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Implementation of Problem-Based Learning Assisted by PhET Simulation to Improve Students' Understanding of Mirror Concepts and Learning Engagement

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Abstract

Physics is one of the subjects that students find difficult to understand. Physics is not only a science that requires memorization, but also requires a deep understanding of its concepts. Physics studies natural phenomena physically and is written in mathematical form, thus emphasizing the aspect of conceptual understanding. In addition to conceptual understanding, another important aspect is student involvement in the learning process. One important topic that needs to be studied is mirrors. The topic of mirrors will be easier to understand if it is practiced so that students can understand it better. Therefore, Phet simulation media is needed. The purpose of this study is to explain the differences in understanding the concept of mirrors between students who use PBL plus PhET and students who use regular PBL, as well as to analyze the differences in student engagement in learning about mirrors between students who use PBL plus PhET and students who use regular PBL. The population in this study consisted of 64 students from MA Mathalibul Huda and 64 students from MA Darul Hikmah Menganti. Data collection methods included tests, observations, and documentation. The collected data were analyzed using N-Gain and t-tests. Based on the research results, there is a difference in concept comprehension between the PBL Plus and regular PBL learning models, with the PBL Plus class achieving a higher average post-test score of 81.03, while the regular PBL class achieved an average post-test score of 62.31. The N-Gain value - Gain of the regular PBL class was 0.22, while the N-Gain value of the PBL Plus class was 0.58, which is categorized as moderate. The T-test resulted in a sig value (2-tailed) of 0.00 < 0.05. Thus, it can be concluded that the PBL Plus learning model is effective in improving students' conceptual understanding of mirror material. In addition, there is also a difference in student learning engagement between the PBL Plus class and the regular PBL class, where PBL Plus shows that the category of active students is higher than that of the regular PBL class based on 4 indicators of student learning engageme.

How to Cite

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INTRODUCTION

Physics studies natural phenomena and explains them in mathematical terms, with an emphasis on conceptual understanding. Some students find physics difficult to learn because it requires conceptual understanding rather than memorization (Liza, 2021). Based on research (Masita et al., 2020) only the use of Phet simulations was evaluated without considering other factors such as student motivation or engagement. The study (Arista et al., 2018) used Viphy-Labs media for learning. The sample used in this study consisted of two schools from two different sub-districts. This was inspired by the study (Ndihokubwayo et al., 2020), which used a sample of schools from three sub-districts. The techniques used in this study were tests and observations. This differs from the study by (Batuyong & Antonio, 2018), which used interviews. In addition, based on research by (Mallari, 2020), it is recommended to use additional media besides Phet Simulation. Therefore, this study uses additional media, namely convex mirrors and concave mirrors. Based on the research (Qothrunnada et al., 2025), the analysis used N gain with dynamic fluid material. The question instrument used was inspired by the research (Ainun Wahyuni et al., 2022), which used a 1-tier multiple choice for concept comprehension tests, whereas this study used a 3-tier multiple choice.

Based on the studies mentioned above, a study entitled "The Application of the Problem-Based Learning Model Assisted by Phet Simulation to Improve Students' Conceptual Understanding of Mirrors and Learning Engagement" was conducted. To improve students' conceptual understanding and engagement, teachers need to be creative in delivering material in the classroom. One solution is to use PhET Simulation. Physics requires analytical skills in understanding each existing material (concept) (Rahmatullah et al., 2021). This application can be downloaded for free through the Google Play Store and several Windows applications, and can be accessed through website (Aqza et al., 2024). PhET simulations can be used by students to explore physics, which will certainly help their understanding and stimulate their curiosity (Ramadhani et al., 2023)

Simulations are useful for helping students develop understanding, actively engage in the scientific process, and increase motivation to learn (Price et al., 2018). Simulation-based learning offers a realistic learning experience and can be an effective approach for developing complex skills (Chernikova et al., 2020) Interactive simulations are tools that provide students with realistic experiences (Rehman et al., 2021)The selection of learning models is as important as the selection of learning media. One type of learning model is problem-based learning (PBL). Problem-based learning (PBL) is a learning model that can shape and develop students so that they have the skills to solve problems in learning activities, as well as encourage students to develop thinking skills so that they can think critically(Murdaningrum et al., 2023) .Problem-Based Learning offers problem solving guided by teachers or educators to help students understand material concepts through problem solving. (Putranta & Kuswanto, 2018). Based on research conducted by (Taqwa et al., 2019)problem-based learning models on the topics of elasticity and Hooke's Law can improve students' conceptual understanding. Students involved in problem-based learning demonstrate better abilities in analyzing complex problems and applying theoretical concepts to real-life situations (Groenewald et al., 2023)

The level of student engagement in learning can be observed through active participation, such as interest in the subject matter, or through students' voices and initiatives to take personal responsibility for their behavior (Subramainan & Mahmoud, 2020). The purpose of this study is to explain the differences in understanding the concept of mirrors between students who use PBL plus PhET and students who use regular PBL, as well as to analyze the differences in learning engagement levels between students who use PBL plus PhET and students who use regular PBL.

