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The Effect of Problem-Based Learning Model on Student Outcomes in Acid-Base Chemistry at MAN 3 Mandailing Natal

Rico Apryanto Rangkuti[1], Lelya Hilda[2], Nur Azizah Putri Hasibuan[3]

[1-3] Chemistry Education. Tarbiyah and Teacher Traning Faculty, Universitas Islam Negeri Syekh Ali Hasan Ahmad Addary Padangsidimpuan, North Sumatera, Indonesia

*Correspondence: ricoapryanto1@gmail.com

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Abstract.

Based on research, students are unable to distinguish between the concepts of acids and bases, and are unable to apply the existing formulas for acids and bases, resulting in students being less active, less able to explore their knowledge, and less able to express their ideas, thereby leading to low learning outcomes. This study aims to determine the significant effect of the Problem-Based Learning model on student learning outcomes in acid-base material. This study was conducted at MAN 3 Mandailing Natal from June 16 to June 26 in the even semester of the 2024/2025 academic year. The research method used in this study was a quasi-experiment, and the research sample consisted of 32 students in each of the experimental and control classes. In the experimental class, there were 16 male students and 16 female students, while in the control class, there were 12 male students and 20 female students. The data collection techniques used were test and documentation. The main instrument used was a multiple-choice test consisting of 15 questions, which were then analyzed using a t-test. The results of the hypothesis test using SPSS version 24 software obtained significant data, namely "$p < 0.05$" so H0 was rejected and H1 was accepted. This indicates that there is a significant effect of the Problem-Based Learning model on student learning outcomes in acid-base material at MAN 3 Mandailing Natal. The implication of this study is that the application of the problem-based learning model affects learning outcomes and motivates students to learn at MAN 3 Mandailing Natal.

1. Introduction

Chemistry learning involves concepts, reactions, and calculations that are abstract in nature. This condition has an impact on students' low interest in learning chemistry. The problems that arise

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are inseparable from the way textbooks present the material, the way teachers teach and transfer chemistry knowledge, the public information received by students, and the students' goals in learning chemistry (Hamid dkk., 2022). The level of learning activity is greatly influenced by the teaching methods used by teachers. Therefore, teachers must be creative and innovative in selecting, identifying, and practicing learning models so that students can actively participate in teaching and learning activities, thereby creating conditions for students to acquire new skills as expected. The success of a learning process can be seen from the number of students who are able to complete the course or obtain a minimum score of 65, which should be at least 85 percent of the total number of students in the class (Zaduqisti, 2022).

One learning model that uses a scientific approach that encourages students to observe, question, associate, and communicate is the Problem-Based Learning (PBL) model (Suswati, 2021). Problem-Based Learning (PBL) is a learning model that encourages students to think critically about problems that arise in the learning process and to be able to solve these problems in groups or individually. The problems that arise in this learning model are problems encountered in everyday life. Problem-Based Learning (PBL) essentially transforms the idea of teaching and learning activities from teachers to students. In this learning model, students are required to work cooperatively and become part of a team (Dalimunthe & Ginting, 2022).

Teachers seek solutions to improve chemistry learning outcomes, both individually and classically, by designing teaching and learning activities that are more active for teachers and students through a scientific approach. One learning model that uses a scientific approach that encourages students to observe, question, associate, and communicate is the Problem-Based Learning (PBL) model (Mulyani & Wiraningtyas, 2022).

Based on the results of observations, there is a lack of interest among students in science lessons in the classroom. Students who are not familiar with science lessons tend to lack curiosity and critical thinking skills. Therefore, it is necessary to provide innovative and enjoyable chemistry teaching materials to give students an interesting picture of chemistry learning and foster their love of science, especially chemistry.

Therefore, based on the above background, in order to determine the effect of problem-based learning (PBL) on learning outcomes in acid-base material, the researcher attempted to improve upon the problems faced by previous researchers. The author conducted a study entitled “The Effect of the Problem-Based Learning Model on Acid-Base Material on Student Learning Outcomes at MAN 3 Mandailing Natal.”

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2. Materials and Methods

This study was conducted in the even semester of the 2024-2025 academic year at MAN 3 Mandailing Natal in Huraba Village, Siabu District, Mandailing Natal Regency, North Sumatra Province. This research is quantitative research using a quasi-experimental design method. The Pre-test-Post-test Control Group Design was used, which involved using a control class and an experimental class to test the approaches used (Sugiyono, 2008). A pre-test was given to assess the initial abilities of the two classes used as research samples. The experimental class was taught using the Problem-Based Learning model, while the control class was taught using the direct instruction approach, which is still teacher-centered (Silitonga, 2013).

