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Factor Analysis of a Diagnostic Test for Mathematics Learning Difficulties Using Exploratory Factor Analysis (EFA)

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Abstract

The development of a diagnostic test for mathematics learning difficulties aims to identify the domains in which students demonstrate the lowest level of mastery. By identifying the domains in which students experience the greatest difficulties, targeted improvements can be implemented more effectively. Therefore, this study analyzes the dominant factors within a diagnostic test that was developed based on mathematical domains. The purpose of this study is to identify the factors within the mathematics domains that have been operationalized in the form of a test instrument. The resulting factors are formed from the correlations among items used to measure students' abilities. Each factor formed must contain at least one mathematical domain represented in the test items. In some cases, a factor may consist of more than one mathematical domain. The identified factors represent the mathematical problem-solving abilities of the test participants. This study employed an exploratory descriptive research method. The research describes the characteristics of the analysis results using Exploratory Factor Analysis (EFA). The calculations were performed using SPSS software, and the resulting output was interpreted according to the characteristics of EFA. The research sample consisted of responses from 323 students. These responses represented answer choices for a diagnostic test comprising 30 questions with five alternative answers for each item. The results of the data analysis identified four mathematical domains, namely Algebra, Calculus, Geometry, and Trigonometry. Furthermore, the analysis of the diagnostic test on students' mathematics learning difficulties revealed nine dominant factors

INTRODUCTION

Implementing learning requires an appropriate and well-designed assessment method (Almufarreh et al., 2023; Hakim et al., 2024; Irawan et al., 2025; Meylani, 2024; Wu et al., 2023). The factors that form the focus of assessment in learning must be clear and measurable. Measurable factors facilitate improvement and enhance the quality of subsequent learning. Learning activities are implemented according to indicators determined based on the domain of the subject matter (Chen et al., 2022; Purnadewi & Widana, 2023; Shi et al., 2023).

Mathematics learning commonly uses tests as an evaluation tool because they can measure students' level of understanding. The tests used in evaluation are adjusted according to their objectives. To determine students' level of understanding in mathematics, summative and formative tests are generally administered (Ministry of Education, Culture, Research, and

Technology, 2022; Mardapi, 2017; Riinawati, 2021). Depending on the domain being assessed, tests may take the form of objective or essay-based questions. However, if the purpose of the test is to identify students' difficulties in learning mathematics, then a diagnostic test for learning difficulties can be developed.

Students' learning difficulties are reflected in the errors they make when answering questions on a given test. Errors in mathematics may occur because of conceptual errors, procedural errors, calculation errors, and errors caused by carelessness (Prastiwi et al., 2022). To identify these errors, tests are designed by considering potential misconceptions and mistakes. If the test format is multiple choice, then in addition to providing the correct answer option, the distractors must also be capable of detecting student errors within certain categories.

By identifying the categories of student errors, more focused improvement efforts can be implemented. The focus of remediation can then be directed only toward the dominant error categories within the tested domain. However, merely identifying the categories and domains of student errors still results in a broad scope for intervention. Detecting student errors based on factors within each tested domain can provide a more precise focus on the factors causing students' learning difficulties. To identify these factors, it is necessary to analyze students' response data.

Exploratory Factor Analysis (EFA) can be used to determine the dominant factors within a test. The purpose of EFA is to identify the construct of an instrument by analyzing responses and examining the relationships or factor structure (Navarro & Foxcroft, 2025; Taherdoost et al., 2020). EFA analyzes diagnostic tests for mathematics learning difficulties to identify the factors underlying the test structure, thereby enabling more targeted improvements based on the identified factor structure.

Several previous studies have applied EFA in instrument development. In the research conducted by Diva Trisyahbani Sutarman (Vi et al., 2026), a diagnostic test was developed in which factor analysis identified six factors related to reading literacy assessment practices in elementary schools. Furthermore, factor analysis conducted by Hadi Gunawan Sakti et al. (2023) identified five factors in the development of instruments measuring students' Pancasila character. In addition, research by Ihsan et al. (2023) identified eight factors influencing students' decisions to purchase products online. Among these previous studies applying EFA to instrument analysis, none specifically discussed mathematics domain tests.

