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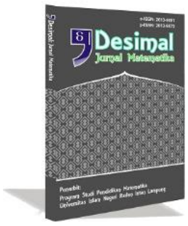

Using learning models problem based learning to improve students' mathematical critical thinking skills

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ABSTRACT

The purpose of this study is to describe how the Problem Based Learning (PBL) learning model improves students' mathematical critical thinking skills on Pythagorean theorem material. A quasi-experimental design was used with a non-equivalent pre-test and post-test control group design. The researchers collected data on critical thinking skills using a descriptive test instrument. The data were analyzed using ANOVA with a significance level of 0.05. The result of data analysis shows that the critical thinking skills of students who learn with the PBL model are better compared to those of students who learn conventionally, and learning to use PBL has similarities to the effectiveness of improving students' critical thinking skills in low, medium, and high level subgroups.

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INTRODUCTION

States that the 21st century learning process is also interpreted as meaningful learning for students, where students play an active role in the learning process while the teacher acts more as a facilitator. Meaningful learning for students aims to equip students with the ability to think critically (critical thinking), find solutions to particular problems (problem solving), be creative, communicate, and collaborate.

According to Sihotang (2019), critical thinking is the ability to consider everything using a consistent way of thinking and reflect on it as a basis for drawing valid conclusions. On the other hand, according to Adharini & Herman (2020) and Zakiah & Lestari (2019), it is a reflective thinking process that focuses on deciding what to believe or do. Critical thinking is a logical and wise thinking process that decides what to believe or do (Syaiful, Huda, Mukminin, & Kamid, 2022).

According to Ennis (2015) and Fridanianti, Purwati, & Murtianto (2018) the basic criteria or elements that critical thinkers must have in problem solving are focus, reason, inference, situation, clarity, and overview, which can be abbreviated as FRISCO.

Students' critical thinking skills and their ability to learn mathematics also need to be developed so that they can understand mathematical concepts well. The importance of critical thinking skills does not mean that students have optimal critical thinking skills. This is indicated by the low critical thinking skills of students.

When implementing learning in the classroom, many students find it difficult to solve problems related to everyday life because they are used to only applying formulas. Therefore, teachers need to relate mathematical concepts and formulas to students' lives or to knowledge that is commonly understood by students (Haking, Syamsuddin, & Idawati, 2020; Hunter, 2021).

This is also in line with the first observations that were made by the researchers at the SMPS Islam Al-Arief Muaro Jambi. At the time of observation, problems were found in the process of learning mathematics. Students are less able to understand the material presented by the teacher, so the learning outcomes are not very good. It can also be said that students' critical thinking skills in mathematics are still relatively low.

According to Sianturi, Sipayung, & Simorangkir (2018), in problem-based learning (PBL), the focus of learning is on the chosen problem, so that students learn not only concepts related to the problem but also the scientific method to solve the problem. Therefore, students not only need to understand concepts relevant to the problems that are the focus of attention but also need to have learning experiences related to the skills of applying the scientific method in problem solving and cultivating critical thinking patterns. Problem Based Learning (PBL) can have different effects and implications for students and teachers. PBL can be an effective learning strategy (Mercy, Lapuz, & Fulgencio, 2020).

The Problem Based Learning (PBL) learning model has appropriate and relevant learning characteristics for improving students' critical thinking skills in mathematics. The stages of this learning are expected to stimulate students to develop and improve their critical thinking skills because producing an appropriate problem solution requires deeper critical thinking skills about the problem to be solved.

The above background prompted the author to explore the learning model using PBL to improve students' critical thinking skills in mathematics.

The approach adopted in this section provides a clear basis for the research questions. By framing the questions in the context of PBL and its potential advantages over traditional teaching methods, the study positions itself to explore the impact of teaching approaches on mathematical critical thinking skills. In addition, the second question extends the investigation to determine whether the effects of PBL are consistent across different subgroups of students. This approach reflects a comprehensive framework that seeks to unravel the nuances of PBL's effectiveness across different ability levels.

METHOD

This is an experimental study with non-equivalent pre- and post-test control groups (Cresswell, 2012, 2015). This research was conducted at a junior high school in Sumatra, Indonesia. A total of 158 students were divided into five classes. This research was conducted using a convenience sampling technique. The sample consisted of 63 students in 2 classes, namely the experimental class (using the PBL learning model) and the control class (using the DI learning model). Class VIII-A is an experimental class consisting of 32 students, and class VIII-C is a control class consisting of 31 students. The pretest and posttest are the same. The results of the pretest are tabulated to determine the students' initial abilities. Pre-test scores are sorted from highest to lowest. 27% of the highest scorers are classified as having high initial ability. 27% of the lowest-scoring students are classified as students with low initial ability. The remaining 46% are grouped as students with medium initial ability. Then the students are grouped into high, medium, and low levels. Finally, a post-test is given to the students to measure how the PBL learning model improves their mathematical critical thinking skills. In addition, the research design can be seen in Table 1.

