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PDEODE Strategy Assisted by GeoGebra: Improving Students' Critical Thinking and Mathematical Analysis

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Abstract

This study aimed to determine the effect of the PDEODE learning strategy on students' critical thinking and mathematical analysis skills. This research is quantitative research with a quasi-Experimental posttest-only control group design. The population of this study was all students of the eighth grade of MTs Negeri 2 Bandar Lampung, with a total population of 256 students. The sampling technique employed was cluster random sampling. The data analysis techniques performed were the normality test and the homogeneity test. The hypothesis testing performed was a Multivariate Analysis of Variance (MANOVA) test. Based on the results of research and the MANOVA test, the PDEODE learning strategy assisted by the GeoGebra application has an effect on students' critical thinking and mathematical analysis skills. Further research is recommended to use the PDEODE strategy and GeoGebra media.

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INTRODUCTION

Advances in technology and information in the 21st century have undoubtedly impacted the (Ardimas et al., 2021). Efforts to improve the quality of education can be made by adapting to changes in technology and information (Salsabila et al., 2020). The utilization of technology in the learning process is carried out to increase the learning process's effectiveness and increase students' capacity and quality to use technology responsibly (Lestari, 2018). Learning will be effective if students interact with diverse learning resources to achieve learning goals (Aspi & Syahrani, 2022). If the learning objectives are achieved, then the effectiveness of the learning is also fulfilled.

Effective learning must be present in every subject. Mathematics must be taught to all students so that they have logical, analytical, systematic, and critical thinking skills (Dewi et al., 2020), creativity (Ramadani & Kusnandi, 2019), and good cooperative skills. Students require these skills related to their ability to live in a developing society. Mathematics education in Indonesia today necessitates students' ability to develop independently and creatively. Teachers will take on the role of supervisors, observing how students absorb data and information. Not only do they need to be able to count, but they also need to be able to think critically (Rachmantika & Wardono, 2019). Therefore, students must possess critical thinking skills.

Analytical skills and critical thinking are fundamental in human life and might later solve a problem for students (Aulia & Yuliani, 2022). Analyzing is essential to problem-solving so students make the best decisions (Winarti, 2017). Analytical skill is an active skill that students demonstrate when confronted with uncommon challenges, uncertainties, questions, or quandaries (Ariska,

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2020). However, according to preliminary research findings, students' critical thinking and mathematical analysis skills remain low. Solving problems in mathematics is frequently associated with numerous methods or phases. The number of ways and complexity of mathematics problems necessitate critical thinking skills. As a result, mathematics and critical thinking are linked (Afifah & Kusuma, 2021). According to the findings of pre-research conducted at MTs Negeri 2 Bandar Lampung, students' critical thinking, mathematical, and analytical skills remain inadequate, and many students' scores do not achieve the predetermined standards.

Heryani et al. found that students' critical thinking skills remain poor because learning activities are still not intended to stress critical thinking skills (Heryani et al., 2021). Giving prediction exercises, having class discussions, and incorporating technology into the mathematics learning system utilizing the PDEODE learning strategy are all potential solutions. The PDEODE strategy improves students' critical thinking and mathematical analysis skills. The capacity to describe, observe, and repeat the discussion can also be used to get answers (Sri & Wulandari, 2013).

Technology, particularly learning media, is supposed to aid in understanding and developing students' thinking while studying subject matter. This process of student understanding is beneficial in both face-to-face learning with teachers and independent learning outside of school (Rahayu et al., 2021). learning media that helps students visualize and understand learning materials is required. GeoGebra software is one type of learning material that can help students learn mathematics more efficiently. GeoGebra is a dynamic and interactive tool that enables extensive investigation of a mathematical idea to inspire students' creative thinking (Atikasari & Kurniasih, 2015).

Using the GeoGebra application has various advantages, including Geometry paintings are typically created more rapidly and thoroughly than with a pencil, ruler, or word. The presence of animation features and manipulation movements (dragging) in the GeoGebra application can give students a more visual experience when learning geometry principles. Feedback/review to check the accuracy of the artwork created makes it easier for learners and teachers to examine and demonstrate the properties of a geometry object (Ekawati, 2016).