METHOD

This research used quantitative methods. The data obtained included data from conceptual understanding questions and data from observation sheets on student engagement. Quantitative data uses a quasi-experimental method. Quasi-experiments are used to determine the difference in ability between classes that received treatment and classes that did not receive treatment (Rubianti et al., 2019). The experimental research design used in this research is a non-equivalent control group design. The research design can be seen in Table 1.

The population used in this research were 11^{th} grade students at Mathalibul Huda Mlonggo Islamic High School and 11^{th} grade students at Darul Hikmah Menganti Islamic High School. The technique used to determine the research sample was purposive sampling with the criterion that the students were science majors. The sample of students from Mathalibul Huda Islamic High School consisted of 64 students, while the sample from Darul Hikmah Islamic High School in Menganti consisted of 64 students.

Table 1. Research Design

Pretest	Treatment	Posttest
O_1	X_1	O_2
O_3	X_2	O_4

Description:

- O_1 : Pretest score for the experiment
- O_2 : Posttest score for the experiment
- O_3 : Pretest score for the control group
- O_4 : Posttest score for the control group
- X_1 : Innovative learning with PhET Simulation
- X_2 : Learning without PhET Simulation

The instrument of conceptual understanding consisted of 15 with 3 tier multiple-choice questions. Indicator conceptual understanding was illustrating, classifiying, comparing, explaining and interpreting. Meanwhile learning engagament used observation sheet. The observation sheet results covered four observation indicators.

a. Readiness of students to receive lessons
b. Concentration in following lessons and learning stages
c. Active participation in group discussions
d. Good cooperation in groups

The reliability was measured using Cronbach's alpha. The results of the analysis obtained a reliability coefficient of 0.919. It can be concluded that the questionnaire in this study, with a Cronbach's Alpha value > 0.60, the instrumen is considered reliable. The difficulty index value was obtained from a small-scale trial with 30 respondents from class XII IPA, who were given 15 questions. The results of the difficulty index analysis showed that the 15 with 3 level multiple-choice questions can be seen in Table 2.

Table 2. Difficulty Index

Number	Value	Interpretation
4,13	0.53	Medium
14,15	0.56	Medium
2, 5,8,9,10 ,12	0.60	Medium
3	0.63	Medium
6,7	0.66	Medium
1	0.70	Medium
11	0.83	Easy

The differentiating power of test items has the benefit of improving the quality of each test item through empirical data and determining the extent to which each test item can distinguish between students' abilities, namely students who have understood or have not understood the material taught by educators (Saputri et al., 2023). The interpretation of test item discriminating power can be seen in Table 3.

Table 3. Differentiating Power Criteria

Number	Interpretation
1,5,6	Enough
2,3,4,7,8,9,10,11,12,13,14,15	Good

The analysis data consist of normality test, n-gain test, and independent sample t-test.

1) Normality Test

The test was conducted on pretest and posttest data. The normality test used was the Kolmogorov-Smirnov test using IBM Statistical Package For Social Sciences (SPSS) 27 for Windows software. The following are research hypotheses.

H_0 : If the concept understanding value is > 0.05, then the data is normally distributed (H_0 accepted)

H_1 : If the concept understanding value is <0.05, then the data is not normally distributed (H_0 rejected)

2) N-Gain

The test concept understanding results were analyzed using N-Gain and T-tests. N- Gain N Gain value is calculated using the formula.

$$N\ Gain = \frac{postest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

N-gain analysis of pre-test and post-test data was performed using Microsoft Excel. The criteria for the N-gain index can be seen in Table 4 (Hake, 1998).

Table 4. N- Gain Index

Gain Index	Criteria
g > 0.7	High
0.3 ≤g≤ 0.7	Medium
g < 0.3	Low

3) Independent Sample T- Test

This test is a statistical test to determine the comparison of means between two unpaired or independent data groups (Paisal et al., 2021). The t-test was performed using the SPSS program. The basis for decision making in the Independent Sample t-test is as follows.

a. If the significance value (two tails) < 0.05, then the data shows the effectiveness of the treatment given.
b. If the significance value (two tails) > 0.05, then the data does not show the effectiveness of the treatment given.