The urgency of this research is strengthened by the persistent challenges in mathematics education in Indonesia. According to data from the Programme for International Student Assessment (PISA) 2022, Indonesian students' mathematics literacy scores remained below the OECD average, indicating widespread difficulties in mathematical problem-solving (OECD, 2023). Similarly, the Trends in International Mathematics and Science Study (TIMSS) 2019 reported that Indonesian students continue to face difficulties in higher-order mathematical thinking skills (Mullis et al., 2020). Without a clear understanding of the specific factors contributing to students' difficulties, teachers cannot design targeted interventions effectively. Therefore, this research provides an empirical foundation for identifying these factors and supporting more effective diagnostic assessment and remediation strategies.

The novelty of this research lies in three key aspects. First, it represents the first comprehensive application of EFA to a diagnostic test specifically designed to identify high school students' mathematics learning difficulties in the Indonesian context, covering the domains of Algebra, Calculus, Geometry, and Trigonometry. Second, the study provides a detailed item-by-item interpretation of how each factor corresponds to specific mathematical abilities, thereby offering practical insights for teachers. Third, the research identifies nine distinct factors from 30 test items, revealing a more nuanced structure of students' learning difficulties than previously understood. This level of detail is unprecedented in mathematics education research in Indonesia and provides a foundation for developing targeted remedial materials.

The factors underlying a test must be well understood in order to improve conceptual understanding and mathematical problem-solving processes. Since no previous research has specifically addressed diagnostic tests for high school mathematics learning difficulties, this study seeks to fill that gap. The discussion aims to identify the factors underlying the developed diagnostic test, and students' responses will be analyzed using EFA.

RESEARCH METHOD

The type of research employed in this study was exploratory descriptive research. The sample was randomly selected from 323 students. The diagnostic test consisted of 30 objective-type test items. The distractors provided in the developed test were designed to diagnose student errors across four categories. These four categories of learning difficulties included conceptual errors, procedural errors, calculation errors, and errors caused by carelessness. Data analysis was conducted to determine the dominant factors within the diagnostic test for mathematics learning difficulties. The analysis was carried out using SPSS with the Exploratory Factor Analysis (EFA) model.

Several important considerations are required when conducting EFA. Before further analysis, a sample adequacy test must first be performed. The sample size is considered adequate if the Kaiser–Meyer–Olkin (KMO) value is greater than 0.05 (Ocy et al., 2025; Taherdoost et al., 2020). If the sample size is adequate, factor analysis can then proceed to the next stage. Factor analysis is appropriate if the analyzed response data do not contain an identity matrix, indicated by a significance (Sig.) value in the Bartlett's Test of Sphericity that is less than 0.05 (Taherdoost et al., 2004).

After the sample size is confirmed to be adequate and the assumptions for EFA are satisfied, the number of factors in the test must be determined. To obtain an initial estimate of the number of factors, the analysis results may include the scree plot and eigenvalues. In determining the number of factors to be retained and interpreted, only factors with eigenvalues greater than 1 are selected (Dian Sari & Radikun, 2024; Taherdoost et al., 2020).

Once the number of factors has been identified, the obtained factors must be interpreted by determining factor names based on the relationships among the test items. Therefore, understanding the correlations among test items and selecting an appropriate rotation method are important steps in the interpretation process (Taherdoost et al., 2020).

RESULTS AND DISCUSSION

As a prerequisite for factor analysis with EFA, it is important to ensure that the sample or data being analyzed is sufficient and correlates with the dominant factors. To determine whether the sample size is sufficient for this study, the KMO table and Bartlett's Test can be used. A sufficient sample size is considered if the KMO value is > 0.50.

Table 1 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.833
Bartlett's Test of Sphericity	Approx. Chi-Square	2.262E3
	df	435
	Sig.	.000

The KMO value in the table is 0.833; this means that the minimum number of samples is met. So, the research sample in the trial of the diagnostic test of students' mathematics learning difficulties is sufficient and further testing can be carried out. Factor analysis can be done by determining the number of dominant factors in the test.

The adequacy of the sample size indicates that the data can be further analyzed to determine the number of measurable factors from the test results. Of the 30 test items, there is a dominant factor in the diagnostic test for learning difficulties. The *scree plot* shows that the ordinate height on abscissas 1 and 2 reaches a value of more than 5, indicating the highest eigenvalue. *The scree plot results* also indicate that the unidimensionality assumption of the test is met.

