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The Effect of Using The PBL (Problem Based Learning) Learning Model Assisted by ChatGPT on Student Learning Outcomes in The Reaction Rate Material

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Abstract

Despite the importance of understanding reaction rate concepts in chemistry, students often struggle with abstract content and low engagement in traditional learning settings. Conventional teaching methods tend to emphasize rote memorization, limiting opportunities for critical thinking and problem-solving. This study investigated the influence of ChatGPT-assisted Problem-Based Learning (PBL) on students' learning outcomes in reaction rate material. A quasi-experimental design with a non-equivalent control group was employed, involving two Class XI groups at SMA Negeri 1 Kabila: XI A as the experimental group (using ChatGPT-assisted PBL) and XI B as the control group (receiving conventional instruction). Learning outcomes were measured using an essay test aligned with cognitive indicators. Results showed greater improvement in the experimental group, with a posttest average of 78.68 compared to 69.23 in the control group. Independent sample t-test analysis revealed a significant difference between groups ($p = 0.001 < 0.05$), and the N-Gain score indicated a higher improvement category in the experimental class. These findings suggest that integrating ChatGPT into PBL enhances students' understanding of reaction rate concepts and supports more effective learning, highlighting the potential of AI-assisted strategies in chemistry education.

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1. INTRODUCTION

Current learning is more oriented toward developing active, independent, and creative student competencies in the learning process. With the implementation of the new curriculum, the Independent Curriculum, students are encouraged to be directly involved in exploring material and solving problems with approaches relevant to everyday life. This is possible when students are highly motivated and actively involved in the learning process (Wahyuni, 2020). In line with these changes, it is crucial to adapt the Independent Curriculum to technological advances, which play a vital role in improving the quality of education.

In the context of modern education, information and communication technology has played a role in improving the quality of learning. One technological innovation whose role in education is increasingly recognized is artificial intelligence (AI), which is now widely applied in various learning models to support the effectiveness of the teaching and learning process. Aldwinarta et al. (2024) stated that the use of AI in education is a crucial step to ensure teaching methods are in line with technological advances. ChatGPT, as an AI product, is able to provide interactive services that help students understand difficult concepts in a more personalized and adaptive way. With the integration of technologies such as ChatGPT, it is hoped that learning will become more efficient, engaging, and relevant to the needs of students who are now more familiar with digital technology.

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Creating a learning process that can make students more active, think critically, and deeply engaged is also a major challenge in the world of education. This is especially important at the high school level (SMA), where students are expected to develop higher-order thinking skills. One chemistry topic that is considered difficult by high school students is reaction rates, a branch of chemical kinetics. Research by Ozgecan & Boz (2012) shows that an active learning approach can help students overcome misconceptions in understanding the concept of chemical kinetics.

Research by Justi (2002) states that reaction rate is one of the most difficult chemistry topics to understand, and many students experience misconceptions because it includes mathematical calculations and the many factors that cause reaction rates to increase. However, reaction rate material is a fundamental part of chemistry and explains many important chemical concepts (Kolomuç & Tekin, 2011). Furthermore, learning in many schools is still dominated by traditional methods, where the teacher is the center of all learning activities. Although there have been efforts by teachers to design varied learning models following the independent curriculum, the implementation often still reverts to the lecture method.

Robiyanto (2021) noted that most learning still uses the lecture method, which makes students passive and less motivated to learn independently. In this context, traditional methods that don't encourage active student engagement negatively impact student learning outcomes.

This is reinforced by observations at SMA Negeri 1 Kabila, which revealed obstacles in the learning process, including a lack of student enthusiasm, a tendency to be pessimistic about completing assignments, and doubts about their own abilities. Other obstacles include limited learning resources, such as textbooks, and teacher-centered learning. The learning process has not yet encouraged students to actively participate in learning activities. These obstacles have resulted in low learning outcomes, resulting in many students not achieving the Minimum Completion Criteria (KKM).