RESULT AND DISCUSSION

This research used two control classes and two experimental classes. It was conducted in two Islamic secondary schools, namely MA Mathalibul Huda Mlonggo and MA Darul Hikmah Menganti. The total number of respondents was 128 students, consisting of 64 students in the experimental class and 64 students in the control class. The research sample was taken using purposive sampling, which used 11th grade science classes. Before statistical data analysis was carried out, the pretest and postest data were tested for normality and The normality test can be seen in Table 5.

The criteria for data to be considered normally distributed is if the Sig. (significance) value is greater than 0.05. In the table above, the normality test results for the pretest and posttest values in each experimental and control class have a Sig. (significance) value greater than 0.05, so the above data is normally distributed. Homogeneity Test used pretest and postest data. The homogeneity test uses Levene's statistic (with SPSS). The homogeneity test is used to determine whether the variance (diversity) of the data groups is the same (homogeneous) or not (Serlyana & Zuhdi, 2024). The pre-test and post-test homogeneity test data can be seen in Tables 6 and 7.

Data can be considered homogeneous if the Sig. value based on the mean value is greater than 0.05. Table 7 shows a significance value based on a mean value of 0.923. The Sig. value of 0.923 is greater than 0.05, so the two pre-test groups can be considered homogeneous. Data can be considered homogeneous if the Sig. value based on the mean value is greater than 0.05. The table above shows a significance value based on a mean value of 0.221. The Sig. value of 0.221 is greater than 0.05, so the two post-test groups can be considered homogeneous.

Table 5. Normality Test

	Class	Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Value	Experimental Postest	.108	64	.063	.948	64	.010
	Control Postest	.107	64	.066	.962	64	.045
	Experimental Pretest	.105	64	.076	.945	64	.007
	Control Pretest	.103	64	.089	.946	64	.007

a. Lilliefors Significance Correction

Table 6. Homogeneity test of pretest

		Levene Statistic	df_1	df_2	Sig.
Val	Based on Mean	.009	1	126	.923
	Based on Median	.014	1	126	.906
	Based on Median and with adjusted df	.014	1	125.982	.906
	Based on trimmed mean	.009	1	126	.925

Table 7. Homogeneity test of postest

		Levene Statistic	df_1	df_2	Sig.
Val	Based on Mean	1.511	1	126	.221
	Based on Median	1.330	1	126	.251
	Based on Median and with adjusted df	1.330	1	125.197	.251
	Based on trimmed mean	1.454	1	126	.230

Conceptual understanding is very important because to make sense of phenomena (Phanphech et al., 2019). Conceptual understanding helps students in transfering conceptual physcis knowledge into daily lives(Banda & Nzabahimana, 2021) Students can record their confidence scores, correct answers, and reasons behind their answers (3 levels). Students' answers can be analyzed to determine misunderstandings, lack of understanding, luck, or actual understanding. The grouping of these categories can be seen in Table 8.

Table 8. Level of Confidence

Answer criteria	Level of confidence (0)	Level of confidence (1)
Right answer	lucky guess	actual understanding
Wrong answer	lack of understanding	misunderstandings

Based on the results of the three-level multiple-choice test for the control class, see Figure 1. Figure 1 shows the percentage of pre-test and post-test scores for the control class, which consisted of 64 students. The "does not understand the concept" category had the highest score with a percentage of 39%. Meanwhile, the "understands the concept" category had a percentage of 17%. The percentage of misunderstanding was 20%. Many students did not understand the concept because they did not have comprehensive knowledge about mirrors. The post-test scores show changes in each category. The "understanding" category increased from 17% to 61% with 39 students. The "misunderstanding" category increased from 20% to 22% with 14 students. Many students still had misunderstandings, especially in choosing the wrong answers.

