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Comparison of Problem-Based Learning and Discovery Learning to Improve Students' Mathematical Critical Thinking Skills

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Abstract: The learning model applied in mathematics learning is expected to shape, develop and even improve students' critical thinking skills. This study aimed to analyze the differences in the improvement of students' mathematical critical thinking skills between students who learn to use the Problem Based Learning model and students who use the Discovery Learning model. The research used a quasi-experimental type with a 2 x 3 factorial design that uses a two-way analysis of variance technique. This research took place at Public Senior High School 6 Ambon. The test instrument used was in the form of descriptive questions, which are based on indicators of mathematical critical thinking skills, according to Facione. Data analysis carried out in this research was in the form of normality test, homogeneity test, gain index analysis, and hypothesis testing. The research hypotheses were tested using Two-Way ANOVA. The results obtained indicate that there is no difference in increasing mathematical critical thinking skills between students who learn by using the Problem Based Learning learning model and students who learn by using the Discovery Learning learning model.

Keywords: critical thinking, problem based learning, discovery learning
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INTRODUCTION

Slavin (2015) states that one of the school's main goals is to form students' critical thinking skills. Leasa et al. (2020) explains that critical thinking is reflective and focuses on decision-making patterns about what to believe as the truth and what to do. Critical thinking activities can improve students' thinking skills and help them learn (Batlolona et al., 2019). Finally, Tuaputty et al. (2021) argues that critical thinking is a skill of examining assumptions, distinguishing hidden values, evaluating evidence, and judging conclusions.

In society, critical thinking is essential because we are constantly faced with problems that require resolution, including solving mathematical problems (Dolapcioglu & Doğanay, 2022). Therefore, students must use their necessary thinking skills to solve the problem. Critical thinking can be developed in the learning process, where a systematic approach allows students to formulate and evaluate to convince the opinions given (van der Zanden et al., 2020). Critical thinking also trains students to be good at reading situations in each problem, considering it, and drawing conclusions on the issue so that the understanding ability built will be more vital and not easily forgotten.

Students with critical thinking skills will be able to process information, analyze, evaluate, and be able to reason logically. It is because necessary thinking skills will encourage students to think independently and be able to solve problems at school and in

everyday contexts so that mathematics learning becomes better and more meaningful (Kabataş et al., 2020). Aloisi & Callaghan (2018) said that students' critical thinking skills would not develop without real and ongoing efforts to continue to be developed. A student's essential thinking ability will not develop appropriately without being challenged to practice it in learning. Someone can possess critical thinking if trained and facilitated by a mentor or coach consistently through directed discussions.

Students' critical thinking skills must be fostered to find various solutions to generate new ideas. Equipping children with necessary thinking skills will increase their mental activity (Wan & Cheng, 2019). Students with strong critical thinking skills will be able to reason, draw conclusions, make decisions, and define problems clearly (W. Hu et al., 2016). Furthermore, Loes & Pascarella, (2017) said that students with good critical thinking skills would be able to collect and evaluate information, apply abstract concepts, accept new ideas, and communicate effectively with others. Critical thinking is a cognitive process and mental activity that is organized and plays a role in decision-making to solve problems. Students develop necessary thinking skills in the classroom through challenging assumptions, identifying and participating in a careful discussion, and self-discipline (Ceylan, 2020).

According to Sachdeva & Eggen (2021), critical thinking in mathematics is an ability that involves knowledge, mathematical reasoning, and cognitive strategies to effectively generalize, prove, or evaluate unfamiliar mathematical situations. Therefore, teachers in learning mathematics must facilitate students in developing critical thinking processes. According to Kertiyani et al. (2022), critical mathematical thinking is thinking that tests, questions, relates, and evaluates all aspects of a situation or problem. Meanwhile, in the mathematical necessary thinking process, students will make statements related to the issues at hand, then connect the problem to their knowledge and experience.