One solution to address this problem is to adopt a learning model that can increase student active participation and critical thinking skills. Problem-Based Learning (PBL) is a learning model that has been proven effective in encouraging students to think critically, creatively, and independently in solving problems. According to Robiyanto (2021), PBL places students in situations where they must solve complex, real-life problems, thus encouraging the development of their analytical and problem-solving skills. In this process, the teacher acts as a facilitator, guiding students in finding solutions.

Combining PBL with AI technology, such as ChatGPT, can have significant positive impacts. Sandu & Gide (2019) emphasized that ChatGPT can assist students by providing immediate feedback and facilitating more dynamic interactions in problem-solving. By utilizing ChatGPT, students can be more actively involved in the learning process, as this AI can help them understand difficult concepts such as reaction rates more clearly and quickly. PBL assisted by ChatGPT offers a learning approach that allows students to participate more actively and improves their learning outcomes. This study focuses on the cognitive aspect of learning outcomes, as this aspect is fundamental in measuring students' conceptual understanding of chemistry.

Based on the existing problems, this study aims to examine "The Effect of the PBL (Problem Based Learning) Learning Model assisted by ChatGPT on Student Learning Outcomes on Reaction Rate Material in Class XI of SMA Negeri 1 Kabila". This study is expected to provide a significant contribution in the development of more effective learning strategies, especially in Chemistry subjects. By understanding how ChatGPT can support the PBL learning model, the results of this study are also expected to be a reference for teachers and educational institutions to integrate technology with innovative and relevant learning models.

2. METHOD

This research was conducted in the even semester of the 2024/2025 academic year. It took place at one of the leading high schools in Bone Bolango Regency, namely SMA Negeri 1 Kabila, located on Jalan Tapa-Kabila, Oluhuta, Kabila District, Bone Bolango Regency, Gorontalo Province.

The type of research used in this study is quantitative research with a quasi-experimental approach using a non-equivalent group pretest-posttest design. The research design is presented in Table 1.

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Table 1. Research Design

No.	Research Class	Pre-test	Treatment	Post-test
1.	Experiment	O_1	X	O_2
2.	Control	O_3	-	O_4

The population of this study was all eleventh-grade chemistry students at SMA Negeri 1 Kabila in the 2024/2025 academic year. The sample in this study was drawn from the population using a purposive sampling technique. The sample was: 20 students of class XI-A as the experimental class and 20 students of class XI-B as the control class. In the experimental class, treatment will be given using the Problem Based Learning (PBL) model assisted by chatGPT, while the control class will use conventional learning methods.

The data collection technique in this study was conducted through pre-tests and post-tests using descriptive test instruments. These instruments were compiled based on competency achievement indicators that focus on cognitive aspects, in accordance with the Basic Competencies and Learning Indicators for the reaction rate material.

Data analysis techniques include: test validity test, test reliability test, data normality test, homogeneity test, to test the hypothesis with the independent sample t-test, and the N-gain test.

3. RESULT ANDDISCUSSION

3.1. Result

The research data includes pre-test and post-test results, prerequisite test results, hypothesis test results, and N-gain results.

Pretest and Posttest Results of Experimental Class and Control Class

The pretest was conducted to determine students' prior knowledge, and the posttest was used to determine whether or not there was an increase in students' knowledge after using the ChatGPT-assisted Problem Based Learning model with conventional learning models. Based on the data obtained, the average scores for the pretest and posttest for the experimental and control classes are presented in Table 2 below.

Table 2. Pretest and Posttest Values of the Experimental Class and the Control Class

Class	Average value(%)	
	Pretest	Posttest
Experiment	34.81	78.68
Control	34.44	69.23

Based on the pretest and posttest data for the experimental and control classes in Table 2. above, it can be seen that there was a significant increase from the pretest to the posttest scores of the two classes as presented in Figure 1. below.