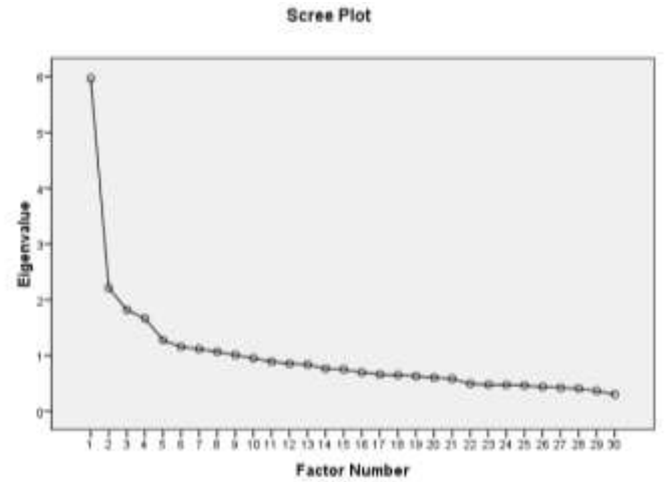

Figure 1 The scree plot results also indicate that the unidimensionality assumption of the test is met.

To determine the number of factors in a diagnostic test for learning difficulties, the results of the analysis in the *Total Variance Explained table must be interpreted*. The number of factors in the test can be determined by ensuring that each factor's eigenvalue is greater than 1. The Total Variance Explained table shows that nine factors have eigenvalues greater than 1.

Table 2 Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5,971	19,903	19,903	2,941	9,805	9,805	2,215	7,384	7,384
2	2,210	7,367	27,270	3,223	10,744	20,549	1,761	5,871	13,254
3	1,818	6,061	33,331	1,562	5,207	25,756	1,490	4,967	18,221
4	1,665	5,549	38,880	1,214	4,047	29,803	1,425	4,750	22,971
5	1,276	4,254	43,134	1,099	3,663	33,465	1,167	3,889	26,861
6	1,156	3,852	46,986	.686	2,288	35,754	1,152	3,840	30,700
7	1,116	3,720	50,705	.611	2,038	37,792	1,137	3,790	34,490
8	1,068	3,561	54,266	.529	1,764	39,556	1,078	3,595	38,085
9	1,010	3,365	57,631	.481	1,603	41,159	.922	3,074	41,159
10	.950	3,168	60,799						
11	.891	2,970	63,769						
12	.854	2,846	66,615						
13	.838	2,793	69,408						
14	.762	2,542	71,949						
15	.752	2,505	74,455						
16	.696	2,320	76,774						
17	.661	2,203	78,978						
18	.651	2,170	81,148						
19	.630	2,098	83,246						
20	.605	2,016	85,262						
21	.581	1,938	87,200						
22	.496	1,654	88,854						
23	.477	1,588	90,442						
24	.471	1,571	92,013						
25	.461	1,538	93,551						
26	.438	1,460	95,011						
27	.421	1,405	96,416						
28	.407	1,357	97,773						
29	.364	1,213	98,986						
30	.304	1,014	100,000						

Extraction Method: Maximum Likelihood.

Since there are 9 factors that have eigenvalues greater than 1, the diagnostic test can be used to measure the 9 dominant factors. Furthermore, the *Total variance explained table* also obtained a cumulative variance value of 41.159, which means that the 9 factors in the mathematics learning difficulties diagnostic test tested can explain up to 41.159 of the research sample variance. After knowing that there are 9 factors in the mathematics learning difficulties diagnostic test, the 9 factors in the difficulties diagnostic test can be described.

Before describing each factor in the diagnostic test for mathematics learning difficulties, a strong correlation between the items must be met. The magnitude of the correlation between items in the instrument can be seen from *the Goodness of fit test table* . *The goodness of fit test* table shows a sig value of 0.494. The correlation between items is strong if the sig value is > 0.05 . Therefore, there is a strong correlation between the items in the diagnostic test for mathematics learning difficulties.

Table 3 Goodness-of-fit Test

Chi-Square	df	Sig.
200,637	201	.494

Given the strong correlation between items, the factors formed from their correlation with the test items will then be determined. The magnitude of the correlation between items and factors can be seen in the *Rotated Factor Matrix table*. The table shows that the magnitude of the item correlations shown indicates the strength of the bond with the factor. The stronger the bond between an item and a factor, the more likely the item will form a factor that measures the mathematical ability domain on the test. Since there are nine factors in the developed diagnostic test, nine new factor domains will be identified from the resulting item bonds. Items for correlation analysis were selected with correlation values greater than 0.3.