Table 1. Research Design

Class	Treatment	Post-test
Experiment	X_1	O_2
Control	X_2	O_2

Information :
X_1: Treatment with Problem Based Learning Model
X_2: Treatment with Direct Instruction

RESULTS AND DISCUSSION

The subject taught in this research is Pythagoras. Prior to learning, students are first given pre-test questions to measure or see the students' initial abilities. After the learning model has been completed or applied, they are given post-test questions to see the results of applying the model and to see how far they have progressed. students' critical thinking skills before and after being given different learning models.

The results of the analysis of the pre-test sample data will later be used to guide the next intervention or treatment. The ultimate goal of this study is to measure the impact of the intervention on improving the mathematical critical thinking skills of the subjects studied. Data on pre-test scores for mathematical critical thinking skills in even semesters is given in Table 2.

Table 2. Data Description of Pre-test Scores for All Class VIII

	N	Min	Max	Mean	Std. Deviation
VIIIA	32	6	25	15.94	4.704
VIIIB	32	8	25	16.25	4.088
VIIIC	31	8	31	15.74	5.279
VIIID	31	6	23	14.03	4.902
VIIIE	32	8	23	15.94	3.706

From the pre-test scores above, the sample for this study can be determined. In order to determine whether students from all classes have the same mathematical critical thinking skills, normality and homogeneity tests are carried out. The normality test is used to find out whether or not the data obtained is normally distributed. The normality test used is the Kolmogorov-Smirnov test.

Then, the results of the normality test will be compared with the 95% confidence level. If the significance value is ≥ 0.05, it can be concluded that the data is normally distributed. The results of the normality test for students' pre-test values can be seen in Table 3.

Table 3. Pre-test Normality Test of All Class VIII

		VIIIA	VIIIB	VIIIC	VIIID	VIIIE
N		32	32	31	31	32
Normal Parameters[a,b]	Mean	15.94	16.25	15.74	14.03	15.94
	Std. Deviation	4.704	4.088	5.279	4.902	3.706
Most Extreme Differences	Absolute	.161	.167	.152	.179	.175
	Positive	.161	.146	.152	.117	.075
	Negative	-.152	-.167	-.110	-.179	-.175
Test Statistic		.161	.167	.152	.179	.175
Asymp. Sig. (2-tailed)		.035[c]	.024[c]	.066[c]	.013[c]	.014[c]

In Table 3, it can be seen that for classes VIII A, VIII B, VIII C, VIII D, and VIII E that have a significance value of more than 0.05, it can be concluded that H_0 is accepted or that the pre-test value data is a normally distributed population. After being tested for normality, the pre-test data of the students was also tested for homogeneity.

Table 4. Pre-test Value Homogeneity Test

		Levene Statistic	df1	df2	Sig.
Value	Based on Mean	.596	4	153	.666
	Based on Median	.657	4	153	.623
	Based on Median and with adjusted df	.657	4	140.969	.623
	Based on trimmed mean	.604	4	153	.661

In Table 4, it can be seen that the significance value is 0.666 greater than 0.05. So, it can be concluded that H0 is accepted, or it can be concluded that the pre-test value data as a population has the same or homogeneous variance.

Once it is known that the population is normally distributed and homogeneous, a sample is taken from the population using the simple random sampling class technique. A combination technique is used to determine two sampling classes. Then the sample group is drawn using the lottery technique. After drawing a lot, it was found that the class used was class VIII A as the experimental class by applying the Problem Based Learning (PBL) learning model and class VIII C as the control class with Direct Instruction (DI).

This data is obtained through a test, which is carried out to measure students' mathematical critical thinking abilities. The results of the students' mathematical critical thinking skills test can be found in Table 5.

Table 5. Descriptive Statistics

	N	Min	Max	Mean	Std. Deviation
Experiment Class	32	21	45	34.84	7.017
Control Class	31	18	46	29.84	7.258

In Table 5, it can be seen that students' mathematical critical thinking skills in the experimental class have a higher average than those in the control class. The experimental class (PBL) has an average of 34.84, while the Direct Instruction (DI) control class has an average of 29.87, which means it is lower than the experimental class.