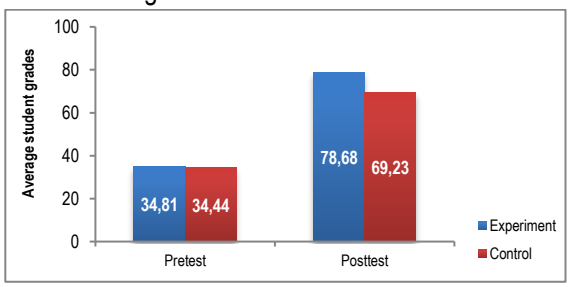

Figure 1. Pretest and Posttest Results Data in the Experimental Class and Control Class

The student learning outcomes measured in this study were cognitive aspects, aimed at determining and measuring students' knowledge before and after treatment. The experimental class was treated with the Problem-Based Learning model assisted by ChatGPT, while the control class used a conventional learning model.

Prerequisite Test Results

This prerequisite test was conducted on the pre-test and post-test learning outcome scores obtained from the experimental and control classes. The prerequisite tests used included normality and homogeneity tests. The following presents the results of the prerequisite tests conducted by the researchers.

1) Normality Test

The data normality test is used to determine whether the data obtained is normal or not, which is a requirement for continuing with statistical analysis. This test uses the Shapiro-Wilk Test assisted by IBM SPSS Statistics 25. The Shapiro-Wilk Test provisions are that if the p-value is greater than 0.05 then the data is declared normally distributed, otherwise if the p-value is smaller than 0.05 then the data is declared not normally distributed. Based on the results of the pretest and posttest data normality tests for the experimental class and the control class, respectively, are shown in Table 3. and Table 4. below.

Table 3. Results of the Pretest Normality Test for the Experimental Class and the Control Class

Class	Shapiro Wilk		
	Statistics	df	sig
Pre-test Control	0.930	20	0.155
Experiment Pre-test	0.930	20	0.155

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Based on Table 3, the significance value for the pretest for the experimental and control classes was 0.155, which means >0.05. This value indicates that the data for each group for the experimental and control classes can be said to be normally distributed.

Table 4. Results of Posttest Normality Testing for the Experimental Class and Control Class

Class	Shapiro Wilk		
	Statistics	df	sig
Posttest Control	0.918	20	0.091
Experiment Posttest	0.952	20	0.391

Based on Table 4, the significance value for the experimental class posttest was 0.392, and the significance value for the control class posttest was 0.091. Each posttest value for the experimental and control classes was >0.05, thus indicating that the data were normally distributed.

2) Homogeneity Test

The next prerequisite test is the homogeneity test. This homogeneity test is used to determine whether the values taken for the experimental and control classes have homogeneous variances. In this study, Levene's Test for Equality of Variances was used with the help of IBM SPSS Statistics 25, with a significance value of 5% or 0.05. The homogeneity test values for the pretest and posttest are presented in Table 5. below.

Table 5. Results of the Homogeneity Test of Pretest and Posttest Data for the Experimental and Control Classes

Mark	Levene Statistics	df1	df2	sig
Pre-test	0.06	1	38	0.938
Post-test	1,079	1	38	0.306

Based on Table 5, containing the results of the pretest and posttest homogeneity tests for the experimental and control classes, the test results for both classes obtained a pretest significance value of 0.938 and a posttest significance value of 0.306. This indicates that the significance value of the data is greater than the significance level of 0.05. Thus, it can be concluded that the pretest and posttest data for both classes have homogeneous variance.

Hypothesis Testing Results

After conducting normality and homogeneity tests, the data were found to be normally distributed and homogeneous. The next step was to test the hypothesis using the t-test. Hypothesis testing was conducted after conducting normality and homogeneity of variance tests, which showed that the data in the experimental and control classes were normally distributed and had homogeneous variance. Therefore, the research hypothesis can be tested using the t-test.

A t-test was used to determine the effect of the ChatGPT-assisted Problem Based Learning model on students' Chemistry learning outcomes. The test used was an independent sample t-test. The calculation in this test used IBM SPSS 25 with a significance level of (2-tailed) <0.05. The data from this study, as calculated using the t-test, can be seen in Table 6. below.

a.t-test Independent-Samples t-test

Table 6. Results of the t-Test for Collaboration Ability

T test (Independent-Samples t-test)	Sig
Student Learning Outcomes	0,000

Based on the results of the Independent t-test analysis in Table 6, it is known that the significance value is 0.000. A significance value showing 0.000 < 0.05, then Ho is rejected. This means that there is an influence of the Problem Based Learning learning model assisted by ChatGPT on students' Chemistry learning outcomes.