Table 4 Rotated Factor Matrix [a]

	Factor								
	1	2	3	4	5	6	7	8	9
Item 16	.594								
Item 1	.528								
Item 15	.474								
Item 7	.451								
Item 11	.427								
Item 9	.361							.307	
Item 12	.325						.305		
Item 8		.577							
Item 2		.538							
Item 25	.416	.491							
Item 29		.350							
Item 6		.334							
Item 5			.587						
Item 18			.566						
Item 23			.306						
Item 19									
Item 22									
Item 14									
Item 24	.328			.711					
Item 17				.450					
Item 28		.305		.438					
Item 27	.321				.888				
Item 26						.627			
Item 20						.518			
Item 21									
Item 30							.774		
Item 13			.306					.553	.322
Item 10								.477	
Item 3								.361	
Item 4									.698

Extraction Method: Maximum Likelihood.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 23 iterations.

The relationship between the items and each factor can be seen in Table 5 and Table 6. The mathematical domain of each factor can be seen from Table 5. The mathematics domains in the learning difficulties diagnostic test are Algebra, Calculus, Geometry and Trigonometry. Each factor encompasses at least one mathematics domain. Within each mathematics domain, student abilities are influenced by content and process attributes. Each student ability attribute is determined based on learning achievement indicators.

Table 5 Items forming the Factors in the Mathematics Learning Difficulties Diagnostic Test

Factor	Test Item Number	Factor Description
1	16,1,15,7,11,9,12,25,24,27	Algebra and Calculus
2	8,2,25,29,6,28	Algebra and Calculus
3	5,18,23,13	Algebra, Geometry and Calculus
4	24,17,28	Geometry and Calculus
5	27	Calculus
6	26.20	Trigonometry and Calculus
7	12.30	Algebra and Calculus
8	9,13,10,3	Algebra
9	13.4	Algebra

Indicators of student learning achievement are used as the focus for developing diagnostic tests for learning difficulties. From the indicators of each domain, the student's abilities that must be mastered when answering test items correctly are developed and determined. The detailed capabilities of each item can provide information about new domains or dominant factors in diagnostic tests. Knowing the factors formed by the test items will help plan improvements to students' mathematical abilities based on these factors. The factors and detailed capabilities measured in diagnostic tests can be seen in Table 6.

Table 6 Details of student abilities based on items that correlate with each factor

Factor	Item	The ability being measured
1	16	Determining the inverse of a function, determining the composition of functions of two functions, and algebraic substitution
	1	Identifying equations or inequalities on linear programming and simplifying inequalities
	15	Determining the composition of functions from two functions and algebraic substitution
	7	Determine the gradient of parallel lines, determine the center of the circle based on the equation of a circle, determine the radius of a circle based on the equation of a circle, computation according to mathematical operations, and determining the equation of a tangent line circle
	11	Determine the form of the equation squares in trigonometric form, determining the factors of quadratic equations, and determining the size of angles
	9	Determine the form of the quadratic inequality from the exponential form, determine the factors of the quadratic equation and derive the roots of the solution in exponential form.
	12	Determine the equation of the sum of two angles and simplify the equation
	25	Performing function examples, solving function derivatives, calculating indefinite integrals, changing the results of function examples back, and changing functions in the form of powers and roots of the results of indefinite integrals.
	24	Determine the boundaries of the area of the region, determine the function to find volume of a rotating object, and using integrals to calculate the volume e of a rotating object
	27	Calculating indefinite integrals of trigonometric functions

