Factor Analysis of Students' Difficulties Understanding the Concept of Logarithms at SMA Negeri 2 Percontohan Karang Baru Aceh Tamiang

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Abstract

This research aims to determine the factors that cause students' difficulties in understanding the concept of logarithms using the factor analysis method. The samples taken were 120 class X students of SMA N 2 Percontohan Karang Baru Aceh Tamiang. Data was obtained using diagnostic test instruments for logarithmic material based on aspects of logarithms as objects, as processes, as functions, and in contextual problems. From these four aspects, Author 2 was able to identify 20 variables that caused students difficulty in understanding the concept of logarithms. The research results show that there are three factors that cause students' difficulties in understanding the concept of logarithms. These factors are: (a) logarithmic expressions (b) logarithmic functions, and (c) logarithmic calculations. The logarithmic expression factor is the dominant factor which has an eigenvalue of 10.282 which is able to explain a variance value of 54.115%.

Keywords: *Factor Analysis; Students' Difficulties; Concept Understanding; Logarithm.*

Abstrak

Penelitian ini bertujuan untuk mengetahui faktor-faktor yang menyebabkan kesulitan siswa dalam memahami konsep logaritma dengan menggunakan metode analisis faktor. Sampel yang diambil adalah 120 siswa kelas X SMA N 2 Percontohan Karang Baru Aceh Tamiang. Data diperoleh dengan menggunakan instrumen tes diagnostik materi logaritma berdasarkan aspek logaritma sebagai objek, sebagai proses, sebagai fungsi, dan dalam permasalahan kontekstual. Dari keempat aspek tersebut, Penulis 2 mampu mengidentifikasi 20 variabel yang menyebabkan kesulitan siswa dalam memahami konsep logaritma. Hasil penelitian menunjukkan ada tiga faktor yang menyebabkan kesulitan siswa dalam memahami konsep logaritma. Faktor-faktor tersebut adalah : (a) ekspresi logaritma (b) fungsi logaritma, dan (c) perhitungan logaritma. Faktor ekspresi logaritma merupakan faktor dominan yang memiliki nilai eigenvalue sebesar 10,282 yang mampu menjelaskan nilai variance sebesar 54,115%.

Kata Kunci: *Analisis Faktor; Kesulitan Siswa; Pemahaman Konsep; Logaritma.*

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INTRODUCTION

Coverage of mathematics material as a general subject in SMA/SMK includes number systems, algebra, geometry, trigonometry, three-dimensional space, statistics and probability theory, limits, and derivatives, integrals, principles of logic (including mathematical induction), basics of integrals, as well as Mathematical competence in supporting the achievement of high school graduate competence, one of which emphasizes the aspect of "*knowing, exploring and using the properties of operations (including composition) in solving problems of systems of equations and inequalities, power and logarithmic functions, algebraic functions, assisted by geometric techniques and interpretations*" (Pujiadi, 2016).

Logarithm which is an aspect of algebra is no exception to the benefits algebra offers (Ansah & Vos, 2016). It finds application in areas such as engineering (Aaron, 1997), medicine (Kinsella, 2007), economics (Azad, 2012), etc.

Despite the benefits associated with logarithms, according to (Wong, Lam, Wong, Leung, & Mok, 2002) most students think logarithms are something that is difficult and has no use in everyday life. (Liang & Wood, 2005) also stated that the topic of logarithms is a difficult topic for students and there is a high prevalence of misconceptions in students' thinking.

The difficulty can lie in one of the four mathematical objects, namely concepts. A concept is an abstract idea that allows someone to classify an object and explain whether the object is an example or not an example of an abstract idea. (Yen, 1999) stated that students often see the notation "*log*" as an object, not an operation. (Hurwitz, 1999) notes that students often have difficulty thinking of logarithms as the output of a function because the notation used for logarithms does not look like the usual *f(x)* notation. (Gamble, 2005) said that teachers often tell students that "logarithms are exponents", but for some reason, students hear the terms "exponent" and "logarithm" but often do not understand the relationship between the two. (Berezovski, 2006) found that students' difficulties in learning logarithms were caused by students focusing more on the procedural approach and relying too much on rules rather than the concept of logarithms themselves.