N-Gain Test Results

The normalized gain (N-Gain) test was conducted to determine the comparison or extent of improvement in students' chemistry learning outcomes after being treated with the Problem Based Learning model assisted by ChatGPT. The results of the N-Gain test can be seen in Table 7. below.

a. Results of the N-Gain Test for the Experimental Class and the Control Class

Table 7. Results of the N-Gain Test for the Experimental Class and the Control Class

Class	N-Gain Value	Category
Experiment	67.58%	Quite Effective
Control	52.92%	Less Effective

Based on Table 7, the results of the N-Gain Test for the Experimental and Control classes show that the percentage of the N-Gain score for the experimental class that was given treatment using the PBL (Problem Based Learning) learning model assisted by chatgpt was 67.58% or included in the fairly effective category and the percentage of the N-Gain score for the control class that was given treatment using the conventional model was 53.35%, included in the less effective category. A visual

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representation of the results of the N-Gain Test for the two classes is shown in Figure 2. below.

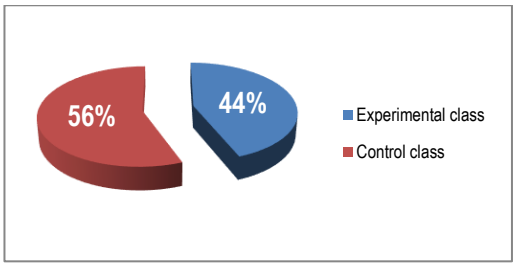

Figure 2. Results of the N-Gain Score Test for the Experimental Class and the Control Class

3.2. Discussion

This study was conducted with the aim of determining the effect of the Problem Based Learning (PBL) learning model assisted by ChatGPT on student learning outcomes in the reaction rate material. This study was conducted at SMA Negeri 1 Kabila involving two classes: class XI A as the experimental class and class XI B as the control class. The experimental class was given treatment by implementing the PBL learning model assisted by the use of ChatGPT in its learning process, while the control class was given treatment using conventional teacher-centered learning.

The research implementation began with collecting data through observations at school where information was obtained that the two classes that would be used in this study had relatively the same abilities, used the same teaching materials, and the same learning process (homogeneous). This research was carried out through the stages of pretest, learning treatment, and posttest with 5 meetings, 1 pretest was carried out before entering the learning process, 3 times teaching and learning activities, and 1 posttest was carried out, this process was carried out the same for the experimental and control classes. Based on the pretest data that had been carried out in the experimental and control classes obtained with the average value of students in the experimental class was 34.81 while in the control class was 34.44. The average shows that students' abilities are still very lacking. However, this very small difference in values indicates that both classes have comparable or homogeneous initial abilities before the learning treatment is given. This is also proven by the test results in both classes obtained a pretest significance value of 0.938 (the significance value of the data <0.05 significance level) and the acceptance of H0 which means that the pretest data of both classes have homogeneous variance. In addition, the experimental and control classes were normally distributed.

The learning process was then carried out by providing treatment to the experimental and control classes. The experimental class used the Problem Based Learning model assisted by ChatGPT, while the control class used the conventional learning model. After four meetings of treatment in each class, a posttest was conducted to assess changes in student learning outcomes. The posttest results showed that the average score of the experimental class increased significantly compared to the control class. This difference indicates a greater improvement in learning outcomes in the experimental class using the PBL model assisted by ChatGPT. Based on observations of classroom learning activities, it was apparent that students in the experimental class displayed high enthusiasm. They actively asked questions, discussed, and used ChatGPT to address confusion about reaction rates, collision theory, reaction rate equations and reaction orders, and factors influencing reaction rates. This student behavior is in line with the cognitive learning motivation theory, which states that students' curiosity and emotional engagement increase when they feel they have control over their learning process (Pintrich, 2003). The PBL model facilitates collaborative experiences, and ChatGPT accelerates students' access to information.

