Journal of Engineering Science and Technology
Special Issue on ISCoE2023 Vol. 19, No. 2 (2024) 9 - 16

PROBLEM BASED-LEARNING IN MATHEMATICAL CRITICAL THINKING ABILITY: A SURVEY ON SENIOR HIGH SCHOOL

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Abstract

This research has the objective to analyze and describe the difference in the improvement of students' mathematical critical thinking abilities who learn with the Problem-Based Learning model assisted by GeoGebra (Geo-PBL) and the Direct Instruction model assisted by GeoGebra (Geo-DI). The quantitative method employed in this research utilized a quasi-experimental nonequivalent pretest-posttest control group design. The research sample consisted of 58 students from grade XI at MAN 1 Medan. Data collection was done using a mathematical critical thinking ability test comprising 4 essay-type questions. Before the test instrument was piloted, it was first validated and tested for reliability to ensure that the data obtained during the research process were valid and reliable. Data were analyzed using IBM SPSS 29.0 statistical software. The research results indicate that students who learn with Geo-DI exhibit a higher improvement in mathematical critical thinking abilities compared to students who learn with Geo-PBL, with the criteria of mathematical critical thinking abilities falling into the moderate category. The research outcomes related to the implementation of Geo-DI can serve as an alternative learning model in the classroom.

Keywords: Geogebra, Mathematical critical thinking ability, Problem based-learning, Survey.

1. Introduction

Critical thinking is one of the important abilities for student [1-3]. The reintroduction of mathematical critical thinking abilities (MCTA) in the 2013 curriculum aims to facilitate students in initiating critical thinking [4]. This is because, with critical thinking skills, students can think rationally and apply it to their mathematical abilities. Mathematical critical thinking is the foundation of the thought process in generating ideas, analyzing arguments, and developing logical thought patterns [5]. The intended thought process is carried out so that in learning, students do not merely memorize and understand concepts but also develop thought patterns and apply them systematically. Therefore, in critical thinking, students can not only remember or understand the concepts they have learned but can also express their critical thinking through easily understandable concepts, interpret data, and apply concepts based on a structured thought pattern [6, 7].

Good critical mathematical thinking abilities make students better understand and master mathematical concepts [8]. In this case, a learning model is needed that develops these abilities, namely problem-based learning (PBL). Many reports on PBL have been well-documented [9-13]. PBL is a learning environment that utilizes problems in instruction, where students need to identify a problem, either a real-life one or a case research before they delve into a subject matter [14]. The problems are designed in a way that students identify the learning needs required to solve them [15]. Apart from PBL and MCTA, GeoGebra software also offers features that facilitate teachers and students in visualizing and demonstrating various activities, thereby providing a positive effect and deepening students' mathematical critical thinking [16, 17]

This research aims to analyze and describe the differences in the improvement of students' mathematical critical thinking abilities between those who learn with problem-based learning assisted by GeoGebra (Geo-PBL) and direct instruction assisted by GeoGebra (Geo-DI) especially derivative, based on four indicators by Facione. The research method employed is quantitative. The novelty in this research lies in expanding the observation aspects by conducting a comparison involving a control class that implements direct instruction.

2. Theory: Mathematical Critical Thinking Ability

Mathematical critical thinking ability has four indicators [18, 19]. The following are indicators of mathematical critical thinking abilities:

i. Interpretation. Can write down the meaning of the problem clearly and precisely. Can write what is asked about the question clearly and precisely. Example: known length: ($6x$+1) cm, width $3x$ cm, and x: 2 cm, and asked to determine the change in the area of the rectangle relative to side x when $x = 2$ cm.
ii. Analysis. Identify relationships between statements, questions, concepts, descriptions, and more. For example, students find the area of a rectangle and the derivative, $L = p \times l$ and $\lim_{h \to 0} \frac{f(x+h)-f(x)}{h}$
iii. Evaluation. Can write down problem solutions. Example: $L = p \times l = (6x + 1) \times 3x = 18x^2 + 3x$. After that find the area of a rectangle, student find the derivative. For example, $L' = 36x + 3$. $L'(2) = 36(2) + 3 = 75$ cm.

iv. Inferention. Students make conclusions about the results they have obtained. For example, the change in the area of the rectangle concerning side *x*, when *x* is 2 cm is 75 cm.