The sample in this study consisted of 32 students in both the experimental and control classes. Among non-probability sampling techniques, the researcher chose purposive sampling, purposive sampling technique in which researchers select participants based on specific characteristics, criteria, or purposes relevant to the study. which is a technique for determining samples based on specific considerations. The sample used in this study consisted of students in class XI MIPA 1 as the experimental class and class XI MIPA 2 as the control class. The reason for selecting students from classes XI MIPA 1 and XI MIPA 2 was that they met the requirements of the purposive sampling technique, namely studying chemistry, particularly acids and bases. In the experimental class, there were 16 male students and 16 female students, while in the control class, there were 12 male students and 20 female students.

The design used in this study was a non-equivalent control group design, which consists of two groups, namely the experimental and control groups. It began with a pretest given to the experimental and control groups, followed by the experimental group being given a specific treatment (Rangkuti, 2016). Finally, a posttest was given to the experimental and control groups to see the effect of the treatment on the experimental group.

The sampling technique used was non-probability sampling, which is a sampling technique that does not give equal opportunity or chance for each element or member of the population to be selected as a sample (Subakti dkk., 2021). The data collection techniques used in this study were learning outcomes and documentation. The main instrument used was a multiple-choice test consisting of 15 questions, which were then analyzed using a t-test.

3. Results

Before the treatment was administered to each class, a pretest was conducted to assess the students' initial abilities in relation to the material to be taught.

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Table 1.

Description of Pretest Data in the Experimental and Control Classes

Data	*Pretest*	
	Eksperimental	**Control**
Lowest Value	60	53
Highest Value	87	73
Average	74.63	64.06

Based on the preliminary test results, the learning outcomes of students in the experimental class on the subject of acids and bases show that the initial abilities of students in the experimental class are better than those in the control class. This is indicated by a higher average score (74.63 > 64.06), a higher maximum score (87 > 73), and a higher minimum score (60 > 53). Thus, although both classes were in the adequate category, the experimental class had relatively better initial readiness. This data is important as a basis for analyzing the posttest results, to see the extent to which the learning treatment affects the improvement in learning outcomes.

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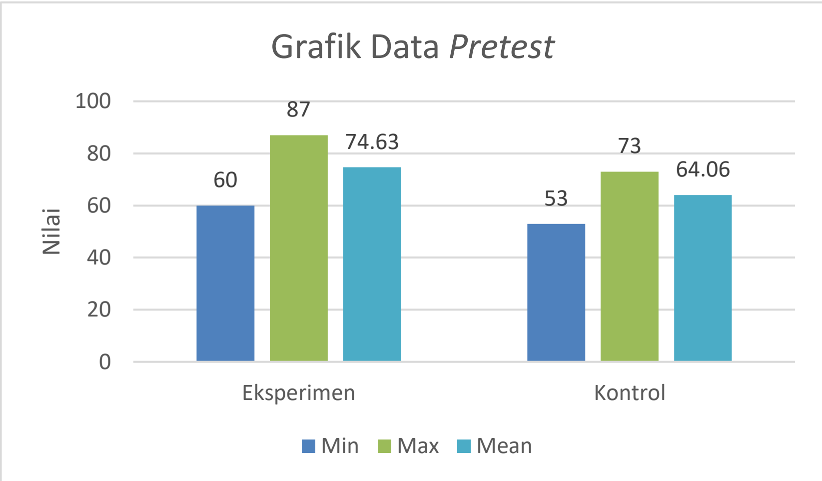

Figure 1.
Pre-test data for the experimental class and control class

After each class underwent treatment, a final test (post-test) was conducted to assess the students' abilities and learning outcomes after receiving treatment.

Table 2.

Description of Post-test Data for the Experimental and Control Classes

Data	*Postest*	
	Eksperimental	**Control**
Lowest Value	100	93

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Highest Value	80	73
Average	86,72	80,13

Based on the final test results (posttest) regarding student learning outcomes on acid-base material for the experimental class, it can be concluded that learning in the experimental class was more effective in improving student learning outcomes than the control class, as shown by the higher average score, lowest score, and highest score. The posttest results show that the experimental class had better scores than the control class. The lowest score for the experimental class was 80, while that for the control class was 73. The difference between the experimental class and the control class was 6.59%, as can be seen in the post-test data graph below.

