspected that intelligence influences language abilities and mathematics learning outcomes. Intelligence factors that had not been achieved had an influence of 52.9% on language development disorders in preschool children [3]. The intelligence factor also influences mathematics learning outcomes [4]. A positive influence of

[DOI: 10.26714/jsunimus.13.1.2025.35-44]

language mastery on students' ability to solve mathematics story problems, so it can be said that language ability influences mathematics learning outcomes [5]. Thus, in this research, it is suspected that intelligence influences mathematics learning outcomes both directly and indirectly through language abilities.

2. LITERATURE REVIEW

2.1. The Path Analysis

Path analysis is considered to be a continuation of multiple regression analysis [6]. In multiple regression, we have Independent variables (X) that influence a Dependent Variable (Y). But, in Path Analysis, we have Independent variables (X) that influence a Dependent Variable (Y), and then this Y influences another Dependent Variable (Z). Figure 1 below interprets the possible relationship between Dependent and Independent Variables in the path analysis [7].

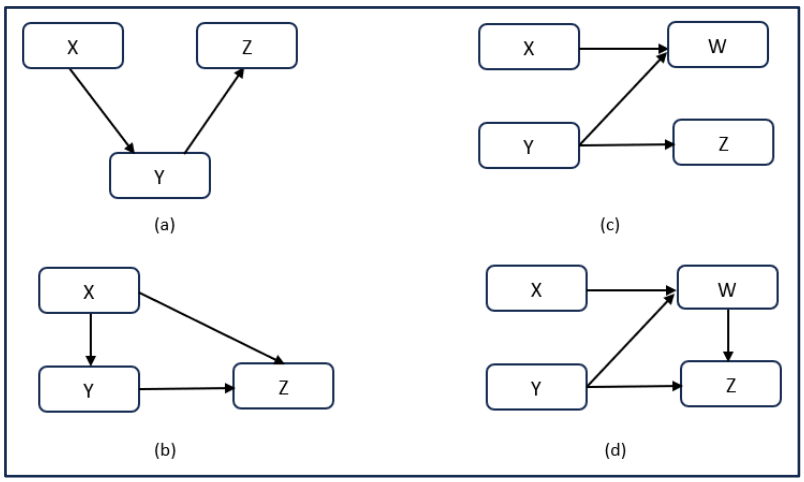

Fig 1. Several Relationships in The Path Model

Seeing Figure 2, then we can build a path analysis model as shown in the following equations (1) and (2).

$$Y = \beta_0 + \beta_1 X + \varepsilon \quad (1)$$

$$Z = \beta_0 + \beta_1 X + \beta_2 Y + \varepsilon \quad (2)$$

Where ε is the error.

2.2. Assumptions

These are some assumptions that should be fulfilled when we build a path model.

2.2.1. Linearity

All connections among variables are assumed to be linear. The validity of a linear model appears plausible since numerous non-linear functions can be effectively represented by linear approximations, especially within a restricted range. In certain cases, non-linearity can be

[DOI: 10.26714/jsunimus.13.1.2025.35-44]

eliminated by transforming the data before statistical analysis; however, some models inherently exhibit non-linear characteristics [8].

2.2.2. Normality

We know that we can assess normality with many methods. But one of the most popular methods is the Skewness and Kurtosis test [9]. We determine the value of Z skewness and Z kurtosis using equations (3) and (4) [10].

$$Z_{skewness} = \frac{\left(\frac{\sum_{i=1}^{n}(x_i - \overline{x})^3}{n}\right)}{\frac{s}{\sqrt{\frac{(6n(n-1))}{(n-2)(n+1)(n+3)}}}} \quad (3)$$

$$Z_{kurtosis} = \frac{\left(\frac{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^4}{n}}{s^4}\right) - 3}{\sqrt{\frac{6n}{(n-2)(n-3)(n+3)(n+5)}}} \quad (4)$$

With n is the amount of data and s is the standard deviation of the data. For a small sample, we reject the null hypothesis when Z skewness and kurtosis are greater than 1.96. For large samples, we can rely on histograms as well as the absolute values of skewness and kurtosis without taking into account z-values. A skewness value greater than 2 or a kurtosis value greater than 7 in absolute terms can serve as threshold values to identify significant departure from normal distribution.