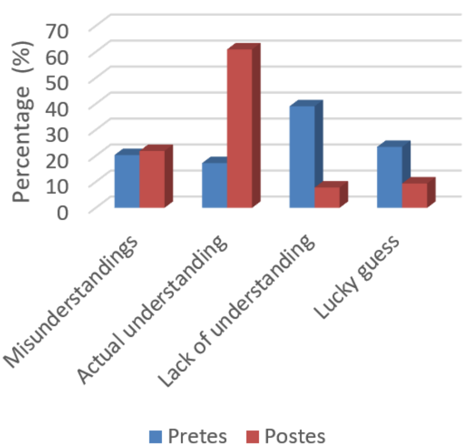

Figure 1. Percentage of Control Class

The pre-test and postest results for the experimental class, which used 15 level 3 multiple-choice questions, can be seen in Figure 2. Figure 2 shows the percentage of pre-test and post-test scores for experimental class consisting of 64 students. The "does not understand the concept" category had the highest score with a percentage of 44%. Meanwhile, the "understands the concept" category had a percentage of 14%. The "misunderstanding" category was 19%. The pre-test scores were almost the same as the percentage of the control class. Many students did not understand the concept because they did not have comprehensive knowledge about mirrors. The post-test results showed significant changes, especially in the "understands the concept" category, which increased to 77% with 49 students. The 'misunderstanding' category decreased from 19% to 13% with 8 students. Only 4 students or 6% remained in the "does not understand" category.

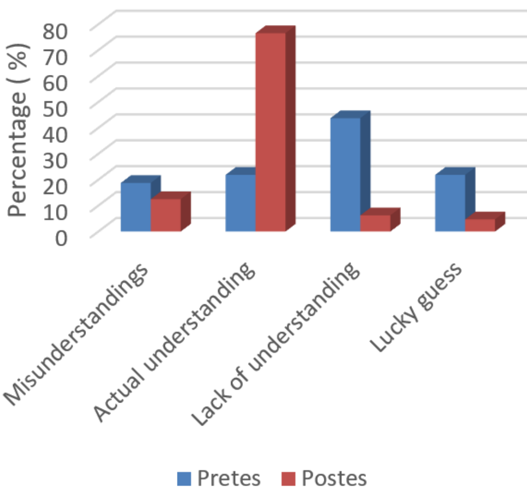

Figure 2. Percentage of Experimental Class

A comparison of the results of the concept comprehension test between the control class and the experimental class shows that the level of comprehension among students in the experimental class was higher, namely 77% with 49 students, while the control class had a concept comprehension level of 61% with 39 students. The percentage of misunderstandings in the experimental class was lower than that in the control class, namely 13% compared to 22%. This shows that the application of the Problem-Based Learning model supported by Phet Simulation was able to improve students' conceptual understanding.

Then, the n-gain test is used to provide an overview of the increase in learning scores in the form of understanding curved mirror concepts before and after implementing the Problem-Based Learning model supported by PhET Simulation. The N-Gain value of the control class is 0.22, while the N-Gain value of the experimental class is 0.58. The N-Gain value of the control class is in the low category, while the N-Gain value of the experimental class is in the medium category. This is in line with research (Musahir, 2022) which shows that the use of Phet Simulation can improve mastery of resistor circuit material through the N-Gain test. The results of the study (Aqza et al., 2024) concluded that the use of Phet Simulation increased student learning outcomes in acid-base material by 57.6%. This is also in line with the use of Phet Simulation based on the study (Mashami et al., 2023), which can increase students' conceptual understanding by 84.62%. The average N-Gain percentage score for the experimental class was in the fairly effective category, so it can be concluded that the Problem-Based Learning model assisted by Phet Simulation for mirror material is quite effective. Based on research by (Masita et al., 2020), the use of Phet Simulation can improve students' understanding of physics concepts in fluid material by producing an N-Gain of 0.62. This is in line with research by (Theasy et al., 2021), which states that the results of research on the use of Phet Simulations to improve students' understanding of physics concepts in the experimental class produced an N-Gain value of 0.73 or 73%, which is in the high category and can improve understanding.

T-Test Analysis used postest data. The results of the Independent Sample T-Test can be seen in the Table 9. the sig value (2-tailed) produces a value of 0.00 < 0.05. Thus, it can be concluded that the PBL Plus learning model is effective in improving students' conceptual understanding of mirror material. Based on Figure 4.2, the sig value (2-tailed) is 0.00 < 0.05, thus it can be concluded that the PBL Plus learning model is effective in improving students' conceptual understanding of mirror material. The use of the PBL and Phet Simulation learning models has a very significant effect on students' learning experiences, thereby improving conceptual understanding (Ilham et al., 2024). This is also supported by research (Qothrunnada et al., 2025) that the use of the Problem-Based Learning model supported by Phet Simulation can significantly improve student learning outcomes.