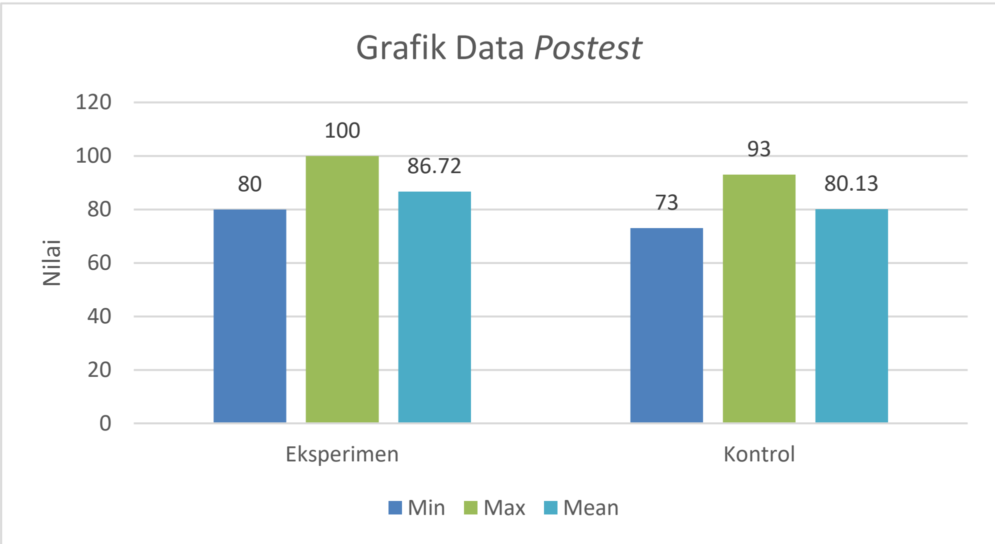

Figure 2.
Posttest Data Graph for the experimental class and control class

Next, a normality test was conducted, and the pretest data on student learning outcomes showed a significant value of 0.128 in the control class and 0.190 in the experimental class. This indicates that the significant values of the control and experimental classes are normally distributed because the significant values are greater than 0.05. The normality test results for the posttest scores of students in the control class showed a significant value of 0.200, while the experimental class showed a significant value of 0.230. indicates that the significant values in the data are greater than the significance level of 0.05. This means that the data is normally distributed in the normality test of the posttest scores in the control and experimental classes.

The next prerequisite test was the homogeneity test on the pretest and posttest learning outcomes in the control and experimental classes. The homogeneity test results for the pretest learning outcomes of students in the control class obtained a significant value of 0.148, while the

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experimental class obtained a significant value of 0.200. This proves that the significant value in the data is greater than the significance level of >0.05. Thus, it can be concluded that the pretest data on the learning outcomes of students in the control class and the experimental class have homogeneous variance.

The results of the normality and homogeneity tests show that the pretest and posttest data on the learning outcomes of students in the control class and the experimental class are normally distributed and homogeneous. Next, hypothesis testing was conducted using the Independent Sample t Test with a significance level (α) of 0.05. The results of the hypothesis testing of the pretest and posttest data are presented in Table 3. below:

Table 3.

Results of the Independent Sample Test Hypothesis Testing of Pretest and Posttest Scores in the Experimental and Control Classes

Data Test	Significance level (α)	Sig. (2-tailed)	Conclusion
Pretest	0,05	0,164	Sig. (2-tailed) > α H0 is accepted, while H1 is rejected. This means that there is no difference in the average pretest learning scores.
Posttest	0,05	0,000	Sig. (2-tailed) < α H0 is rejected, while H1 is accepted. This means that there is a difference in the average posttest learning scores.

Based on the results of the independent sample t-test of the pretest scores at α = 0.05, a significance value (2-tailed) of 0.164 was obtained. This significance value (2-tailed) is greater than 0.05, so H0 is accepted. This means that there is no significant difference in the average pretest learning scores between the control class and the experimental class. Therefore, the sample is suitable for use in the study, and the results of the independent sample t-test posttest with a significance level (α = 0.05) obtained a significance value (2-tailed) of 0.000. The significant value (2-tailed) obtained is less than 0.05, so H0 is rejected and H1 is accepted. This shows that there is a significant difference in the average posttest learning scores of students in the control class and the experimental class.

The conclusion of this study shows that there is a significant effect of using the Problem-Based Learning model on learning outcomes in acid-base material at MAN 3 Mandailing Natal. This is evidenced by the results of the hypothesis test on the posttest, where the significance value obtained is smaller than the specified significance level (α = 0.05). Thus, the use of the Problem-Based Learning model is effective in improving student learning outcomes in the learning process.