Various previous studies on the PDEODE strategy have been conducted. Previous similar studies have shown that the PDEODE learning model can improve students' critical thinking skills (Heryani et al., 2021; Mailani et al., 2020), concept understanding (Widyastuti et al., 2019), and misconception reduction (Samsudin et al., 2020; Zulfikar et al., 2019). However, according to available research, no learning medium in the form of GeoGebra software has been used. Furthermore, the PDEODE learning strategy has not been employed in school to assess students' mathematical analysis skills. As a result, this study assesses students' critical thinking, mathematical, and analytical abilities utilizing the PDEODE learning technique and GeoGebra software.

METHODS

The quasi-experiment research method was utilized in this research. There were two research classes, one experimental class and one control class (comparison class). The quantitative research method was used to acquire numerical data, process it, and evaluate hypotheses using consistent statistical analysis. Three classes were compared in the study. Experimental class 1 employed the PDEODE learning strategy, Experimental class 2 employed the PDEODE learning strategy with the assistance of the GeoGebra application, and the control class employed the traditional learning strategy. Figure 1 depicts the research stages.

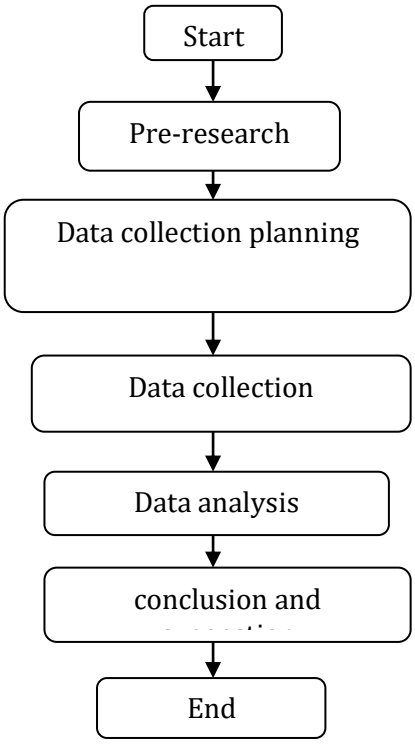

Figure 1. Flowchart of Research Stages

The research's population consisted of 256 eighth-grade students from MTs Negeri 2 Bandar Lampung during the 2022/2023 academic year. The population is general objects or subjects with certain characteristics (Sugiyono, 2015). In this research, the cluster random sampling technique was used. Cluster random sampling is a basic sampling technique in which each group in the population (8 class groups) is chosen at random by three class groups using a lottery. The sampling technique is the sampling procedure (Sugiyono, 2017). The research sample can be seen in Table 1.

Table 1. Research Sample

No.	Class	Total
1	Experimental class 1	32
2	Experimental class 2	32
3	Control class	32
	Total sample	**96**

RESULT AND DISCUSSION

Observation Data

Data collected in this study was used to examine the hypothesis's results in the experimental and control classes. At the end of the fifth meeting, the researchers administered a test assessing students' critical thinking and mathematical analytical skills. The data from the observation of the critical thinking skills of experimental and control classes are described in Table 2.

Table 2. Observation Data of Critical Thinking Skills

Class	X_{max}	X_{min}	Central Tendency			Group Variance	
			$\bar{x}$	M_e	M_O	R	S_d
Experimental 2	98	60	76,18	76	80	38	10,13
Experimental 1	92	60	73,43	72	72	32	10,70
Control	90	50	65,62	64	56	40	11,83

According to Table 2, there was a difference in the average value in experimental class 2 (PDEODE learning strategy assisted by the GeoGebra application) compared to experimental class 1 (PDEODE learning strategy) and the control class (conventional learning strategy). According to the table above, the average score of the posttest results of critical thinking skills obtained by experimental class 2 is 73.43, experimental class 1 is 76.18, and the control class is 65.62.

Table 3. Observation Data of Mathematical Analysis Skills

			Central Tendency			Group Variance	
Class	X_{max}	X_{min}	$\bar{x}$	M_e	M_O	R	S_d
Experimental 2	98	70	77,63	76	70	28	7,63
Experimental 1	98	62	76,45	76	80	36	8,27
Control	88	56	68,93	68	60	32	8,70

According to Table 3, there was a difference in the average value in experimental class 2 (PDEODE learning strategy assisted by the GeoGebra application) compared to experimental class 1 (PDEODE learning strategy) and the control class (conventional learning strategy). Table 3 depicts that the average score of the posttest results of mathematical analysis skills obtained by experimental class 2 is 77.63, experimental class 1 is 76.45, and the control class is 68.93.