Then (Berezovski & Zazkis, 2006) found that students had difficulty recognizing logarithms as numbers. They expressed doubt that problems in calculating logarithmic expressions involving only numbers using either a calculator or manual calculations interpret the understanding of logarithms as numbers. Students may have learned the procedure by which certain types of problems are presented but do not understand that logarithmic expressions are numbers.

This is in line with research by (Kastberg, 2002) which reports that students who can solve problems do not necessarily perceive logarithmic expressions as numbers. (Tabaghi, 2007), in his research identifying students' difficulties in understanding the concept of logarithms using the context of APOS theory, found that most students' understanding of the meaning of logarithmic arithmetic did not go beyond the "process" level, because understanding the meaning of logarithmic arithmetic as exponential cancellation requires an understanding of exponentials with real exponents. (Hoon, Singh, & Ayop, 2010) in their research found that students were able to do routine calculations in logarithms, but were less able to solve problems that required high-level cognitive thinking. (Ganesan & Dindyal, 2014) stated that students' errors in logarithms can be related to their understanding of the topic which implies knowledge of their mathematical thinking and mental constructs. (Weber, 2016) focuses on logarithms as numbers or operators, where logarithms can be conceptualized as inverse exponents (*i.e.* structurally). Since the indirect definition is still valid in algebra textbooks despite the many problems reported in the educational literature, it may be a major cause of student difficulties. (Dintarini, 2018) found that some students did not fully understand the meaning of logarithms. In the end, students had difficulty applying the definition of logarithms to problems. At first, students seemed able to calculate the logarithm value of a number but failed when faced with more complex logarithms.

Meanwhile, (Rafi & Retnawati, 2018) found that the common mistakes students made in logarithmic material were technical errors, distorted theorems or definitions, unverified solutions, and data usage errors. (Liang & Wood, 2005) also found that students appeared to be able to perform routine calculations but were less able to answer questions that required a higher level of cognitive thinking. In addition, many errors are not caused by a lack of knowledge but appear to be due to an over-generalization of algebraic rules. Students tend to have low understanding regarding the initial concept of logarithmic functions, students have difficulty understanding the application of logarithmic functions, and difficulties in solving logarithmic functions.

According to (Hayati & Budiyono, 2018), the possible causes of errors in logarithmic learning come from teachers, students, or learning tools. Student errors in completing several tasks related to logarithmic function material became an obstacle in the next learning process.

According to (Sinaga, et al., 2014) students must be able to master the concepts and properties of logarithms before studying logarithmic functions. Then, what are the dominant factors that actually cause students to have difficulty understanding the concept of logarithms? This question is what makes the author interested in exploring students' difficulties in understanding logarithmic material at SMA Negeri 2 Percontohan Karang Baru Aceh Tamiang.

RESEARCH METHODS

The location of this research was conducted at the SMA Negeri 2 Percontohan Karang Baru Aceh Tamiang. 120 class X students were taken as a sample. To obtain research data, Author 2, who is a Mathematics teacher at the research location, used a diagnostic test instrument for logarithmic material based on the aspects proposed by (Williams, 2011), namely the logarithm is divided into four parts; logarithms as objects, as processes, as functions, and in contextual matters. Furthermore, from these four aspects, Author 2 compiled a questionnaire and succeeded in identifying 20 factor items that caused class X students to have difficulty understanding the concept of logarithm. The indicators can be seen in Table 1:

Table 1. Indicators of Students' Difficulties in Understanding the Concepts of Logarithm

Index	Indicator
X_1	know the meaning of $^a\log b$
X_2	know that logarithmic expressions are numbers, and don't need to be approximated by decimals
X_3	flexibly change the form of logarithmic expressions using logarithm rules
X_4	know the rules of logarithmic notation and how they relate to the order of operations
X_5	knows that a logarithmic expression must have a base and an argument
X_6	simplifies logarithmic expressions
X_7	estimate the value of a logarithmic expression
X_8	use logarithms by eliminating the base of exponential expressions when solving exponential equations
X_9	uses logarithms to find the value of the exponent in an expression
X_{10}	Use logarithms in the repeated division problem
X_{11}	connecting square (or other) roots with logarithms
X_{12}	"insert" a value in the function domain that will produce a single value
X_{13}	know logarithm function graphs in general and understand how to make logarithm graphs
X_{14}	understand that logarithmic functions have a finite domain, and an infinite range
X_{15}	explains why there are vertical asymptotes, but no horizontal asymptotes, in logarithmic graphs
X_{16}	connect logarithmic functions and exponential functions as inverses
X_{17}	understand the constraints of solutions to equations and inequalities involving logarithms
X_{18}	solve real-world problems involving logarithmic properties
X_{19}	recognize when real-world problems are most easily solved using logarithms
X_{20}	explains why logarithms are useful in the real world

