The Effect of The Problem-Based Learning (PBL) Model with a Multi-Representation Approach on Students' Critical Thinking Skills in The Buffer Solution Concept

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Abstract. This study aims to determine the effect of the Problem-Based Learning model on students' critical thinking skills with multi-representation approach on buffer solution concept. The research applied an experimental research method. This type of research is quite experimental. The design used in this study is a non-equivalent control group design. The population in this study were all students of XI IPA. Samples were taken using a purposive sampling technique and involved students of class XI IPA 1 and XI IPA 2. The researcher conducted an essay test with five questions that had been examined for validity and reliability to determine the effect of the problem-based learning model on students' critical thinking skills with multi-representation approach of the buffer solution concept. The hypothesis testing uses a t-test and obtains a value of $t_{count} = 4.98 > t_{table} = 1.67655$. Thus, H_o is rejected, and H_a is accepted. In conclusion, there is an effect of the problem-based learning model on students' critical thinking skills with multi-representation approach on the buffer solution concept.

1 Introduction

One of the important skills to develop is critical thinking ability. Therefore, education is necessary to develop high-level, creative, innovative, and effective thinking skills to improve the quality of human resources to compete nationally and internationally because we, as human globalization. The era of globalization is a challenge associated with human competitiveness to high-level thinking. Covered in it is the critical thinking ability[1]. Critical thinking skills are a child who can be critical or think critically when carefully examining the experience, evaluating his knowledge and ideas, and considering previous arguments-arguments[2]. While according to Ennis[3], Giving a critical thinking definition is thinking we are reasonable and reflective by emphasizing decision-making on what to believe or do. The problems that are often found in each school are still many schools that do not implement the active learning process, of Learning so it is unable to develop the student's critical thinking skills. Because it suits the researcher's experience, schools only stand on the surface of the problem, not teaching how deep thinking is. The teacher encourages students only to provide the correct answer and does not encourage them to bring up new ideas or think of conclusions. This chemical learning is classified as complex lessons that most students still have difficulty understanding chemical lessons because chemistry contains abstract theories and calculations. Therefore, if we other study chemical theories, we need to know the three aspects: macroscopic, microscopic, and symbolic. The current Learning emphasizes two levels of representation, namely macroscopic and symbolic. Most schools still rarely apply submicroscopic levels of chemical learning, so students tend only to memorize substance and abstract symbolic representations (in the form of description of words), but students are unable to imagine and explain how the process and structure of a substance that reacts so many students who are not able to understand chemistry intact[4].

Based on the interview with the chemical teacher that the problem is still many of the students still lack critical thinking ability. This is because the students have not been in accordance with the indicator or the one parameter one can be said to think critically because of the five indicators there is a weakness of students in this material of this buffer solution. That is, the students are still less precise in providing the conclusion and the reason is presented an image-related image and the basis, students also have not been able to explain further related to what is the addition of bases or acids in the material of the buffer solution.

Based on these problems, the teacher should use the learning model that corresponds to the characteristics of the students and utilizes all the learning facilities in the school so students are not bored in receiving lessons and are active in the learning process in the classroom. One attempt to resolve the issue is to use the Problem-Based Learning (PBL) learning model. Problem-Based Learning is a learning model that challenges learners to

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find real-open or open-ended troubled individuals or groups. The problem faced by students is selected with the aim of generating students in questioning by re-connecting with everyday life to encourage students to think critically and analyze.

The PBL learning model is widely used in every Learning, but not all chemistry learning materials can use the PBL learning model. But for the concept of buffer solution, it is very appropriate to use this learning model. This is because buffer solutions are closely related to everyday life and can be a "problem" in the PBL learning stage. In addition, buffer solutions are closely related to the chemical multi-representation approach because the concept of buffer solutions is material whose concepts are partly abstract. Because the concept of buffer solution which is still abstract causes difficulties for students in learning and understanding chemical concepts. In learning the concept of buffer solution, students are required to learn continuously, namely through the introduction of objects by direct observation, describing them at the molecular level, and describing them in the form of symbols and chemical formulas[5].