The Normality Test

After obtaining the posttest scores, the next step was to perform a prerequisite test consisting of the normality and homogeneity tests. The normality test is a prerequisite to determine whether the research sample is normally distributed. The test results are presented in Table 4.

Table 4. The Results of the Normality Test on Critical Thinking kills

Methods		Kolmogorov-Smirnov [a]			Shapiro-Wilk		
		Statistic	**Df**	**Sig.**	**Statistic**	**df**	**Sig.**
Critical Thinking	Control	,110	32	,200 *	,963	32	,331
	Experimental 1	,131	32	,176	,948	32	,124
	Experimental 2	,099	32	,200 *	,977	32	,720

*. This is the lower limit of the actual significance.
A. Lilliefors significance correction

Table 4 shows that the normality test performed was Kolmogorov-Smirnov on experimental class 1 (PDEODE learning strategy), experimental class 2 (PDEODE learning strategy assisted by the GeoGebra application), and the control class (conventional learning strategy). The obtained significance values higher than 0.05 are 0.331, 0.124, and 0.720. Therefore, it can be concluded that the data for each class is normally distributed.

Table 5. The Results of the Normality Test on Mathematical Analysis Skills

		Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	Methods	**Statistic**	**Df**	**Sig.**	**Statistic**	**Df**	**Sig.**
Mathematical analysis	Control	,113	32	,200 *	,957	32	,234
	Experimental 1	,117	32	,200 *	,971	32	,528
	Experimental 2	,118	32	,200 *	,959	32	,251

*. This is the lower limit of the actual significance.
A. Lilliefors significance correction

Table 5 shows that the normality test performed was Kolmogorov-Smirnov on experimental class 1 (PDEODE learning strategy), experimental class 2 (PDEODE learning strategy assisted by the GeoGebra application), and the control class (conventional learning strategy). The obtained significance values higher than 0.05 are 0.234, 0.528, and 0.251. Therefore, it can be concluded that the data for each class is normally distributed.

The Homogeneity Test

The homogeneity test is used to see whether the data population's variance is the same. The homogeneity test in this study was conducted on the data of students' critical thinking and mathematical analysis skills. The data variance test was performed on the SPSS program, presented in Table 6.

Table 6. The Homogeneity Test Result on Critical Thinking

		Levene's Statistic	df1	df2	Sig.
Critical thinking	Based on Mean	1.158	2	93	,319
	Based on Median	1.125	2	93	,329
	Based on the Median with Adjusted df	1.125	2	92.734	,329
	Based on the trimmed mean	1.147	2	93	,322

Based on Table 6, the result of the homogeneity test on critical thinking skills is *0.319* (lower than 0.05). Therefore, it can be concluded that the data comes from a population that has the same variances (homogeneous).

Table 7. The Homogeneity Test Result on Mathematical Analysis Skills

		Levene's Statistic	df1	df2	Sig.
Mathematical analysis	Based on Mean	,846	2	93	,432
	Based on Median	,695	2	93	,502
	Based on the Median with Adjusted df	,695	2	89.762	,502
	Based on the trimmed mean	,829	2	93	,440

Based on Table 7, the result of the homogeneity test on mathematical analysis skills is *0.432* (lower than 0.05). Therefore, it can be concluded that the data comes from a population that has the same variances (homogeneous).

Hypothesis Testing

After it is known that the research data comes from a normally distributed population and a homogeneous population, the next step is hypothesis testing. Hypothesis testing uses the Manova Test (Multivariate Analysis Of Variance). The Manova Test calculation in this study used SPSS 22, and the first test was carried out to test the effect between subjects/variables (Test of Between-Subject Effects), which can be seen in Table 8 below.