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4. Discussions

This study aims to determine the effect of implementing the Problem Based Learning (PBL) model on student learning outcomes in acid-base systems. Six cognitive domain indicators based on Benjamin Samuel Bloom (Bloom's Taxonomy) were used in this study to measure student learning outcomes. The PBL learning model was implemented in the experimental class, while conventional learning with lecture and question-and-answer methods was implemented in the control class. According to Benjamin Samuel Bloom in the book by Ananda Rusydi et al., learning outcomes are divided into three domains, namely cognitive, affective, and psychomotor (Ananda & Hayati, 2020). The Problem-Based Learning model is based on real-life situations to help students better understand the material and actively participate in the learning process (Bengi Birgili, 2022).

The PBL learning model was applied to class XI IPA 1 accompanied by acid-base practical work. Conventional learning was used for the control class. The experimental class was divided into two groups, each of which discussed the topic and material on acids and bases and solved problems given by the teacher in the form of exercises and videos that were shown, and each group presented in front of the class.

Both groups were given different experiments. The first group conducted an acid-base experiment using natural turmeric with natural indicators of soap salt and promag to determine the acid-base properties of each indicator. The second group conducted an acid-base experiment using natural dragon fruit ingredients with natural indicators of soap salt and promag to determine the acid-base properties of each indicator. The different findings of each group were presented and responded to by the other group.

The results of the practical work carried out by the two groups were different. The group that conducted the experiment using turmeric as an indicator with salt, soap, and promag solutions produced different color changes in each indicator. After turmeric was added to the soap solution, the color changed to light yellow. After turmeric was added to the promag solution, the color changed to brown. After turmeric was added to the salt solution, there was no color change, as can be seen in the image below.

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Figure 3.

Group 1 used turmeric as an indicator

Meanwhile, in the group that conducted the experiment using dragon fruit as an indicator with salt solution, soap, and promag, a color change occurred. In the soap solution, after adding dragon fruit, the color changed to dark purple. In the promag solution, after adding dragon fruit, the color changed to yellow. In the salt solution, after adding dragon fruit, there was no color change, as can be seen in the image below:

Figure 4.

Group 2 used dragon fruit indicators.

By using the PBL model, students in the class were more active and found it easier to carry out learning activities in the classroom, so that students in the class understood acids and bases better and found the learning process easier (Nainggolan ddk., 2019).

The learning outcomes of students who applied the PBL model were greater than those who used conventional learning methods (Laamena ddk., 2021). This is because the PBL model requires students to work together with their groupmates to solve problems, enabling them to exchange ideas and information with one another. Thus, working together in PBL encourages various discoveries and dialogues as well as the development of students' social and thinking skills. With this PBL model, quiet students become active in speaking up when they are in a group, and students are also free to express their opinions to find solutions to problems in learning. Furthermore, teachers relate lessons to everyday life by conducting simple practical exercises, which enable students to pay attention during the learning process. Practical exercises make it easier for students to understand

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the material because they do it themselves, so students are enthusiastic about finding out what the learning objectives are (Zakiyah dkk., 2014).

This study is supported by a journal article by Rampi et al., which states that the PBL learning model can improve learning outcomes and student activity in acid-base material (Rampi dkk., 2021). This PBL learning method increases students' curiosity, making them more active and enthusiastic in participating in lessons, and enabling them to more easily discover and understand the material presented.

The effect of the PBL learning model is reflected in the difference in the average percentage of learning outcome indicators in the post-test of the experimental class, which was 84.4 in the very good category, while the control class was only 74.7 in the good category. The higher percentage obtained by the experimental class shows that the application of the PBL learning model is more effective than learning using the lecture and question and answer methods.

5. Conclusions

Based on the results of data analysis and discussion in the previous chapter, it can be concluded that there is a significant effect of the Problem Based Learning model on student learning outcomes in acid-base systems. This is based on the results of hypothesis testing and the differences in the learning outcome test results of the experimental and control classes. The hypothesis test results using SPSS version 24 software obtained data that sig < α, namely 0.000 < 0.05 at a significance level of 5%, so $H0$ was rejected and $H1$ was accepted. The test results showed that the average post-test score of the experimental class was higher (84.4) than that of the control class (73.1). The significant effect of the Problem-Based Learning model on student learning outcomes in acid-base material at MAN 3 Mandailing Natal is based on learning steps that actively involve students in solving problems. Students are not only required to achieve predetermined learning objectives, but they are also required to work together in groups to gather information, solve problems, and be accountable for the results of their presentations, thereby improving their learning outcomes.

Overall, this study proves that Problem-Based Learning can be used as an innovative and relevant alternative learning model to improve the quality of chemistry learning, especially in acid-base material. This model not only helps students understand concepts in depth but also fosters learning motivation, self-confidence, and the ability to work together, which are very important in the 21st-century learning process.

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