Factor	Item	The ability being measured
2	8	Determining the general function of the remainder theorem, factoring quadratic equations, solving systems of linear equations in two variables using the elimination method, and solving systems of linear equations in two variables using the substitution method.
	2	The ability to identify powers and logarithms, determine mathematical operations on logarithms, compute logarithms, and substitute equations.
	25	Performing function examples, solving function derivatives, calculating indefinite integrals, converting the results of function examples back, and converting functions into exponents and roots of the results of indefinite integrals.
	29	Rationalize the root form, and use the limit properties of functions to calculating the indeterminate form of an algebraic function
	6	Determine the equation of a circle, determine the gradient of a line, determine the length of the radius of a circle and complete calculations according to mathematical operations.
	28	Factoring quadratic functions, simplifying function limits, and calculating limits at a given point
3	5	Determining the discriminant conditions for quadratic equations, computing according to mathematical operations, factoring quadratic inequalities, and determining the resulting region based on the roots of quadratic inequalities
	18	Determining the position of points and lines in three-dimensional space, determining the shape and length of the sides formed by points and lines in three-dimensional space, determining the angles of triangles formed by points and lines in three-dimensional space and carrying out arithmetic operations based on the cosine rule.
	23	Determine the limits of the area of the region, determine the function to find the area of the region under the curve, and use the integral to calculate the area of the region under the curve.
	13	Describe the form of a double angle, determine the form of a quadratic equation in trigonometric form, factor a quadratic equation, and determine the size corners
4	24	Determine the boundaries of the area of the region, determine the function to find volume of a rotating object, and using integrals to calculate the volume e of a rotating object
	17	Determine the position of the point, and lines, in three-dimensional space, determine the shape and length of the sides formed by points and lines in three-dimensional space, determine the distance from a point to a line in three-dimensional space, and perform arithmetic operations based on the Pythagorean theorem
	28	Factoring quadratic functions, simplifying function limits, and calculating limits at a given point
5	27	Calculating indefinite integrals of trigonometric functions
6	26	Performing function examples, performing trigonometric function derivatives, calculating indefinite integrals, converting the results of function examples back, and converting functions into exponents and roots of the results of indefinite integrals.
	20	Determine all the edges formed by points and planes in three dimensions, determine the angles formed by points and planes in three dimensions, and determine the cosine of the angle using the cosine rule
7	12	Determine the equation of the sum of two angles and simplify the equation
	30	Using the limit properties of functions to calculate trigonometric forms
8	9	Determine the form of inequality square of exponential form, determining the factors of quadratic equations and deriving the roots of solutions in exponential form
	13	Describe the form of a double angle, determine the form of a quadratic equation in trigonometric form, factor a quadratic equation, and determine the size corners

Factor	Item	The ability being measured
	10	Determine the shape quadratic inequalities from power inequalities, factoring quadratic inequalities, determining the results of solving inequalities, and determining the area of the results
	3	Determine mathematical operations on exponentials, determine the results of computing the form of exponential equations, and factor quadratic equations.
9	13	Describe the form of a double angle, determine the form of a quadratic equation in trigonometric form, factor a quadratic equation, and determine the size corners
	4	Determine the discriminant conditions for quadratic equations, perform computations according to mathematical operations, and factor quadratic equations.

Based on Table 6, each dominant factor found in the diagnostic test for student learning difficulties can be interpreted as follows.

1. Factor 1: students' ability to complete function computations on function composition, exponentials, trigonometric equations, function derivatives and integral functions.
2. Factor 2: students' ability to complete function computations on function limits, remainder theorems, and circle equations
3. Factor 3: students' ability to determine the resulting area, calculations using trigonometric rules, and the area of the curve
4. Factor 4: students' ability to determine the boundaries of regions and factors of equations
5. Factor 5: students' ability to solve trigonometric function integrals
6. Factor 6: students' ability to determine the derivatives of trigonometric functions and the dimensions of sides and angles in three dimensions
7. Factor 7: students' ability to solve trigonometric equations and limit forms of trigonometric functions
8. Factor 8: students' ability to complete operations with exponents
9. Factor 9: students' ability to determine discriminants and solve double angle equations

CONCLUSION

From the results of the discussion, it can be concluded that there are nine factors that can be measured in the diagnostic test developed to identify students' difficulties in learning mathematics. The factors obtained reflect the students' ability to correctly complete each test item. Mathematically, the domains identified are Algebra, Calculus, Geometry, and Trigonometry. Meanwhile, the new domains derived from the factor analysis, based on the relationships among the items, consist of nine factors. These factors are: (1) students' ability to perform function computations involving function composition, exponential functions, trigonometric equations, derivatives, and integral functions; (2) students' ability to perform function computations involving function limits, the remainder theorem, and circle equations; (3) students' ability to determine the resulting region, perform calculations using trigonometric rules, and determine the area under a curve; (4) students' ability to determine regional limits and factors of equations; (5) students' ability to solve integrals of trigonometric functions; (6) students' ability to determine derivatives of trigonometric functions and calculate the sizes of sides and angles in three-dimensional geometry; (7) students' ability to solve trigonometric equations and determine the forms of trigonometric function limits; (8) students' ability to perform operations involving exponents; and (9) students' ability to determine discriminants and solve double-angle equations.

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