Implementing the PBL learning model with a multi-representation approach is expected to help students understand the problems presented. Multi-representation can help students implement Learning because problems presented in the form images, videos, graphs or diagrams will make the problems contributed clear and encourage students to think more critically[6].

PBL is a learning model that centers or optimizes students' thinking skills through systematic group work, where the teacher only becomes a facilitator who directs learning by presenting a problem then students can solve a problem through the stages of the scientific method[7]. The PBL Learning Model is a learning model that demands the mental activity of students to understand concepts through situations and problems presented at the beginning of Learning, with the aim of training to solve problems[8].

PBL is a model that makes students gain new knowledge to complete a problem. Then this PBL is often known as a collaborative learning model because students and teachers blend their potential. The PLB Learning Model Steps are: 1) Provide the orientation of the problem to learners; 2) Organize learners to examine; 3) Help independent investigations and groups; 4) develop and present the work; 5) Analyze and evaluate the process of overcoming the problem[9].

Ennis[2] Situating thinking is a process to produce decisions that make sense of something done. According to Ennis[3] There are several critical thinking indicators grouped into five thinking skills, namely: 1) Elementary Clarification (providing a simple explanation), 2) Basic Support (building basic skills); 3) Inference (concluded); 4) Advance Clarification (Providing further explanation); 5) Strategy and Tactics (arranging strategy and tactics) Multi representation has three main functions, namely as a complement, capable of interpreting and understanding builders. Multi-representation as a complement is used to provide a complementary submission or help complement the cognitive process of[11]. Three chemical representation levels consist of macroscopic representations, submicroscopic representations, and interconnected symbolic representations in chemical Learning. On macroscopic representation is confronted with the observed events[10].

According to Treagust[11], The macroscopic level is the chemical phenomenon that can be observed directly, including daily student experience. Macroscopic levels are levels associated with a chemical phenomenon that can be seen or perceived with the senses of senses. Macroscopic representations describe the real observation of a chemical phenomenon that can be a perception of panca senses such as colour changes, temperature, pH and forming of deposits that can be observed when the occurrence of chemical reactions [4]. Submicroscopic representation is related to the unusable particles where this representation supports clarifying the macroscopic events that occur[14]. While symbolic is presented in the form of chemical equations, symbols, images, diagrams/charts[12].

Based on previous research by Wela[13] shows that the critical thinking skills of the class X edition by applying the model-based basement model with the multi-representation approach indicates the average value for the experimental class that has the treatment of the PBL model with the help of multi-representation of 78.8, while for the control class that does not get the average value of the value of 74.1, it can be said that the difference in the critical thinking skills of students who learned by using the MBP model of the Multi-representation PBL with students who only conventional Learning.

Based on the description of the researcher conducting research titled " The Effect of The Problem-Based Learning (PBL) Model with a Multi-Representation Approach on Students' Critical Thinking Skills in The Buffer Solution Concept".

2 Method

2.1 Type of Research

This study uses a quantitative approach. The method in this study is the quasy experiment (a mercy experiment) with the non-equivalent control group design, and this design consists of two groups of one subject of the subjects given certain treatments (experimental groups) while one other group is used as a control group.

2.2 Subject

The subject of this study is XI IPA 1 and XI IPA 2 graduate students at SMAN 3 Gorontalo 2021/2022, less than 51 students. This research technique uses the Purposes Popposive technique. Where in the determination of this sample with a certain consideration [14].

2.3 Procedures

This study uses Non-equivalent Control Group Design, and this design consists of two groups of one subject of a group of treatment (special group) while one other group is used as a control group. The two classes begin with a pre-test, then given different treatments drafted by the class, then last post-test.