A quantitative approach is used to analyze the collected data so that the factors that cause difficulties in understanding the logarithmic concept can be identified. The *Explanatory Factor Analysis* (EFA) type factor analysis method was chosen to reduce the variables represented by the questionnaire constituent items and the *Principal Components Analysis* (PCA) technique was used to form the factors. According to (Johnson & Wichern, 2007), *Principal Components Analysis* (PCA) is the simplest procedure for extracting factors. This method forms a linear combination of observed indicators.

RESULTS AND DISCUSSION

Based on (Sugiyono, 2008), a variable is said to be valid for use as a reflection of a concept if its correlation value with the total other variables is ≥ *0.30* and the concept being measured can be trusted if the value of Cronbach's Alpha is ≥ *0.60*. The validity of the items and the reliability of the questionnaire were tested with the SPSS 20 application. The results of the validity and reliability tests are shown in Table 2.

In Table 2, it can be seen that of all the variables, there is one variable that is invalid, namely variable if variable X_5 is removed, it will change the *Cronbach's Alpha* value from *0.949* to *0.951* so that variable X_5 can be removed. Taking into account the 19 remaining questionnaire statement items after the X_5 indicator was issued, the reduction of the 19 items into the factors they represent is carried out by *Explanatory Factor Analysis* (EFA) through the stages as explained by (Hair, Black, Babin, & Anderson, 2010).

The data feasibility test is used to see whether the data in the questionnaire is suitable for processing using factor analysis. The data suitability test is determined by looking at the Bartlett test of sphericity, *Kaiser Meyer-Olkin* (KMO), and *Measures of Sampling Adequacy* (MSA) values that are sought for each indicator. The quantity values that must be met according to (Johnson & Wichern, 2007) the *Bartlett test of sphericity* value with significance < *0.05*, the KMO value must be ≥ *0.50* and the MSA value must be ≥ *0.50*. The KMO value obtained from all variables is *0.913*, where the KMO value meets the requirements. In general, factor analysis can be used on all variables formed. The significance value in the Bartlett test is *0.000* < *0.05*, so it is concluded that the correlation between the variables that form factors can be explained by other variables.

Table 2. Validity and Reliability Test

Index	Variable	Item Total Correlation	Cronbach's Alpha if < 0.60, Item deleted
X_1	know the meaning of $^a\log b$	0.749	0.945
X_2	know that logarithmic expressions are numbers, and don't need to be approximated by decimals	0.805	0.944
X_3	flexibly change the form of logarithmic expressions using logarithm rules	0.823	0.944
X_4	know the rules of logarithmic notation and how they relate to the order of operations	0.707	0.946
X_5	knows that a logarithmic expression must have a base and an argument	0.142	0.951
X_6	simplifies logarithmic expressions	0.728	0.945
X_7	estimate the value of a logarithmic expression	0.394	0.95
X_8	use logarithms by eliminating the base of exponential expressions when solving exponential equations	0.696	0.946
X_9	uses logarithms to find the value of the exponent in an expression	0.494	0.949
X_{10}	Use logarithms in the repeated division problem	0.808	0.944
X_{11}	connecting square (or other) roots with logarithms	0.790	0.944
X_{12}	"insert" a value in the function domain that will produce a single value	0.627	0.947
X_{13}	know logarithm function graphs in general and understand how to make logarithm graphs	0.861	0.943
X_{14}	understand that logarithmic functions have a finite domain, and an infinite range	0.645	0.947