Because path analysis is one of the multivariate models, then we also need to check the normality assumption multivariately. We determine the skewness and kurtosis values by using equations (5) and (6) respectively [9].

$$b_{1,p} = \frac{1}{n^2}\sum_{i,j=1}^{n}\left(\left(\boldsymbol{X}_i - \overline{\boldsymbol{X}}\right)^t \boldsymbol{S}^{-1}\left(\boldsymbol{X}_j - \overline{\boldsymbol{X}}\right)\right)^3 \quad (5)$$

$$b_{2,p} = \frac{1}{n^2}\sum_{i=1}^{n}\left(\left(\boldsymbol{X}_i - \overline{\boldsymbol{X}}\right)^t \boldsymbol{S}^{-1}\left(\boldsymbol{X}_i - \overline{\boldsymbol{X}}\right)\right)^3 \quad (6)$$

Where $\boldsymbol{X}_i^t = \left(X_{1i}, X_{2i}, \ldots, X_{pi}\right)$, i = 1, 2, …, n; is an n vector of independent observations on X, $\overline{\boldsymbol{X}}^t = \left(\overline{X}_{1i}, \overline{X}_{2i}, \ldots, \overline{X}_{pi}\right)$is the sample mean matrix and $\boldsymbol{S}$ is the covariance matrix.

2.2.3. Recursive Relation

Recursive relation means a unidirectional causal model lacks feedback loops or reciprocal effects, with a one-way causal flow. In a recursive model, a variable cannot simultaneously act as both cause and effect [11].

[DOI: 10.26714/jsunimus.13.1.2025.35-44]

2.2.4. Data Measurement Scale

Data measurement scale in Path analysis should be categorized into intervals or ratios.

2.3. Parameter Estimation

Because path analysis is an expansion of regression analysis, then, we can use OLS (Ordinary Least Square) as a method to estimate the parameter. By minimizing the square of errors, then we have the estimation of the parameter as shown in equation (7) [12].

$$\hat{\beta} = (X^t X)^{-1} X^T Y \quad (7)$$

3. METHODOLOGY

This research uses a quantitative research approach and is designed as ex post facto research. The research was conducted at Kesatrian 1 Junior School Semarang in February 2022. Data used in this research is secondary data taken from report cards and IQ test scores. The population in this study was all 328 students of Kesatrian 1 Junior School Semarang. In this research, the sampling technique used is probability sampling, which gives all members of the population an equal opportunity to be selected as samples. Because the data is secondary, the researcher decided to use all the data obtained for analysis. With 236 secondary data obtained, the amount of data that was complete and suitable for analysis was 221 data, so the sample used was 221.

The data collection technique in this research uses documentation. Documentation is a data collection technique using three types of sources, namely writing (paper), place, and people [13]. Data collection with documentation in this research was used to obtain IQ score data as intelligence data, Indonesian language report card scores as language ability data, and mathematics report card scores as mathematics learning outcomes data.

The data analysis technique uses path analysis with assumptions including the relationship between variables is linear and additive, the data is normally distributed, has a recursive relationship pattern, the measurement scale is a minimum interval, sampling uses probability sampling, variables are assumed to be measured without error, and the model is identified based on relevant theories and concepts.

4. RESULTS AND DISCUSSION

4.1. Result

4.1.1. Assumption Check

The first thing that should be checked is the **linearity of variables**. Table 1 shows the linearity test.

Table 1. Linearity Test Result

Variables	F Statistic	F Critical Value
X vs Y	1.146	1.553
X vs Z	1.488	1.553
Y vs Z	1.637	1.694

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Table 1 shows that the value of each F-statistic is smaller than the F-Critical Value, then we can conclude that the relationship among variables is linear.

Meanwhile, the assumption that the relationship model between variables is additive, is proven by the form of path analysis equations (8) and (9) which can be seen that the model used is additive, so the relationship model between variables is additive.

Besides linearity, we also checked the **normality** of the endogen variable. Table 2 shows the skewness and kurtosis coefficient of the endogen variable.

Table 2. Coefficient of Skewness and Kurtosis

Variables	Skewness	Kurtosis
Z	-0.005	0.031

Table 2 shows that the normality test results show a skewness coefficient value of -0.005 and a value of -0.005 kurtosis coefficient is 0.031. Both the skewness coefficient and kurtosis coefficient have values less than 1.96, so the data can be said to be normally distributed.