2.4 Data, Instruments and Data Collection Techniques

The research data is known through the results of the description of the critical thinking ability amounting to 5 numbers provided as pre-test and post-test. The result of this test was then analyzed using staticity calculated and then determined the percentage of critical thinking ability. The instrument used in this research is the critical thinking process of the instrument of the process of the description of 5 items. Critical thinking skills tests are respectively each critical thinking indicator. The data collection technique in this study is to use a critical thinking ability test. The test is a way to implement measurement activities in which there is a question to be done of learners[15].

Before the test is used, then the validation of the test instrument is first done by three people in chemical fields. In addition, the test instrument is also validated by students who are not research samples. Valid instruments mean the measuring tool to obtain data must also be valid. Validity testing can be done empirically and rationally. Empirical validity is obtained through empirical analysis, while rational validity is obtained through logical thinking [16].

Here's the formula to test the validity of instrument [17].

$$r_{xy}= \frac{N(\sum XY)(\sum X)(\sum Y)}{\sqrt{(N\sum X^2-(\sum X)^2)(N\sum Y^2-(\sum Y)^2)}} \quad (1)$$

On this test for which the criterion is if $r_{hitung} > r_{tabel}$, then it can be stated that this item is valid, while if $r_{hitung} < r_{tabel,}$ then it can be stated that this item is invalid (invalid).

The most popular method used in research to test for internal consistency is to determine coefficient alpha. Various calculations for coefficient alpha have been developed in the literature.

$$r_{11}= \left(\frac{n}{n-1}\right)\left(1-\frac{\sum S_i^2}{S_t^2}\right) \quad (2)$$

The Cronbach's alpha coefficient, the value of which is between 0 and 1, approaches +1, and it is stated that internal consistency is high[18].

2.5 Data analysis technique

Test Critical Thinking Skills Students In use All students to further analysis by using the following steps: 1) Provide raw scores on every student's answer to the Essay test based on score criteria; 2) Calculate the total score of the Essay test for each student based on every aspect of student critical thinking ability; Then determine the value of the critical thinking ability of students by changing raw scores into the value based on the formula:

$$NP= \frac{R}{SM} \times 100\% \quad (3)$$

Based on the information obtained from the results of the essay test analysis, the value is then interpreted in the form of categories to facilitate reading and draw conclusions in the categories of very good, well, enough, less. good or very bad.The full catalogue can be seen in Table 1 below:

Table 1. Category Score

Interval score	Category
81-100 %	Very Good
61-80 %	Good
41-60 %	Enough
21-40 %	Not good
0-20 %	Very less

Normality Test

This normality test aims to check whether the data to be analyzed is normal. To know that the sample data taken from the normal distribution population is used with the lilies test. The lilies test formula is as follows:

$$L_{count}= \text{Max} \mid f(z)-S(z)\mid \quad (4)$$

Conclusion: If $L_{hitung} \leq L_{tabel}$, then H0 is accepted.

Homogeneity Test

After normally distributed data, then the result of the homogeneity test of the variant (F-Test), namely:

$$F_{hit}= \frac{S^2 terbesar}{S^2 terkecil} \quad (5)$$

$$S^2= \frac{\sum X^2-(\sum X)^2}{n(n-1)} \quad (6)$$

With the criteria, homogeneous samples $F_{hit} < F_{tab}$ (F $\alpha_{(dk1,dk2)}$), with $\alpha = 0{,}05$ [14].

Hypothesis Statistics

Hypothesis testing in this research is done by test t. The hypothesis statistics to be tested are formulated as follows:

$H_0 : \mu_1 = \mu_2$(no effect)

$H_a : \mu_1 \neq \mu_2$(take effect)

Accepted H_0 if $t_{count} \leq t_{table}$ and reject H_0 if tcount > t_{table} With Degrees of Freedom (DK) = N1 + N2 - 2. H_0 (Zero hypotheses) there is no effect of using the problem-based learning model on the critical thinking skills with multi-representation approach students at SMAN 4 Gorontalo. H_a (Alternative hypothesis) there is an influence of the use of problem-based learning models on the critical thinking skills with multi-representation approach students at SMAN 4 Gorontalo.