Index	Variable	Item Total Correlation	Cronbach's Alpha if < 0.60, Item deleted
X_{15}	explains why there are vertical asymptotes, but no horizontal asymptotes, in logarithmic graphs	0.854	0.943
X_{16}	connect logarithmic functions and exponential functions as inverses	0.409	0.95
X_{17}	understand the constraints of solutions to equations and inequalities involving logarithms	0.622	0.947
X_{18}	solve real-world problems involving logarithmic properties	0.740	0.945
X_{19}	recognize when real-world problems are most easily solved using logarithms	0.472	0.949
X_{20}	explains why logarithms are useful in the real world	0.849	0.943

The next step is to carry out the MSA test, according to (Johnson & Wichern, 2007) the MSA value must be ≥ *0.50*, in this study the MSA criteria used was > *0.60*. The MSA test for all variables can be seen in Table 3.

The results of the MSA test state that each indicator has an MSA value, which means that each indicator meets the MSA requirements, so that the factor analysis process can be continued.

To determine the number of factors formed, factors with an eigenvalue of more than 1 are the factors that will be selected. The greater the eigenvalue of a factor, the better the factor is at representing a number of variables. By using the *Principal Component Analysis* (PCA) method, factors with an eigenvalue of more than 1 can be seen in Table 4.

In Table 4 it can be seen that there are 3 factors with a cumulative percentage of *67.338%* which are able to explain the factors that cause difficulties in understanding the concept of logarithms.

Table 3. MSA Value of All Indicators

Index	Variable	MSA Value
X_1	know the meaning of $^a\log b$	0.887
X_2	know that logarithmic expressions are numbers, and don't need to be approximated by decimals	0.966
X_3	flexibly change the form of logarithmic expressions using logarithm rules	0.918
X_4	know the rules of logarithmic notation and how they relate to the order of operations	0.883
X_6	simplifies logarithmic expressions	0.838
X_7	estimate the value of a logarithmic expression	0.820
X_8	use logarithms by eliminating the base of exponential expressions when solving exponential equations	0.938
X_9	uses logarithms to find the value of the exponent in an expression	0.893
X_{10}	Use logarithms in the repeated division problem	0.955
X_{11}	connecting square (or other) roots with logarithms	0.968
X_{12}	"insert" a value in the function domain that will produce a single value	0.953
X_{13}	know logarithm function graphs in general and understand how to make logarithm graphs	0.941
X_{14}	understand that logarithmic functions have a finite domain, and an infinite range	0.868
X_{15}	explains why there are vertical asymptotes, but no horizontal asymptotes, in logarithmic graphs	0.955
X_{16}	connect logarithmic functions and exponential functions as inverses	0.741
X_{17}	understand the constraints of solutions to equations and inequalities involving logarithms	0.935
X_{18}	solve real-world problems involving logarithmic properties	0.843
X_{19}	recognize when real-world problems are most easily solved using logarithms	0.909
X_{20}	explains why logarithms are useful in the real world	0.950

Table 4. Number of Factors Formed

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	10.282	54.115	54.115
2	1.363	7.175	61.290
3	1.149	6.048	67.338

In this study, factor analysis with *Principal Component Analysis* (PCA) extraction obtained 3 factors that cause difficulties in understanding the concept of logarithms. These factors have a total of 19 variables. The three factors in the *Principal Component Analysis* (PCA) extraction method are each given a name according to the grouping of results on factor rotation. The results of the *varimax factor rotation* can be seen in Table 5.

Table 5. Results of Factor Rotation with the Varimax Method

Factor 1		**Factor 2**		**Factor 3**	
Variable	**Loading Value**	**Variable**	**Loading Value**	**Variable**	**Loading Value**
X_6 (simplifies logarithmic expressions)	0.840	X_{16} (connect logarithmic functions and exponential functions as inverses)	0.858	X_7 (estimate the value of a logarithmic expression)	0.778
X_{18} (solve real-world problems involving logarithmic properties)	0.827	X_{14} (understand that logarithmic functions have a finite domain, and an infinite range)	0.735	X_9 (uses logarithms to find the value of the exponent in an expression)	0.728
X_1 (know the meaning of ${}^a\log b$)	0.812	X_{19} (recognize when real-	0.588	X_{12} ("insert" a value in the	0.488