Some researchers describe that the results of learning mathematics in schools have not shown satisfactory results (Umam & Susandi, 2022). Teachers concentrate too much on procedural and mechanical problem-solving exercises rather than mathematical understanding. Students tend to be passive because the teacher is the only source of information in learning activities and usually explains informative concepts through examples of questions and exercises. The results of learning mathematics using a conventional approach that is generally teacher-centered and uses expository methods cause students to be passive, lacking in exploring abilities in applying mathematical thinking skills, such as logical thinking, critical thinking, creative thinking, and other abilities (Loes & Pascarella, 2017). Learning is still dominated by explaining the material using the lecture method. The teacher has not carried out meaningful learning, which is done by starting education by presenting problems related to everyday life so that students can easily remember the material. The teacher has not let students think freely to look for concepts and solve problems related to the material presented (Lin et al., 2020).

Every student has mathematical critical thinking skills, but the problem is how to develop and improve students' mathematical necessary thinking skills through learning mathematics. These problems can be overcome by using innovative learning models. Creative and fun learning models can support learning to be more meaningful for students. However, not all learning models are appropriate and suitable for solving mathematical problems. Problem-based learning is a learning model that is suitable for solving mathematical problems. Problem-based learning requires teachers to apply meaningful learning by presenting issues related to everyday life. Teachers must also fully provide opportunities for students to think freely to find concepts and solve problems. Burgess et al. (2020) explained that problem-based learning is believed to create a pleasant learning environment where issues can encourage students to learn. The

difficulties posed can be a way for students to gain new knowledge before they can solve existing problems.

Learning that can build and develop students' mathematical critical thinking skills is learning designed to enable students with non-routine problems to be solved by students both individually and in groups. Liu et al. (2016) said that the learning models considered quite influential on students' critical thinking skills are the Problem Based Learning model and the Discovery Learning model. These two models have something in common: they require students to use their thinking skills optimally, or it can be said to think critically in problem-solving.

In addition, the learning model prioritized in implementing the 2013 curriculum is learning that refers to a scientific approach, often referred to as the 5 M (mengamati, menanya, mencoba, menalar dan mengkomunikasikan)-(observing, asking, trying, reasoning and communicating). Innovative learning models based on scientific approaches in the 2013 curriculum include the Discovery Learning and Problem Based Learning models. Both learning models are considered suitable for mathematics because students learn to discover new things from experience. It can increase student activity, student curiosity, and students' critical thinking skills (Samaras et al., 2021).

According to the results of research by Batlolona et al., (2020), PBL provides permanent knowledge with a scientific approach that produces skills. The study conducted by Son et al. (2020) states that the DL learning model provides better mathematics learning achievement than PBL learning and direct learning.

Another factor that must be considered in learning mathematics is the initial mathematical ability of students. The initial mathematical ability of students is one of the essential roles in the smooth running of a learning activity because it describes the readiness of students to accept the lessons to be delivered. According to Uno Yuanita et al., (2018), the initial ability results from learning before getting higher. Therefore, the students' initial ability is essential for the teacher to know before starting learning. It can be known whether students already have the initial knowledge, which is a prerequisite for taking part in education, and the extent to which students see the material presented. (Wartono et al., 2018).

According to Laurens et al. (2018), early mathematics abilities are cognitive abilities that students have before they take mathematics lessons that will be given and are a prerequisite for them to learn new tasks or advanced studies. Early skills are essential prerequisites for individual knowledge construction and learning outcomes. Students can construct new knowledge based on the initial abilities they already have. Students can connect various knowledge they already have to build new knowledge.

Research conducted by Gunawan et al. (2020) shows that students can solve problems well if they have a high initial ability level. Still, those with low initial ability can improve their problem-solving skills if problem-solving strategies are explained. In addition, Resmol & Leasa, (2022) research says that there is an effect of initial knowledge and interest in learning together on learning achievement. This study aimed to analyze the differences in the improvement of students' mathematical critical thinking skills between students who learn to use the problem Based Learning model and students who use the Discovery Learning model.