Next, we checked the **recursive relation** among variables. Figure 2 shows that the relationship between variables has a causal flow system in one direction towards the endogenous variable and there is no reverse flow, so the model has a recursive relationship pattern.

Another thing we checked is about the **data scale**. This research uses secondary data which has a ratio scale measurement. The ratio scale is a data scale similar to the interval scale but with an absolute zero value, so this research variable uses a minimum interval scale.

4.1.2. Hypothesis Test

A path diagram is obtained in Figure 2 below.

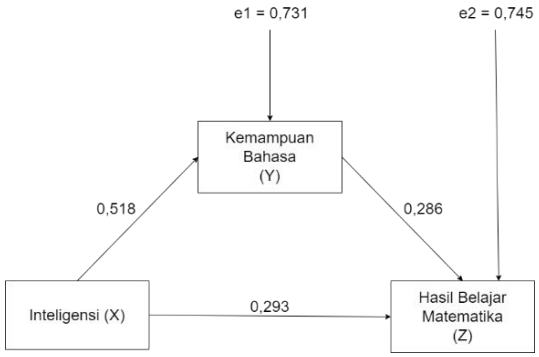

Fig 2. A Path Diagram

Thus, the structural equation is presented in the form of equations (8) and (9).

$$Y = 0{,}518X + 0{,}731 \quad (8)$$

$$Z = 0{,}293X + 0{,}286Y + 0{,}745 \quad (9)$$

Based on the calculations, the results of the path coefficients for direct influence, indirect influence, and total influence between variables with the standardized solution value are shown in Table 3.

[DOI: 10.26714/jsunimus.13.1.2025.35-44]

Table 3. The Path Coefficient

	The Effects		
Variables	Direct	Indirect	Total
X to Y	0.518	-	0.518
X to Z	0.293	0.148	0.441
Y to Z	0.286	-	0.286

As we can see in Table 3, it appears that the direct influence of IQ (X) on language skill (Y) is 0.518 with an absolute contribution of 0.5182 × 100% = 26.8%. The direct effect of language ability (Y) on mathematics learning outcomes (Z) is 0.286 with an absolute contribution of 0.2862 × 100% = 8.2%. Thus, the indirect influence of intelligence (X) on mathematics learning outcomes (Z) through language ability (Y) is 0.518 × 0.286 = 0.148. This shows that there is an indirect influence of intelligence (X) on mathematics learning outcomes (Z) through language ability (Y) of 0.148. Meanwhile, the total influence can be determined by adding up the values of the direct influence and the indirect influence. So, the effect of total intelligence (X) on mathematics learning outcomes (Z) is 0.293 + 0.148 = 0.441 with an absolute contribution of 0.4412 × 100% = 19.4%. The results of path coefficient testing are shown in Table 4.

Table 4. Linearity Test Result

Variables	Path Coefficient	t-value
X to Y	0.518	1.553
X to Z	0.293	1.553
Y to Z	1.637	1.694

From Table 4, we can see that the t-statistic value for IQ (X) on language ability (Y) is greater than the t-table value, which means that the path coefficient for intelligence on language ability is positive and significant. The t-statistical value for IQ (X) on mathematics learning outcomes (Z) is also higher. The value of the t-table is greater, meaning that the path coefficient of intelligence on mathematics learning outcomes is positive and significant. Likewise, the t-statistic value for language ability (Y) on mathematics learning outcomes (Z) is also greater than the t-table value, which means that the path coefficient for language ability on mathematics learning outcomes is positive and significant. Meanwhile, the R-square coefficient of determination is 0.255, meaning that mathematics learning outcomes are influenced by IQ and language skills simultaneously by 25.5% and the remainder is influenced by other variables not included in the model. For model fit, the output is obtained as in Figure 3.

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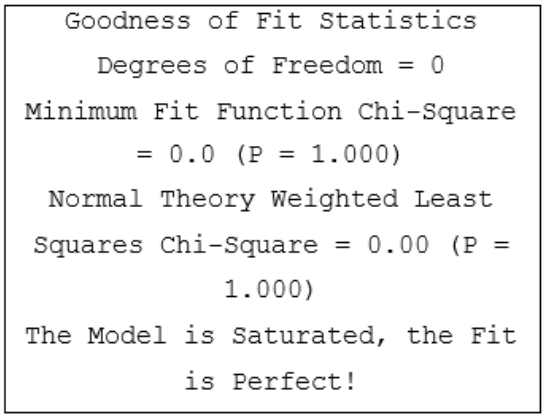

Fig 3. The Goodness of Fit

From Figure 3, we have the Chi-Square value = 0.00, degrees of freedom = 0, and p-value = 1.00 > 0.05. This shows that the theoretical correlation matrix is identical to the empirical correlation matrix, and there are no insignificant path coefficients. So, the model fit is considered very good.