Learning in the experimental class follows the stages of the problem-based learning model, namely orienting students to learn, guiding individual and group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process. These stages are applied consistently in three meetings using LKPD (Worksheets) compiled based on PBL syntax and combined with the assistance of ChatGPT technology as a supporting medium for independent learning. During the learning process, the teacher not only provides general instructions but also provides complete scenarios for using ChatGPT in each section of the LKPD, including the format of questions that must be typed by students and a section for recording answers provided by ChatGPT. The purpose of using this model is for students not only to understand the concept theoretically, but also to be able to build understanding

through observation, discussion, data exploration, and collaborative problem-solving.

In the first meeting, the activity began with an apperception to build students' interest in learning, followed by an orientation stage towards the problem. Students were divided into five groups, then given a Student Worksheet (LKPD) containing images and contextual discourse regarding fast and slow reactions, such as paper burning and metal rusting. Students were asked to observe the images and answer prompt questions, then discuss possible factors that influence reaction speed. This activity aims to direct students to formulate problems relevant to the learning topic, namely reaction rate.

The second stage is organizing students for learning. In this stage, students work in groups to find information to answer questions raised in the previous stage. The worksheet directs students to access learning videos and explore information through ChatGPT. Through conversations with ChatGPT, students can obtain additional explanations regarding the basic concepts of reaction rate, collision theory, and factors that influence reaction speed. They can also look up definitions, examples, and simple explanations to strengthen their understanding of the material.

The third stage is guiding individual and group investigations. Teachers guide students in developing arguments based on video observations, questions and answers using ChatGPT, and group discussions. Students answer questions in the worksheet based on the given phenomena, such as the effect of concentration on reaction rate, determining reaction order from experimental data, and analyzing various factors that influence reaction speed. In this stage, students process information from various sources into structured knowledge.

The fourth stage is developing and presenting the results of the work. Each group compiles the results of their discussions and presents their answers to the class. Students explain their analysis of the observed phenomena, answer questions based on reaction rate calculations, and convey their understanding of the effects of temperature, concentration, surface area, and catalysts. The teacher provides clarification and reinforcement for each discussion result presented.

The final stage is analyzing and evaluating the problem-solving process. Students are asked to write down their learning conclusions in the student worksheet (LKPD) and note key points that emerged from the group discussion. The teacher also facilitates reflection on the learning by reinforcing key concepts and answering follow-up questions. This activity aims to refine student understanding and ensure that all material is thoroughly mastered.

Meanwhile, the control class was implemented with a conventional learning model, a model commonly used by teachers at the research school, using lecture and assignment methods. Learning began with students observing the phenomena illustrated in the worksheet. The teacher then presented material on reaction rates, collision theory, and factors affecting reaction rates, such as temperature, concentration, catalysts, and surface area. After the material was presented, students were given a worksheet containing descriptive questions to work on individually, aimed at assessing their understanding of the material. At the end of the lesson, the teacher provided feedback on students' work to reinforce the material.

After all learning processes in the experimental and control classes were completed, students were given a posttest to determine their abilities after receiving the treatment. The posttest results showed an average score of 78.68 for the experimental class, while the average score for the control class was 69.23. These scores indicate that students' Chemistry learning outcomes in the posttests of the experimental and control classes that received the treatment improved.

In addition, a hypothesis test was conducted to prove whether there was an effect after being given different treatments. The hypothesis test used was the independent sample t-test. The calculation in this test used IBM SPSS 25 with a significance level used of (2-tailed) <0.05. The data from this study, as in the calculation results using the t-test, can be seen in Table 6. and the results obtained were 0.000 > 0.05, which means Ha is accepted and H0 is rejected. This means that there is an effect of the Problem Based Learning learning model assisted by ChatGPT on students' Chemistry learning outcomes. This finding is in line with (Ruslan et al., 2024) who showed that the integration of ChatGPT in learning can improve students' understanding and help them solve problems independently.