METHODS

This research is quantitative. The type of research used was quasi-experimental. The research design used was a 2 x 3 factorial design with a two-way analysis of variance (Two Way Anova) technique. The research design is as follows.

Table 1. Research Design Matrix

Learning model (A)	Initial Mathematical Ability /EMA (B)		
	High (B_1)	Medium (B_2)	Low (B_3)
PBL (A_1)	A_1B_1	A_1B_2	A_1B_3
DL (A_2)	A_2B_1	A_2B_2	A_2B_3

This research took place at Public Senior High School 6 Ambon, Amahusu. The population in this study were all students of class XI, which consisted of 4 classes. At the same time, the sample was selected using a purposive technique by taking class XI IPA 1 to be used as experimental class 1, namely the class that learned using the PBL learning model, and class XI IPA 2 as practical class 2, namely class who learn using the DL learning model. The research procedure is divided into three stages. The first stage was drafting and research instruments carried out in early April 2022. Next, the research implementation stage was carried out from July to October 2022. The third stage was data analysis and article completion.

Furthermore, students were grouped based on the Early Mathematical Ability (EMA) category. The criteria for grouping students' EMA based on the average score (x) and standard deviation (SB) are as follows:

Table 2. Criteria for Grouping EMA

EMA value	EMA Category
EMA $\geq \bar{x}$ + SB	High
$\bar{x}$ – SB $\leq$ EMA < $\bar{x}$ + SB	Medium
EMA < $\bar{x}$ – SB	Low

Adaptation of Somakim (2011)

Data collection techniques in this study are observation and tests. The test instrument used is in the form of descriptive questions based on indicators of mathematical critical thinking skills adapted from Facione, namely: (1) interpreting ability, (2) analyzing ability, (3) evaluating ability, and (4) inferencing ability, which are described in the table. 3.

Table 3. Indicators of Students' Mathematical Critical Thinking Skills

Indicators	Definitions
Interpretation	Understand the problem indicated by writing what is known or asked in questions correctly
Analysis	Identify the relationships between the statements, questions, and concepts given in the problems shown by making mathematical models correctly and giving explanations correctly
Evaluation	Use the right strategy in solving problems, complete and correct in doing calculations
Inference	Make the right conclusion

Adaptation of Facione (1994)

Data analysis carried out in this study was in the form of normality test, homogeneity test, gain index calculation, and hypothesis testing. In addition, the research hypotheses were tested using Two-Way ANOVA.

To find out the amount of the increase in students' mathematical critical thinking skills, and analysis was carried out on the results of the pretest and posttest. The N-Gain

data were grouped based on the students' initial mathematical abilities (high, medium, low). The analysis was carried out using the formula proposed by Hake (Wijayanti, 2017) as follows:

$$G = \frac{posttest\ score\ -pretest\ score}{maximum\ score - pretest\ score}$$

The Gain Index was classified according to the criteria as shown in Table 4.

Table 4. Classification of Gain

Gain Index	Criteria
Gain > 0,7	High
0,3 < *Gain* ≤ 0,7	Medium
Gain ≤ 0,3	Low

Adaptation of Hake (1998)

RESULTS & DISCUSSION

Results

The data from the students' initial test results were grouped by EMA category for experimental class 1 and experimental class 2 as presented in Table 5.

Table 5. Grouping of Students Based on EMA

EMA Category	Experiment Class 1	Experiment Class 2
High	5	5
Medium	17	16
Low	2	3
Total	24	24

Based on the table 5, in experimental class 1, 20.83% of students had a high initial ability, 70.83% had a medium initial ability, and 8.33% had a low initial ability. Meanwhile, in experimental class 2, 20.83% of students had a high initial ability, 66.67% had a medium initial ability, and 12.50% had a low initial ability. Thus, the students' initial mathematical ability in the two dominant classes is at a medium level.

The results of the pretest and posttest were analyzed to measure the increase in students' mathematical critical thinking skills. The results of the pretest and posttest obtained values for the two experimental classes as shown in Table 6.