Factor 1		Factor 2		Factor 3	
Variable	**Loading Value**	**Variable**	**Loading Value**	**Variable**	**Loading Value**
		world problems are most easily solved using logarithms)		function domain that will produce a single value)	
X_{20} (explains why logarithms are useful in the real world)	0.799	-		-	
X_4 (know the rules of logarithmic notation and how they relate to the order of operations)	0.770	-		-	
X_2 (know that logarithmic expressions are numbers, and don't need to be approximated by decimals)	0.724	-		-	
X_{13} (know logarithm function graphs in general and understand how to make logarithm graphs)	0.707	-		-	
X_{15} (explains why there are vertical asymptotes, but no horizontal	0.689	-		-	

Factor 1		**Factor 2**		**Factor 3**	
Variable	**Loading Value**	**Variable**	**Loading Value**	**Variable**	**Loading Value**
asymptotes, in logarithmic graphs)					
X_3 (flexibly change the form of logarithmic expressions using logarithm rules)	0.672	-		-	
X_{10} (use logarithms in the repeated division problem)	0.653	-		-	
X_{11} (connecting square (or other) roots with logarithms)	0.630	-		-	
X_{17} (understand the constraints of solutions to equations and inequalities involving logarithms)	0.609	-		-	
X_8 (use logarithms by eliminating the base of exponential expressions when solving exponential equations)	0.597	-		-	

In variable X_{12} (*entering a value in the function domain which will produce a single value*) it is shown that the loading value is *0.488*, based on the provisions of the loading value according to (Hair, Black, Babin, & Anderson, 2010) it is explained that for a sample of 120 students the recommended loading value is *0.50*, so that the variable X_{12} cannot be included in the factor because the loading value is below *0.50*.

Next, factor interpretation is carried out by grouping indicators that have a minimum weighting factor of 0.50, and the variables that have a weighting factor of less than 0.50 will be removed from the model. Based on Table 4, it can be seen that there are 18 variables spread across 3 factors with a total variance of *67.338%*. Based on the results of the *varimax rotation*, it can be seen that the variables in each factor that cause difficulties in understanding the concept of logarithms form three factors. Each of the three factors is given a new name according to the grouping of variables in that factor. However, it should be noted that the factor naming process is not very scientific and is based on the subjective opinion of the analyst (Hair, Black, Babin, & Anderson, 2010).

Factor 1: The first factor is called *the logarithmic expression* factor which has an eigenvalue of *10.282* and can explain a variance value of *54.115%*. This means that 54.115% of the difficulties in understanding the concept of logarithms are determined by *the logarithmic expression* factors. This factor is formed from 13 variables based on Table 5.

Factor 2: Indicator the second factor is called *the logarithmic function* which has an eigenvalue of *1.363* and is able to explain a variance value of *7.175%*. This means that *7.175*% of the difficulties in understanding the concept of logarithms are determined by *the logarithmic function factors.* This factor is formed from three indicators, with the X_{16} indicator (*connecting the logarithm function and exponential function as an inverse*) having the largest loading factor value with a value of *0.858*. It can also be interpreted that the difficulty of understanding the relationship between logarithmic functions and exponential functions will make it increasingly difficult for students to solve logarithms in the real world.

Factor 3: The third factor is called *the logarithmic calculation* which has an eigenvalue of *1.149* and can explain a variance value of *6.048%*. This means that *6.048*% of the difficulties in understanding the concept of logarithms are determined by *the logarithmic calculation factors*. This factor is formed from 2 indicators with indicator X_7 (*estimating the logarithmic expression value*) which has the largest loading factor value with a value of *0.778*. This means that to be able to estimate the value of a logarithmic expression, students must have calculation skills in mathematics lessons.

CONCLUSION

Research on the factors that cause difficulty understanding the concept of logarithms in class X students of SMA N 2 Percontohan Karang Baru Aceh Tamiang concluded that; there are three factors identified that cause difficulties in understanding the concept of logarithms. The three factors extracted from the 19 original variables are: (a) *logarithmic expression*, (b) *logarithmic function*, and (c) *logarithmic calculation*. The logarithmic expression factor is the dominant factor which has an eigenvalue of *10,282* which can explain the variance value of *54,115%*.

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