According to Sugiyono[19] if both groups compared to the above hypothesis have been tested, and the results of these two groups are normally distributed and have homogeneous variance, then the next step is to test the t-using the following formula:

$$t = \frac{\overline{X_1} - \overline{X_2}}{(dsg)\sqrt{\frac{1}{n1}+\frac{1}{n2}}} \quad (7)$$

Whereas dsg represents the combined standard deviation value, $\bar{x}_1$ denotes the average value of Group 1 data, and $\bar{x}_2$ denotes the average value of Group 2 data.

3 Result and Discussion

This quantitative research aims to determine the influence of *problem-based learning* models with a multi-representation approach on students' critical thinking skills on the concept of buffer solution. The research was conducted at SMAN 4 Gorontalo, the sample used in this study was 51 students consisting of an experimental class of 26 people and a control class of 25 people. The data collection uses critical thinking skills tests in the form of descriptions. Data collection was carried out twice, namely, pre-test and post-test. From the pre-test and post-test results, students' average critical thinking ability is shown in Table 2 below.

Table 2. Pre-test and Selling Practice Scores Critical Thinking

Class	**Average Value**	
	Pre-test	***Post-test***
Experimental	31,15	81,73
Control	37,8	64,20

Based on Table 2 that there was a significant increase between the control class and the experimental class from the *Pre-test* to *Post-test.* However, the experimental class is higher than the control class of the two classes.

The critical thinking ability is obtained based on critical thinking ability tests, where the test is composed following the critical thinking indicator. Based on the pre-test and post-test data results reviewed in the inquiry, the ability to think it's in the control class and experiment can be seen in the following four tables.

Table 3. Pre-test results of the control class and experimental class based on indicator Critical thinking skills

Critical thinking ability	**Class control**	**Class experimental**
	Persentase (%) and category	**Persentase (%) and kategory**
Elementary Clarification (provides a fundamental explanation)	28 (Less)	28,8 (Less)
Build essential skills adapting to the source (ability to reason)	30 (Less)	30,8 (Less)
Inference	37 (Less)	33,7 (Less)
Advance Clarification (giving further explanation)	35 (Less)	25,96 (Less)
Strategy and Tactics (Setting Strategy and Tactics)	59 (Less)	36,5 (Less)
Average	**37,8 (Less)**	**31,15 (Less)**

Table 4. Post-test results of the control class and experimental class based on indicator Critical thinking skills

Critical thingking ability	**Class control**	**Class experimental**
	Persentase (%) and category	**Persentase (%) and category**
Elementary Clarification (provides a fundamental explanation)	58 (Enough)	95,2 (Very good)
Build essential skills adapting to the source (ability to reason)	60 (Enough)	67,31 (Good)
Inference	64 (Good)	84,62 (Very good)
Advance Clarification (giving further explanation)	61 (Good)	80,77 (Good)
Strategy and Tactics (arranging strategy and tactics)	78 (Good)	80,77 (Good)
Average	**64,2 (Good)**	**81,73 (Very good)**

Then conduct a hypothesis test. However, normality tests and homogeneity tests are first carried out. The results of the normality test and the homogeneity test of the following Tables 5 and 6, respectively

Table 5. Test Normality

Source data	**L_{hitung}**		**L_{tabel}**	**Conclusion**
	Pre-test	***Post-test***		
Class experimental	0,142	0,120	0,169	Normal
Class control	0,151	0,165	0,172	Normal

Based on Table 5 result of the normality test with a significant level of 0.05, pre-test and post-test data in the experiment class and control is a normal distribution. This is because $L_{hitung} \leq L_{tabel}$, so H_0 is acceptable.