Table 6. The Results of Pretest and Posttest Experiment Class 1 and Experiment Class 2

Learning	Ideal	*Pretest Score*				*Postest Score*			
Model	Score	X_{min}	X_{max}	$\bar{x}$	S	X_{min}	X_{max}	$\bar{x}$	s
PBL	48	7	17	11,88	3,05	27	39	34,50	3,88
DL	48	8	20	12	3,43	28	39	34,25	3,25

From the pretest and posttest results of the two experimental classes, experimental class 1, before being given treatment, had an average value of 11.88, and after being given treatment, it had an average value of 34.50. In experimental class 2, before being given treatment, it had an average value of 12, and after being given treatment, it had an average value of 34.25. Thus, it can be said that there is an increase in

value after being given treatment in each experimental class. The increase in students' mathematical critical thinking skills seen from the analysis of the normalized gain scores in terms of the EMA category is presented in Figure 1.

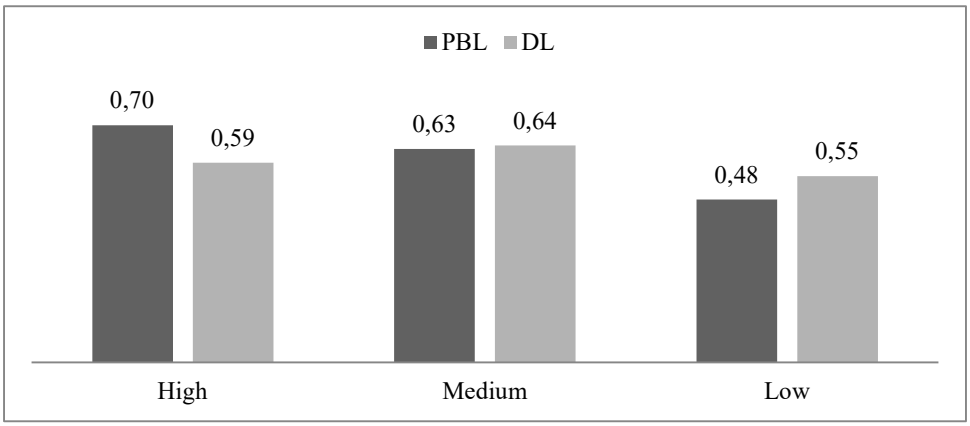

Figure 1. Graph of Average N-gain for Various Levels of Students' Mathematical Critical Thinking Skills

It can be seen in figure 1 the average difference in increasing mathematical critical thinking skills between students who study using the PBL model and the DL model in terms of the EMA category. In the high EMA category, the average N-Gain of the PBL model is 0.70, and the DL model is 0.59, with a difference of 0.11. In the medium category, the average N-Gain of the PBL model is 0.63, and the DL model is 0.64, with a difference of 0.01. In the low EMA category, the average N-Gain of the PBL model is 0.48, and the DL model is 0.55, with a difference of 0.07. Thus, the highest increase was in the high EMA category, and the lowest increase was in the medium EMA category.

Before testing the differences in the improvement of students' mathematical critical thinking skills, the normality and homogeneity of the data were tested first. The results of normality and homogeneity tests are presented in Table 7 and Table 8.

Table 7. Normality Test Results

	Experiment Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Experiment	Statistic	df	Sig.	Statistic	df	Sig.
Gain score	PBL	.141	24	.200*	.887	24	.012
	DL	.107	24	.200*	.959	24	.414

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 8. Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
.038	1	46	.846

From Table 7, it can be seen that the value of sig. The experimental class 1 and the experimental class 2 are greater than 0.05, which is 0.200. It shows that the data gain of the two experimental classes is normally distributed. Meanwhile, for the homogeneity test (Table 8), it can be seen that the sig. 0.846 is greater than 0.05. It shows that the data gain of the two experimental classes has the same or homogeneous variance. After the prerequisite test is met, then the hypothesis test is carried out. To see whether there are differences in the improvement of students' mathematical critical thinking skills, the Two Way Anova test was used. The test results are presented in Table 9.