To support these results, an N-Gain test was also conducted to see how much improvement in student learning outcomes before and after treatment. The results of the N-Gain test showed that the experimental class obtained a score of 67.58%, which is included in the fairly effective category, while the control class obtained a score of 53.35%, which is also included in the less effective category. Based on the higher N-Gain value category of the experimental class, it can be concluded that the use of the Problem Based Learning learning model assisted by ChatGPT is more effective in improving student learning outcomes on the reaction rate material in class XI of SMA Negeri 1 Kabila compared to conventional learning.

Based on the data processing results, it appears that the Problem Based Learning model assisted by ChatGPT is able to improve learning outcomes, especially in the cognitive domain. The learning outcome indicators measured include the ability to understand the concept of reaction rate, identify factors that influence it, and analyze experimental data based on collision theory, all of which fall within the cognitive domain levels C2–C4 according to Bloom's Taxonomy. This is consistent with findings (Kurniasari, 2023) that the Problem Based Learning model is effective in building students' conceptual understanding and critical thinking skills in chemistry learning.

This finding is supported by constructivism and cognitivism theories, which emphasize the importance of active student involvement in building understanding through meaningful learning experiences. Problem-Based Learning (PBL) encourages students to construct their own knowledge through contextual problem-solving. This is further supported by research (Sabora et al., 2022), which states that problem-based learning models are more effective in improving students' problem-solving abilities, especially given the more complex syntax of problem-based learning models.

When this process is aided by technology like ChatGPT, learning becomes more interactive. This is reinforced by Saputra (2020), who stated that utilizing digital technology in learning can be an effective strategy in addressing the challenges of education in the 4.0 era. ChatGPT makes it easier for students to quickly access information, understand scientific terms, and obtain alternative explanations that reinforce the concepts being learned.

Furthermore, the ChatGPT-assisted PBL learning model in the experimental class provided students with instant feedback, enabled them to elaborate on their ideas, and facilitated students' ability to ask follow-up questions as needed. Research by (Eryilmaz and Kara, 2022) shows that AI-based chatbots like ChatGPT can increase students' cognitive engagement and help them understand the material more deeply.

Thus, these results not only demonstrate the empirical success of the ChatGPT-assisted PBL model in improving cognitive learning outcomes but also align with the theoretical foundations supporting this approach. This study specifically assessed learning outcomes from a cognitive perspective, confirming the clear and measurable scope and focus of the research.

4. CONCLUSION

Based on the research data and the results of the analysis, it can be concluded that the Problem Based Learning (PBL) model assisted by ChatGPT has a significant effect on students' learning outcomes, particularly on the topic of reaction rate. This is evidenced by the results of the independent sample t-test, which showed a significance value (2-tailed) of 0.000, which is less than 0.05. Therefore, H_0 is rejected and H_a is accepted. It can thus be concluded that there is a significant effect of the PBL model assisted by ChatGPT on the learning outcomes of grade XI students at SMA Negeri 1 Kabila. The average post-test score of students in the experimental class using the PBL model with ChatGPT assistance was 78.68, which is higher than the control class that only reached 69.23. This finding indicates that the application of the PBL learning model supported by AI technology, namely ChatGPT, can improve students' understanding of chemistry concepts, especially on the topic of reaction rate. Moreover, the results of the normalized gain (N-Gain) test showed that the experimental class achieved a score of 67.58%, which falls into the moderately effective category, while the control class only reached 53.35%, categorized as less effective. This further supports the conclusion that using the PBL model assisted by ChatGPT is more effective in significantly improving student learning outcomes compared to conventional learning methods.

5. ACKNOWLEDGEMENTS

Based on the results of this study, the author suggests that further research is needed to determine the effect of the problem-based learning model assisted by ChatGPT on student learning outcomes in other materials, so that it can measure more broadly the extent to which the influence of the problem-based learning model assisted by ChatGPT can be developed in the learning process.

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