Table 6. Uji Homogenitas

Pretest		Posttest		Conclusion
Class experimental and control		Class experimental and controll		
f_{hitung}	f_{tabel}	f_{hitung}	f_{tabel}	Homogen
1,93	2,01	1,81	2,01	

Table 6 contains the results of homogeneity tests of pre-test and post-test data in experimental and control classes. Test results on both classes obtained $f_{hitung} \leq f_{tabel,}$ Where to pre-test of 1.93 and the post-test is 1.81 while the ftable value is 2.01 so that F_{hitung} obtained is smaller than F_{tabel}. Based on the test results, the pre-test and post-test data are both homogeneous classes. After testing, normality and homogeneity tests were carried out hypothesis test. The calculation results using the T test can be seen in Table 7 below:

Table 7. Hypothesis test results

Data groups	Average	Variant	T_{hitung}	t_{tabel}
Experimental	81,73	113,9	4,98	1,67655
Control	64,20	205,6		

Based on Table 7, the hypothesis test results used the T-test obtained t_{hitung}=4,98. Data calculation results show the value $t_{hitung,} > t_{tabel}$ is 4,98 > 1,67655, which means H_a is accepted, and H_0 is rejected.

Discussions

The aim of this study was to investigate the influence of the PBL learning model with a multi-representation approach on students' critical thinking skills regarding the concept of a buffer solution. The study had two class treatments: the experimental class and the control class. After giving different treatments to these two classes, we obtained data on students' critical thinking skills. The experimental class used the PBL model with a multi-representation approach, while the control class used the PBL model. The experimental class's essential skills of thinking score were 81.73, while the control class scored 64.20. Then a hypothesis test was conducted to demonstrate the different treatments' impact and obtained a result of 4.98 > 1.67655. This indicates that we accept Ha and reject H0. The difference in critical thinking average between the experimental class (81.73) and the control class (64.20) supports this conclusion.. Therefore, we can conclude that the PBL learning model with a multi-representation approach and the PBL learning model without a multi-representation approach influence students' critical thinking skills. Fig. 1 below shows a significant increase in critical thinking skills based on the pre-test and post-test data.

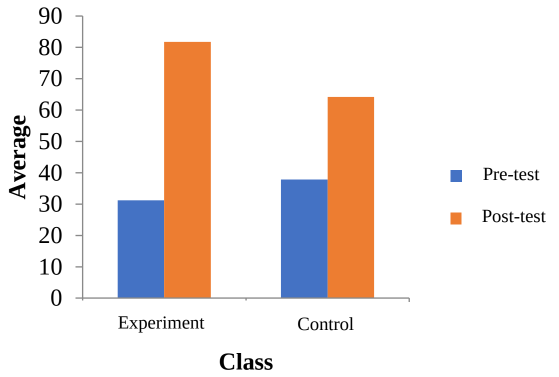

Fig 1. Increased Change of Critical Thinking Skills

The PBL model with a multi-representation approach positively influenced students' critical thinking skills. This conclusion can be drawn from the significant increase in the average score of the pre-test and post-test and the difference in scores between the experimental and control classes, with the experimental class achieving the highest average score. This can be seen in Fig. 1.

There are four stages of treatment carried out. In the first stage of the experimental class, students are given concrete problems either delivered in speech/narration or presented in representations such as videos and pictures. While in class, the problem control given to students is only given in the form of speech/narration only. In the second stage of the experimental class, students are organized through verbal, symbolic, and image representations in discussion activities. In the control class, the teacher only organizes students using oral representations. In the third stage, both classes are given the same treatment: guiding students to conduct experiments to solve the problems. The difference between the two is that in the control class, the problems described are still abstract, while in the experimental class, the problems are displayed using learning videos and LKS, and the experimental class also displays LKS multi-representations. In the fourth stage, students in the experimental class solve and present problems with various representations, while in the control class, students solve and give problems using only one representation. Another factor distinguishing students' critical thinking skills is that students' analytical power in solving problems is less than optimal. Good analytical skills will have an impact on the development of good critical thinking skills as well[20].