Table 9. T-Test

Sig .(2- tailed)	t_{count}	N of items
.000	5.647	128

Phet simulations in physics learning can effectively improve students' conceptual understanding (Ula et al., 2025). Not only that, but in its application, Phet Simulation can change the learning process from being teacher-centered to student-centered, which has an impact on students being more active and interactive during the learning process. This statement is supported by (Fajri Yanti, 2019), who states that Phet Simulation offers contextual learning by bringing the real world into the classroom and encouraging students to be active in learning. Based on research by (Rahmawati et al., 2020), the use of animation or simulation can improve conceptual understanding. This is consistent with research form (Mahzum et al., 2024) showing that the sig value is < 0.05.Research conducted by (Gani et al., 2020) also revealed differences in the level of conceptual understanding between the control and experimental classes when using Phet Simulation because the use of Phet Simulation made students very interested in learning science concepts.

Student learning engagement was analyzed using quantitative data obtained from student observation sheet scores. Student engagement refers to students who are actively involved in their learning tasks and activities in the classroom (Lathifaturrohmah AJ & Yunikawati, 2022). Based on research conducted by (Lei et al., 2018), student engagement has a significant effect on student academic achievement, where high levels of student engagement correlate with high academic achievement.The observation sheet results covered four observation indicators: students' readiness to receive lessons, concentration in following lessons and learning stages, active participation in group discussions, and good cooperation within the group.

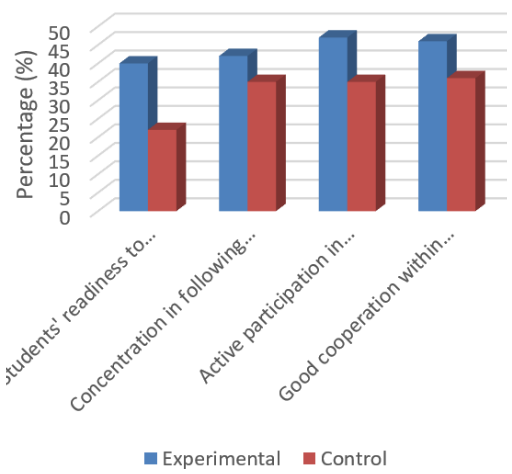

Figure 3. Percentage of Student Engagment

Based on the Figure 3, it can be seen that in all indicators of student learning engagement, there are significant differences between the experimental class and the control class. In the experimental class, the indicator with the highest percentage is active participation in group discussions with a percentage of 47% or a total of 32 students. The indicator with the lowest percentage is student readiness to receive lessons, with a percentage of 40% or 27 students. The percentage of student learning engagement in the experimental class shows a percentage above 40%. In the control class, the indicator with the highest percentage is good cooperation in groups, with a percentage of 36% or 23 students. The indicator with the lowest percentage was students' readiness to receive lessons, with a percentage of 22% or 14 students. The percentage of student learning engagement in the control class showed a percentage below 40%. The indicator with the lowest percentage in both the experimental and control classes was "students' readiness to accept lessons." This was because students' motivation to take physics lessons was still low as they considered physics a difficult subject to understand. Therefore, teachers needed to choose interesting models and media so that students would not always consider physics a difficult subject.

Indicator 4 shows that the experimental class had better student learning engagement than the control class. Students were very interested in using PhET Simulations. Based on research by (Ramadhani et al., 2023), the use of Phet Simulation has been proven to increase student engagement and activity in the learning process. Similar findings are also mentioned in research by(Fitria et al., 2023), which shows that Phet Simulation has a positive impact on student activity in the learning process. The use of Phet Simulation can increase student engagement and encourage active participation from students, especially during the learning process (Ilham et al., 2024). Research by (Larashati & Supardi, 2025) also supports that the use of Phet Simulation can increase student engagement by 92%, which falls into the very active category.

CONCLUSION

The results of the study show a difference in conceptual understanding between the PBL Plus and regular PBL learning models, with the PBL Plus class achieving a higher post-test score of 81.03 while the regular PBL class achieved an average post-test score of 62.31. The N-Gain value for the regular PBL class was 0.22, while the N-Gain value for the PBL Plus class was 0.58, which was categorized as high. T-test (two tails) value is 0.00 < 0.05. Thus, it can be concluded that the PBL Plus learning model is effective in improving students' conceptual understanding of mirror material and that there is a difference in student learning engagement between the PBL Plus class and the regular PBL class, where PBL Plus, based on 4 indicators of student learning engagement, shows that the category of active students is higher than in the regular PBL class.

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