The normality test results of the post-test scores of students' mathematical problem-solving abilities at a significance level of 0.05 are as shown in Table 6.

Table. 6 Normality Test

	Statistic	df	Sig.
Standardized Residual for Mathematical Critical Thinking Ability	.073	95	.200*

It can be seen that the experimental class (PBL) and the control class (DI) have a significance value ≥ 0.05, it can be concluded that $H0$ is accepted or it can be said that the experimental class and the controls are normally distributed.

After testing the data for normality, the post-test data are tested for homogeneity. The results of the homogeneity test are compared at the 95% confidence level. If the significance value is ≥ 0.05, it can be concluded that the data are homogeneous. The results of the homogeneity test of students' posttest scores can be seen in Table 7.

Table 7. Homogeneity Test

Levene Statistic	df1	df2	Sig.
1.276	8	45.377	.280

In Table 7, it can be seen that the significance is greater than 0.05, so it can be concluded that H_0 is accepted, where the student's posttest value data has the same or homogeneous variance.

The improvement of students' mathematical critical thinking skills on the Pythagorean Theorem material can be calculated using N-gain. The N-gain scores for each class can be seen in Table 8.

Table 8. Experiment Class and Control Class N-gain scores

Class				Statistic	Std. Error
NGain_Percent	PBL	Mean		67.8686	2.92722
		95% Confidence Interval for Mean	Lower Bound	61.8985	
			Upper Bound	73.8388	
		5% Trimmed Mean		68.1363	
		Median		67.0683	
		Variance		274.196	
		Std. Deviation		16.55886	
		Minimum		37.78	
		Maximum		92.77	
		Range		54.99	
		Interquartile Range		29.87	
		Skewness		-.078	.414
		Kurtosis		-1.131	.809
	DI	Mean		55.3428	3.03588
		95% Confidence Interval for Mean	Lower Bound	49.1427	
			Upper Bound	61.5429	
		5% Trimmed Mean		54.5338	
		Median		49.4253	
		Variance		285.713	
		Std. Deviation		16.90306	
		Minimum		31.11	
		Maximum		95.56	
		Range		64.44	
		Interquartile Range		20.62	
		Skewness		.785	.421
		Kurtosis		-.147	.821

Based on the results of the calculation of the N-gain score test, it can be seen that the average N-gain score for the experimental class (PBL) is 67.8686, or 67.87%, which is in the fairly effective category. With a minimum N-gain score of 37.78% and a maximum of 92.77%. Finally, the results of the N-gain score calculation show that the average N-gain score for the control class is 55.3428, or 55.34%, which is in the less effective category. With a minimum N-gain of 31.11% and a maximum of 95.56%.

After the normality test and homogeneity test were carried out on the pre-test and post-test data, the dependent sample t-test was then carried out. In this study, the aim was to determine the difference in the mean of two paired samples, namely the pre-test and post-test data.

In the PBL class, from calculations performed using Excel, T_{Count} = -24.62 and T_{Table} = 2.0395, so it can be decided that H0 is rejected and H1 is accepted because T_{Count} is not between -2.0395 and 2.0395. This means that there is a difference in the average pre-test and post-test scores in the PBL class.

Whereas in the Direct Instruction (DI) class, from calculations performed using Excel, T_{Count} = -22.46 and T_{Table} = 2.0395, so it can be decided that H0 is rejected and H1 is accepted because T_{Count} is not between -2.04225 and 2.04225. This means that there is a difference in the average pre-test and post-test scores in the Direct Instruction (DI) class.

Interaction results between the application of Problem Based Learning (PBL) and Direct Instruction (DI) learning models on students' mathematical critical thinking skills.

Because it has fulfilled the prerequisites, a two-way ANOVA test can be carried out. Results are presented in Table 9.

Table 9. Dependent Variable: Mathematical Critical Thinking Skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	16013.253[a]	8	2001.657	45.945	.000
Intercept	382731.371	1	382731.371	8785.025	.000
Learning Model	670.079	2	335.039	7.690	.001

Based on the results of the two-way ANOVA test performed on the post-test scores of students' mathematical critical thinking skills in the experimental class and the control class, for the interaction between the PBL model and Direct Instruction (DI) on students' mathematical critical thinking skills. In the experimental class, a significance of 0.001 or < 0.05 is obtained, so H0 is rejected or H1 is accepted, which means that there is an interaction between the PBL learning model and Direct Instruction (DI) in influencing students' mathematical critical thinking skills.