3. Method

The quantitative method employed in this research utilized a quasi-experimental nonequivalent pretest-posttest control group design. The research took into account the class conditions already established by the school. Thus, we did not randomly reassign students to classes. Two classes were involved in this research, namely the experimental class and the control class. The research sample consisted of 58 students from the XI grade of MAN 1 Medan, Indonesia. The experimental class comprised 29 students, while the control class comprised 29 students. The sampling technique used was purposive sampling. Data collection was carried out using a test of mathematical critical thinking abilities. The critical thinking test consists of 4 essay-type questions and is designed to measure mathematical critical thinking abilities. The aspects measured include interpretation, analysis, evaluation, and inference. Before the test instrument was piloted, it was first validated and its reliability was tested to ensure that the data obtained during the research process are valid and reliable. The data was analyzed using IBM SPSS 29.0 statistical software. Before conducting statistical tests, a check for normality and homogeneity was performed. N-Gain was utilized to assess the improvement in students' critical mathematical thinking abilities in both classes. Detailed information for the SPSS is explained in the literature [20, 21].

4. Results and Discussion

4.1. Improved mathematical critical thinking skills based on learning

Below is an explanation of the results of descriptive statistical analysis related to the improvement of critical mathematical thinking abilities based on the instructional models. Descriptive statistical analysis was employed to address the first research question. The results can be observed in Table 1.

Based on Table 1, the average, standard deviation, and skewness of the SPSS output results are obtained as follows. (1) the average increase in critical mathematical thinking skills for students who learn with PBL is 0.49. This shows that the increase obtained is lower than the average increase in the mathematical critical thinking abilities of students who study with DI (average N-Gain = 0.55). The criteria for improvement scores in both class groups are in the medium category. (2) The standard deviation value (s = 0.179) for increasing the mathematical critical thinking skills of students who learn with PBL is more varied compared to the increase in critical mathematical thinking skills of students who learn with DI. (3) If we look at the skewness value, the two classes get different scores. The skewness value in the PBL class = -0.100, so the PBL class graph tends to be negatively skewed. This means that the values for increasing critical mathematical thinking skills tend to gather at large values. Meanwhile, the skewness value in the DI class = 0.626, which means that the DI class graph tends to be similar to positive and the values for increasing mathematical critical thinking skills tend to converge at small values.

Table 1. Descriptive analysis result of students' improvement in critical mathematical thinking abilities based on instructional models.

Group				Statistic	Std. Error
NGain_Score	PBL	Mean		0.499	0.033
		95% Confidence Interval for Mean	Lower Bound	0.431	
			Upper Bound	0.567	
		5% Trimmed Mean		0.502	
		Median		0.493	
		Variance		0.032	
		Std. Deviation		0.179	
		Minimum		0.190	
		Maximum		0.760	
		Range		0.570	
		Interquartile Range		0.310	
		Skewness		-0.100	0.434
		Kurtosis		-1.062	0.845
	DI	Mean		0.556	0.021
		95% Confidence Interval for Mean	Lower Bound	0.514	
			Upper Bound	0.599	
		5% Trimmed Mean		0.552	
		Median		0.534	
		Variance		0.012	
		Std. Deviation		0.111	
		Minimum		0.380	
		Maximum		0.840	
		Range		0.460	
		Interquartile Range		0.160	
		Skewness		0.626	0.434
		Kurtosis		0.293	0.845

4.2. Implementation of learning toward the acquisition of mathematical critical thinking skills

Researchers used a paired sample t-test with the assumption that the distribution of pretest and posttest scores for mathematical critical thinking skills is normally distributed and the population variance is homogeneous. The following are the SPSS output results of the paired sample t-test in Table 2.

Table 2. Paired sample t-test.

		Mean	Std. Deviation	Std. Error Mean	T	df	Sig. (2-tailed)
Pair 1	Pretest PBL - Posttest PBL	-32.000	12.595	2.339	-13.682	28	<0.001
Pair 2	Pretest DI - Posttest DI	-42.655	7.884	1.464	-29.134	28	<0.001

Based on Table 2, the SPSS output results of the paired sample t-test above, the results are as follows. (1) comparison of the pretest and posttest of students' mathematical critical thinking abilities with PBL learning in Pair 1 results obtained a significant level of < 0.001 where the significance value is smaller than the value $\propto = 0.05$. The meaning is that implementation of the PBL model has a significant effect on the acquisition of critical mathematical thinking skills. (2) the results of Pair 2 show that the comparison of the pretest and posttest of mathematical critical thinking skills with DI learning obtained a significant level of < 0.001 where the significance value was smaller than the value $\propto$ = 0.05. The meaning is that hypothesis number 2 regarding the implementation of the DI model has a significant effect on the acquisition of critical mathematical thinking skills.