4.2.Discussion

The test results show that there is a positive and significant influence of intelligence on the language abilities of students at Kesatrian 1 Junior School Semarang because the value of t statistic > t critical value is 8.969 > 1.971, whereas in the research the direct influence of intelligence on language abilities is 0.518 with an absolute contribution of 26.8 %. Each individual's language development is related to cognitive development, which means that intelligence is one of the factors that greatly influences the development of language abilities [14]. In general, individuals with a normal intelligence category will have good language skills, while individuals with a high intelligence category will be able to read and understand speech at a relatively young age. The same thing was also stated by Yusuf, namely that intelligence is one of the factors that influence language development. Where the language development of individuals with a normal level of intelligence or above will be faster than individuals who experience mental slowness which makes it difficult for them to speak[2]. The results of this research are also supported by previous research conducted by [3] which concluded that intelligence factors that have not been achieved influence language development disorders in preschool children. Thus, it can be said that the higher the student's intelligence, the higher the student's language ability. Apart from language skills, intelligence also influences students' mathematics learning outcomes.

The results of the research show that intelligence has a positive and significant effect on the mathematics learning outcomes of students at Kesatrian 1 Junior School Semarang because the value of t statistic > t critical value is 4.289 > 1.971, where in the research the magnitude of the influence of intelligence on mathematics learning outcomes directly is 0.293 and indirectly through language ability is 0.148 and the total influence is 0.441, with an absolute contribution of intelligence to mathematics learning outcomes of 19.4%. This is by the statement by [15], which states that one of the factors that influences academic success is intelligence. In line with this statement, [16] also stated that in general, someone who has high intelligence will find it easier to achieve success through the achievements they have obtained. The results of this research are also supported by previous research conducted by [4], who in

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his research concluded that intelligence factors influence students' mathematics learning outcomes. Thus, it can be said that the higher the student's intelligence, the higher the student's mathematics learning outcomes.

Mathematics learning outcomes are also influenced by language skills. The results of the research show that there is a positive and significant influence of language skills on the mathematics learning outcomes of junior high school students Kesatrian 1 Semarang because the value of t statistic > t critical value is 4.200 > 1.971, where in the research the magnitude of the influence of language ability on mathematics learning outcomes was 0.286 with an absolute contribution of 8.2%. This is by the statement of [17], who explains that language is needed in learning where the essence of the purpose of the learning is to convey and impart information to students. Without language skills, students will find it difficult to understand the intent and meaning of the knowledge and information they have obtained. The results of this research are also supported by previous research conducted by [5], who in his research concluded that there is a positive influence of language mastery on students' ability to solve mathematics story problems, which means that language ability influences mathematics learning outcomes. Thus, it can be said that the higher the students' language skills, the higher the students' mathematics learning outcomes.

Meanwhile, the model proposed in this research is appropriate or fits the data because from the calculations the Chi-Square value is 0.00, degrees of freedom = 0, and p-value = 1.00 > 0.05. This shows that the theoretical correlation matrix is identical to the empirical correlation matrix, and there are no insignificant path coefficients. So, the model is accepted and no paths are removed.

5. CONCLUSION

Based on the data obtained and the results of the analysis that has been carried out, the conclusion that can be put forward from this research is that the model formed from the mathematics learning outcomes of students at Kesatrian 1 Junior School Semarang contains several influencing factors, namely intelligence and language ability. The results of the path analysis show that there is a positive and significant influence of intelligence on language abilities, intelligence on mathematics learning outcomes, and language abilities on mathematics learning outcomes. Some suggestions that can be given, namely to parents, are to provide a stimulus for student growth and development to increase student intelligence because students' language skills and mathematics learning outcomes are influenced by student intelligence. It is also hoped that teachers and parents can work together in assisting students in terms of education, both at school and outside school. Meanwhile, suggestions that can be given to future researchers are to add several factors as other variables that can influence student mathematics learning outcomes.

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