Research has shown that the use of problem-based learning (PBL) makes students more active in learning and accustoms them to using real-world problems, which can improve their critical thinking skills in mathematics. This is in line with the findings of Susanti, Juandi, & Tamur (2020), which state that the PBL model is a learning model that can direct students to get to know objects in mathematics and direct students directly in the learning process so as to make students active.

Learning with PBL begins with problem analysis, independent learning, and reporting, which are very important for predicting students' abilities (Yew & Goh, 2016). According to Isrok'atun & Rosmala (2018), PBL is learning that begins by confronting students with a problem that exists in the real world and guiding them to be able to solve it through learning activities or experiences carried out during the learning process. The PBL learning model focuses on problems and questions so that it is able to make students solve problems by using concepts and principles that are appropriate and not far from mathematical literacy, which helps students solve problems. According to Syaiful, Muslim, Huda, Mukminin, & Habibi (2019), Problem Based Learning (PBL) has a more significant effect on increasing students' mathematical problem-solving abilities.

The results of the post-test of mathematical critical thinking skills using the PBL learning model are shown in Figure 1.

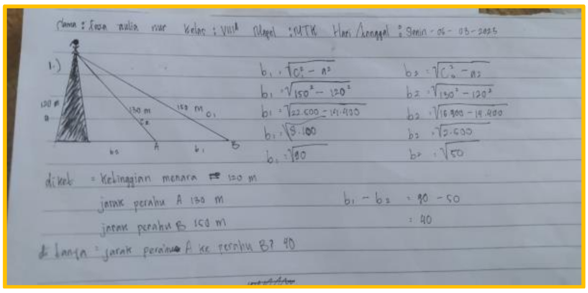

Figure 1. Post-Test Results of Students' Mathematical Critical Thinking Ability in Experimental Class (PBL)

Based on Figure 1, it can be seen that the students were correct in answering the post-test questions, but they had not completed the answers to the questions perfectly. Then in the picture, the students' answers to the post-test questions were incomplete in terms of writing down the information in the question, writing down the results of the answers to the roots, but the roots were still there, not writing down the units, and not checking the answers properly.

Research by Hendriana, Johanto, & Sumarmo (2018), Prabawati, Herman, & Turmudi (2019), and Sutarsa & Puspitasari (2021) explained that the problem-based learning (PBL) learning model can improve students' mathematical critical thinking skills.

The results of the post-test of mathematical critical thinking skills using the Direct Instruction (DI) learning model are shown in Figure 2.

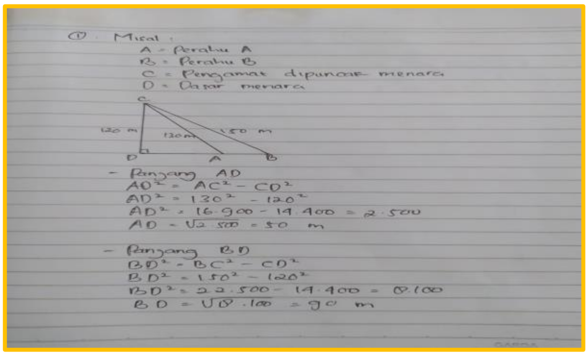

Figure 2. Post-Test Results of Students' Mathematical Critical Thinking Ability in Control Class (DI)

Based on Figure 2, it can be seen that the students did not solve the problem correctly because there were still steps that had not been completed and they did not conclude the answers obtained and re-examine the problems given.

The PBL and Direct Instruction (DI) class post-test results are in the appendix. In the PBL class, there are 18 students who have scores above the KKM and 14 students who have scores below the KKM. Meanwhile, for the Direct Instruction (DI) class, there were 7 students who scored above the KKM and 24 students who scored below the KKM.

CONCLUSIONS AND SUGGESTIONS

Learning with PBL can be used as a model in learning mathematics to improve students' mathematical critical thinking skills, especially in the aspects of making generalizations and considering the results of generalizations, identifying relevance, formulating problems into mathematical models, making deductions using principles, providing examples of inference, and reconstructing arguments.

Learning mathematics with PBL emphasizes student activity in the learning process to optimize student engagement, and it turns out to be a sufficient and effective way to create a learning atmosphere that requires teacher skills in terms of material in learning mathematics. Therefore, teachers are expected to keep trying to improve their teaching skills and mathematical abilities through various sources. For example, the results of training and research.

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