After getting the output results of the paired sample t-test, the paired sample correlation test is carried out. The output results of the paired sample correlation test can be seen below in Table 3.

Table 3. Paired samples correlation.

		N	Correlation	Significance	
				One-Sided p	Two-Sided p
Pair 1	Pretest PBL & Posttest PBL	29	0.155	0.211	0.422
Pair 2	Pretest DI & Posttest DI	29	0.604	<0.001	<0.001

Based on Table 3, the results of the paired sample correlation test, the analysis results are as follows. (1) the results of Pair 1 show that there is no relationship between the pretest and post-test scores for critical mathematical thinking ability with a correlation value of 0.155 and a significance level of 0.422. This means that there is no significant positive relationship between the pretest and posttest of students' critical mathematical thinking skills and PBL learning so that $r^2 = 2{,}4\%$ of the variation in posttest scores cannot be explained by variations in pretest scores. (2) the results of Pair 2 show a relationship between the pretest and posttest scores for mathematical critical thinking ability with a correlation value of 0.604 and a significant level of < 0.001. What this means is that there is a significant positive relationship between the pretest and posttest of mathematical critical thinking skills and DI learning, so that $r^2 = 36\%$ of the variation in the pretest scores can be explained by the variation in the pretest scores.

The results of the descriptive analysis indicate that there has been an improvement in students' critical mathematical thinking abilities falling into the moderate category. This condition explains that the Geo-PBL or Geo-DI instructional models can facilitate students in enhancing their critical mathematical thinking abilities. Each model has unique characteristics in guiding the learning process. The use of GeoGebra assists students in understanding the concept of derivative functions. The implementation of Geo-PBL and Geo-DI shows that there is a difference in the acquisition of students' critical mathematical thinking abilities. With PBL, students can construct their knowledge about critical thinking, and problem-solving abilities, and acquire knowledge, and essential concepts from the subject matter they are researching [22, 23]. Furthermore, the direct instruction model is an instructional approach that can help students learn basic skills and acquire information that can be taught step by step [24, 25]. Direct instruction models are specifically designed to develop student's learning of well-structured procedural and declarative knowledge that can be learned incrementally. The theoretical foundation of the direct instruction model is social learning theory, also referred to as learning through observation or behavior modeling theory [26, 27].

The analysis results in Table 2 explain the difference in students' acquisition of critical mathematical thinking abilities before and after the implementation of Geo-PBL and Geo-DI. Table 3 shows the difference in students' critical mathematical thinking abilities before and after the application of both models. The research results indicate that the post-test scores for critical mathematical thinking abilities after implementing Geo-PBL and Geo-DI are higher than the pre-test scores before the implementation of Geo-PBL and Geo-DI. The correlation analysis between pre-test and post-test scores in Table 3 illustrates a significant positive relationship between pre-test and post-test scores for students' critical mathematical thinking abilities in Geo-PBL and Geo-DI learning. This aligns with reference [28] assertion that DI focuses on student learning rather than teacher instruction. Learning using the DI model presents problems at the beginning of the learning process, and students seek to solve these problems. Subsequently, students solve these problems, enabling them to understand the material on their terms.

5. Conclusion

The research results indicate that the criteria for improving students' critical mathematical thinking abilities fall into the moderate category. The implementation of Geo-PBL and Geo-DI each has a significant impact on students' critical mathematical thinking abilities, with students who learn with Geo-DI showing a higher improvement compared to those who learn with Geo-PBL. This research has limitations, namely, the research subjects were only high school students in grade XI. Therefore, further research is needed to implement the DI (Direct Instruction) model at other educational levels. Furthermore, the aspect of students' mathematical abilities is limited to their critical mathematical thinking skills, thus measurement at a higher mathematical level needs to be pursued. Based on the research outcomes and the limitations of this research, further research can be conducted by developing the DI model as an alternative learning model.

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