Table 9. Two Way Anova Test Results

Dependent Variable: N-gain

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.090[a]	5	.018	3.523	.009	.295
Intercept	9.577	1	9.577	1865.909	.000	.978
Class	.000	1	.000	.087	.770	.002
EMA	.062	2	.031	6.001	.005	.222
Class * EMA	.033	2	.017	3.219	.050	.133
Error	.216	42	.005			
Total	19.081	48				
Corrected Total	.306	47				

a. R Squared = .295 (Adjusted R Squared = .212)

a. Test the difference in increasing students' mathematical critical thinking skills based on the learning model.

H_0 : There is no difference in increasing mathematical critical thinking skills of students who learn by using the PBL learning model and those who learn by using the DL learning model.

H_1 : There is a difference in increasing mathematical critical thinking skills of students who learn by using the PBL learning model and those who learn by using the DL learning model.

In Table 9, it can be seen that the value of Sig. for both experimental classes of 0.770 is greater than the value of = 0.05. It means that H_0 is accepted and H_1 is rejected or it can be said that there is no difference in increasing mathematical critical thinking skills of students who learn by using the PBL learning model and those who learn by using the DL learning model.

Based on the average N-Gain value of experimental class 1 and experimental class 2, the difference in the increase in the two classes is very small, with a difference of 0.01, namely experimental class 1 of 0.63 and experimental class 2 of 0.62.

This shows that PBL and DL learning models can improve students' mathematical critical thinking skills. The stages of the PBL and DL learning models make students constantly challenged to learn. They work together in teams when looking for solutions to real problems, and this problem is used as a benchmark to increase curiosity and the ability to analyze the initiative on the subject matter (Dwijayanti et al., 2020).

b. Test the difference in increasing students' mathematical critical thinking skills based on students' initial mathematical abilities.
   H_0 : There is no difference in increasing students' mathematical critical thinking ability of with high, medium, and low initial abilities.
   H_1 : There are differences in improving students' mathematical critical thinking skills with high, medium, and low initial abilities.

In Table 9, it can be seen that the value of Sig. for EMA, 0.005, is smaller than the value of = 0.05. It means that H_0 is rejected and H_1 is accepted, or it can be said that there is a difference in the increase in mathematical critical thinking skills of students who have high, medium, and low initial abilities. The difference can be shown in Figure 2.