Based on the study's results, it was obtained that students' critical thinking skills in the experimental class were higher than those in the control class. However, not all samples in the control class have low critical thinking skills, and vice versa not all samples in the experimental class have high critical thinking skills. High critical thinking skills in experimental classes are influenced by different treatments using PBL models with a multi-representation approach. The critical thinking skills of experimental and control class students in answering multi-representation questions can be seen in Fig. 2 below.

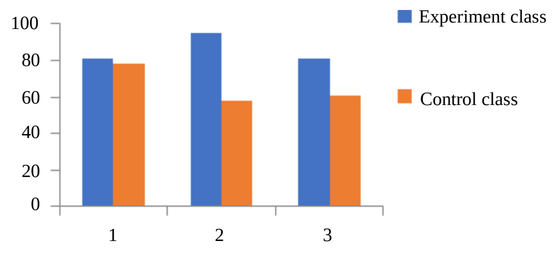

Fig. 2. The Characteristic Character Cath of Student In Progression About Multi-representation

Based on Fig. 2, we can observe that the PBL model with a multi-representation approach has an impact on students' critical thinking skills. It enables students to comprehend the given problems more quickly. This is because the questions given are easier for students to understand and analyze well. After all, they are displayed in attractive pictures and graphics. Another interesting reason is that students can understand the problem and can express ideas as a whole just by looking at the shape of the picture. As for the control class, students have difficulty understanding and analyzing problems represented in various forms because students are less able to analyze problems, and understanding is not optimal, so students are less able to solve problems about chemical processes represented sub-microscopically.

Several indicators can be used as a reference for someone who can be said to think critically. The following is the improvement of critical thinking skills of experimental and control class students, which can be seen from the following indicators (Fig. 3).

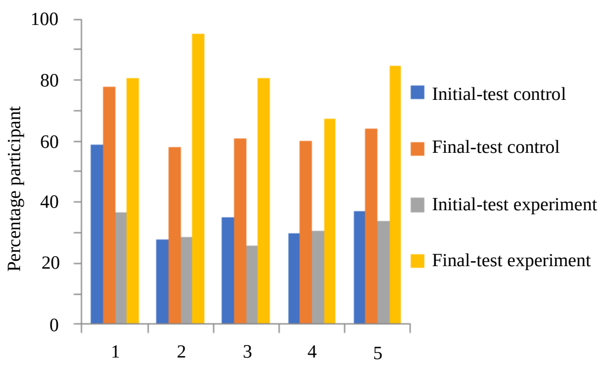

Fig. 3. Critical thinking charts of each indicator in the experiment and control class

Based on these five indicators, the experimental class demonstrated the highest percentage in providing a simple explanation, while the lowest percentage was in basic skills. On the other hand, the control class showed the highest percentage of 78% in the first indicator of setting strategies and tactics, while the lowest percentage of 58% was in the first indicator of providing a simple explanation. In conclusion PBL with a multi-representation approach positively impacts students' critical thinking skills. This is in line with the results of research conducted by Wela et al[13], which is the effect of critical thinking ability of students who learned to use a PBL model with a multi-representation approach on students who only learned to use the PBL model.

Applying PBL models with multi-representation approaches in chemistry learning can facilitate the development of students' critical thinking skills. This is because the learning process is directly related to contextual issues related to the presented learning materials through various representations, which enable students to understand and identify problems and collect information from various sources to investigate them. The use of various representations in chemistry learning can also minimize difficulties in learning and solving chemistry problems for students. Brener argues that students' problem-solving success depends on how they represent a situation and the skills they use to represent the problem, including the use of words, tables, graphics, equations, and symbol manipulation in mathematics. The three main functions of multi-representation, namely completing information, limiting interpretation, and building understanding, support this argument.[21].

4 Conclusion

The results of data analysis and discussion lead to the conclusion that the Problem-Based Learning (PBL) model with a multi-representation approach has an impact on critical thinking skills in the buffer solution concept. This is evident from the significant difference in critical thinking average scores between the experimental class (81.73) and the control class (64.20).

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