Table 8. Test of Between-Subject Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Squared	F	Sig.	Partial Eta Squared
Corrected strategy	Critical Thinking	2166.583a -	2	1083.292	7.169	,001	,134
	Mathematical Analysis	2388.083b -	2	1194.042	11.868	,000	,203
Intercept	Critical Thinking	480817.042	1	480817.042	3182.094	,000	,972
	Mathematical Analysis	517147.042	1	517147.042	5140.036	,000	,982
Method	Critical Thinking	2166.583	2	1083.292	7.169	,001	,134
	Mathematical Analysis	2388.083	2	1194.042	11.868	,000	,203
Error	Critical Thinking	14052.375	93	151.101			
	Mathematical Analysis	9356.875	93	100.612			
Total	Critical Thinking	497036.000	96				

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Squared	F	Sig.	Partial Eta Squared
	Mathematical Analysis	528892.000	96				
Corrected Total	Critical Thinking	16218.958	95				
	Mathematical Analysis	11744.958	95				

Table 8 shows that in the row of learning strategies for critical thinking skills, the value is 0.000 with a significance degree of 0.05. It shows that the p-value is smaller than 0.05, so H_0A is rejected, and H_1A is accepted. In conclusion, there is an effect of the PDEODE learning strategy on critical thinking skills. In line with the learning strategy of mathematical analysis ability, the p-value was 0.000 with a significance level of 0.05. This result shows that the p-value is smaller than 0.05, so H_0B is rejected, and H_1B is accepted.

In conclusion, there is an effect of the PDEODE learning strategy on mathematical analysis ability. Furthermore, researchers conducted Multivariate tests to see the effect of learning strategies on students' critical thinking skills and mathematical analysis simultaneously. Multivariate tests were conducted using the SPSS 22 program. The results of multivariate testing can be seen in Table 9.

Table 9. Multivariate Testing

	Value	F	Df of Hypothesis	Error df	Sig.	Partial Eta Squared
Pillai's Trace	,244	6.453	4.000	186.000	,000	,122
Lambda Wilks	,757	6.871a	4.000	184.000	,000	,130
Hotelling's Trace	,320	7.283	4.000	182.000	,000	,138
Roy's Largest Root	,317	14.751b	2.000	93.000	,000	,241

Based on Table 9, students' critical thinking ability and mathematical analysis skills obtained a value of 0.000 with a significance degree of p-value of 0.05. This result shows that the p-value is smaller than 0.05. Thus, H_0AB is rejected, and H_1AB is accepted. In conclusion, there is an effect of the PDEODE learning strategy on students' critical thinking ability and mathematical analysis abilities. Based on the results of the data analysis, the following is a discussion of the three hypotheses tested:

1. The First Hypothesis
   Based on the analysis, H_{0AB} is rejected. The PDEODE learning strategy assisted by the GeoGebra application affects critical thinking and mathematical analysis skills based on research conducted at MTs Negeri 2 Bandar Lampung in eighth grade. PDEODE learning strategy is performed by grouping the students, where each group is asked to discuss and explain the results of their discussion. The PDEODE learning strategy can improve critical thinking and mathematical analysis skills by revealing initial thoughts to be discussed with their groups and explaining the results of their discussions to other groups.
2. The Second Hypothesis
   Based on the analysis, H_{0A} is rejected. There is an effect of the PDEODE learning strategy assisted by the GeoGebra application on the critical thinking skills of eighth-grade students.
3. The Third Hypothesis
   Based on the analysis, H_{0B} is rejected. There is an effect of the PDEODE learning strategy assisted by the GeoGebra application on the mathematical analysis ability of eighth-grade students.

The PDEODE strategy can improve students' critical thinking and analysis skills. This statement aligns with previous research on the application of PDEODE that can improve students' critical thinking skills, and students respond well to the PDEODE learning strategy (Sri & Wulandari, 2013). Besides, the GeoGebra application is vital in improving these two skills. Previous research revealed that the GeoGebra application can improve students' critical thinking (Batubara,

2019). This media has also been widely applied for student analysis of geometry material (Kholid et al., 2022).

Furthermore, this media can foster students' HOTS (Misrom et al., 2020). Based on the explanation above, there is an influence of learning strategies on students' critical thinking and mathematical analysis skills. The PDEODE learning strategy, assisted by the GeoGebra application, provides an outstanding response for more enthusiastic students in the learning process.

CONCLUSION

Based on a series of data analysis tests and hypothesis testing, it can be concluded that there is an effect of the PDEODE (Predict-Discuss Explain-Observe-Discuss-Explain) learning strategy assisted by GeoGebra on students' critical thinking and mathematical analysis skills. The results of this test can be seen from the results of the MANOVA test. Further research is recommended to use the PDEODE strategy and GeoGebra media.

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