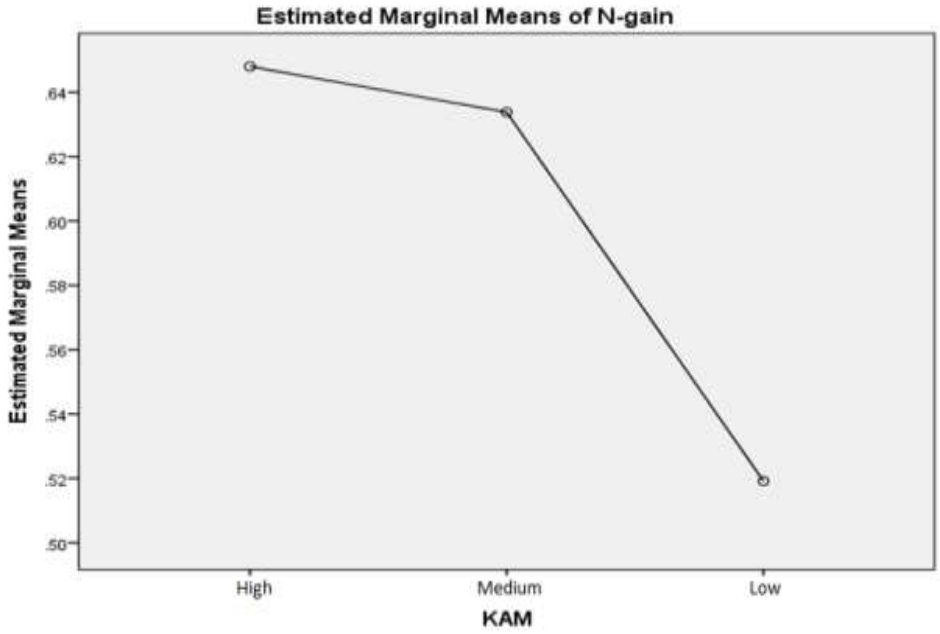

Figure 2. Improvement of Critical Thinking Ability Based on EMA

Based on the picture above, it can be seen that the increase in mathematical critical thinking skills of students who have high EMA is better than medium and low EMA. Furthermore, improving students' mathematical critical thinking skills with medium EMA is better than low EMA. It shows that students' initial mathematical abilities significantly affect the improvement of mathematical necessary thinking skills. The students with high initial abilities have better essential thinking skills. The bridge to the final ability is the student's initial ability. Every learning process stems from students' initial ability to be developed into new abilities.

c. Test the interaction of learning models and students' initial mathematical abilities to improve mathematical critical thinking skills.
   H_0 : There is no interaction between the learning model and students' initial mathematical ability to improve mathematical critical thinking skills.
   H_1 : There is an interaction between the learning model and students' initial mathematical ability to improve mathematical critical thinking skills.

In Table 9, it can be seen that the value of Sig. for class and EMA of 0.050. It means the same as the value of = 0.05. This means that the learning model and the initial mathematical ability of students are believed to be 95 percent able to affect the improvement of students' mathematical critical thinking skills. The interaction of the learning model and EMA is shown in Figure 3.

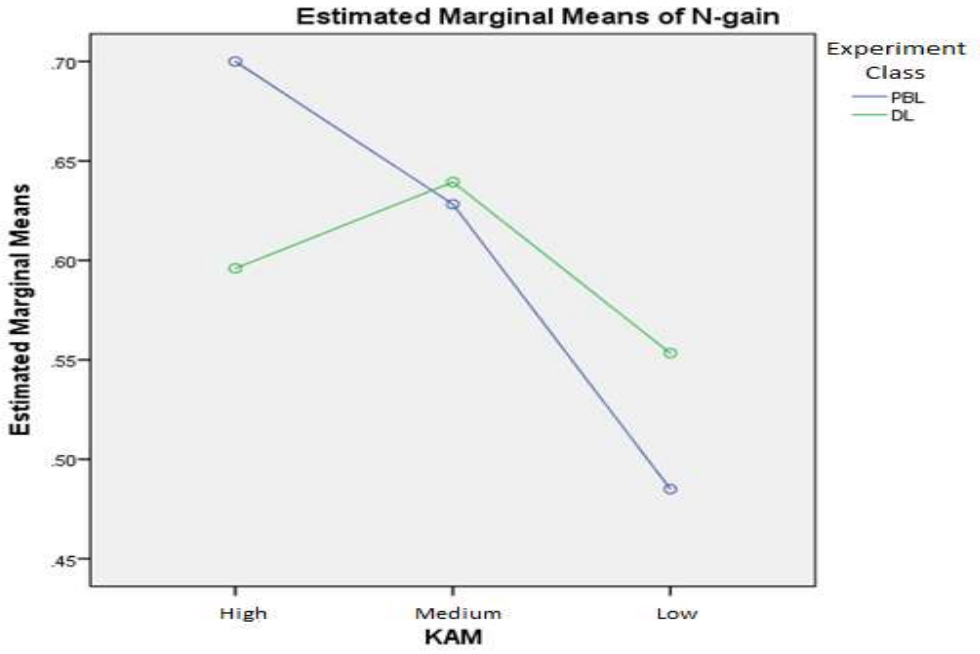

Figure 3. EMA Interaction and Learning Model

Based on the picture above, it can be seen that in the high EMA category, the improvement in mathematical critical thinking skills of the PBL model is better than the DL model. In the medium EMA category, the DL model is better than the PBL model, and in the low EMA category, the DL model is better than the PBL model.

Discussion

The findings show that PBL is superior to DL, this is because PBL is a learning model where students are involved in authentic problems and with the knowledge they have can solve problems, which requires them to develop knowledge, understanding and apply improved student understanding. certain to produce a solution (Leasa et al., 2021). PBL is a learning model for lifelong learning and is influential in developing new competencies in students with problems in learning, related to the material being taught (Pu et al., 2019). In addition, PBL is an innovative learning approach that can function as a context and stimulus for students to learn a concept in learning (Rotgans et al., 2011).

The strength of PBL is that problem solving is a great technique to help students develop higher order thinking skills such as creative thinking, problem solving and communication skills. The courage of students to be active in class depends on the teacher's role as a friend in guiding and making students more enthusiastic (Burgess et al., 2020).

The application of PBL strategies can improve students' critical thinking skills (Nizlel et al., 2022). The essence of PBL in the form of presenting various authentic and meaningful problems for students, can serve as a springboard for investigation and investigation (Dawood et al., 2021). PBL focuses on challenges that enable students to think at a higher level. As with innovation in general, PBL is not developed based on psychological theory, but the PBL process includes the use of metacognition and self-regulation. PBL is known as an active learning approach that is progressive and centered on learning on unstructured problems (real world or imitated complex problems) and is used as a starting point to the end during the learning process (X. Hu et al., 2019).

The average score for each ability to think critically mathematics shows a difference between the PBL and DL groups in terms of the average score. That the magnitude indicator shows the criteria for being high in the PBL group and moderately high criteria in the DL group. The high criterion illustrates that students are quite capable of deep critical thinking overcoming learning difficulties and doing assignments (Loyens et al., 2023).

Furthermore, the PBL indicator is included in the high criteria experimental group and moderate criteria in the control group. In the control class, students still experience a little worry about their ability to complete assignments given by the teacher regarding the learning material provided. Student confident and able to complete tasks given by the teacher by discussing with peers and teachers, or seek answers from various sources. At PBL model, there is a learning syntax that makes it easier for students to find material independently concept through group discussion. The experimental class scored highly on the last indicator, generality, however the control class also got high marks. The high criteria for this generality indicator proves that students believe they can complete various assignments and various materials in learning given by the teacher (Shanta & Wells, 2022).

With the PBL model, students at The experimental class achieves high criteria because students can learn based on their abilities experienced in solving problems and finding things to get new ideas with teacher guidance. The teacher's guidance and direction will assist students in achieving learning goals. The PBL model provides opportunities for students to practice discussing and collaborate to solve subject-related problems and guide students to discover concepts independently to improve students' self-efficacy. Research done by van Peppen et al. (2021) shows that the PBL learning model is effective in increasing students' self-critical thinking skills. Even though the data shows there is no difference between PBL and DL, the N-gain score shows that the PBL learning model can improve students' critical thinking at high and medium criteria (Thompson, 2019).

CONCLUSION

Based on the results of research and discussion, several conclusions were obtained as follows: (1) there is no difference in the improvement of mathematical critical thinking skills of students who learn by using the PBL learning model and those who learn by using the DL learning model; (2) there are differences in the improvement of students' mathematical critical thinking skills who have high, medium, and low initial abilities; (3) the learning model and the initial mathematical ability of students are believed to be 95 percent able to affect the improvement of students' mathematical critical thinking skills. Therefore, even though there is no difference between the two existing models, in the critical thinking criteria the PBL class at high and moderate levels is

superior to DL. Therefore PBL should be used as an alternative model that is suitable for supporting the mathematics learning process, so that students are more involved in discussing and solving problems related to the subjects studied and guide students to discover concepts independently to solve a problem so that students become more confident and confident. The PBL model is expected to be used by teacher in the future as an alternative model to help students acquire good higher order thinking, which will be beneficial for their mathematics learning outcomes.

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