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The Influence of the Problem Based Learning Model Assisted by PhET Simulation on Students' Learning Outcomes in Parabolic Motion Material

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ABSTRACT

This study aims to determine the effect of the Problem-Based Learning (PBL) model assisted by PhET Simulation on students' learning outcomes in parabolic motion material in Grade XI-Physics at SMA Negeri 1 Suwawa. This research is experimental with a One Group Pretest-Posttest Design. The sampling technique used in this study is total sampling. The population includes all Grade XI students majoring in Physics at SMA Negeri 1 Suwawa for the 2024/2025 academic year, consisting of three classes. The sample includes the entire population: Class XI A as the experimental class, Class XI C as the first replication class, and Class XI B as the second replication class, determined randomly through a lottery method. The data collection technique was conducted using a test in the form of 10 essay questions that had been validated by expert lecturers. The data obtained from the tests were analyzed using statistical tests, including the Liliefors normality test, hypothesis testing, and N-gain analysis. Based on the research results, the average posttest scores were 84.3 for the experimental class, 79.7 for the first replication class, and 82.8 for the second replication class. The hypothesis test results showed that the average scores of all sample classes were higher than the minimum passing score (KKM), which is 70. Based on the analysis of the course average normalized gain, the experimental class achieved 0.78, the first replication class 0.72, and the second replication class 0.75, indicating a high category for all sample classes. Thus, the use of the PBL model assisted by PhET Simulation significantly affects high school students' learning outcomes in parabolic motion material.

Introduction

The development of science and technology (IPTEK) and the phenomenon of globalization demand the presence of high-quality human resources (HR). Education plays a crucial role in shaping superior human resources. This is supported by Law of the Republic of Indonesia Number 20 of 2003 Article 1 Paragraph 1, which serves as the formal foundation for the education system in Indonesia. The law explains that education is a planned effort to create a learning environment and learning process capable of developing students' potential while shaping spiritual values, noble character, self-control, personality, intelligence, and skills that benefit individuals, society, and the nation. Education is understood as a conscious effort in the learning process covering spiritual, moral, knowledge, skills, and habits delivered through teaching, training, or research aimed at maximizing students' potential (Yusuf & Bektiarso, 2020).

Educational issues in Indonesia continue to be a concern. Science, as a key component of knowledge, is also affected by these educational challenges. Based on the results of the Programme for International Student Assessment (PISA) published by the Organisation for Economic Co-operation and

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Development (OECD) in 2018 and released in March 2019, Indonesia ranked 74th out of 79 countries worldwide. The survey showed that the average science proficiency score of Indonesian students was 389, while the OECD average score was 489. This indicates that Indonesian students' science skills are still far behind those of students from other PISA member countries.

Natural science is a discipline aimed at understanding the order of nature, encompassing facts, concepts, principles, discovery processes, and scientific attitudes. Physics, as part of science, explains various natural phenomena through research involving experiments, measurements, and data interpretation using mathematical approaches based on general laws. Physics is not merely about memorizing theories or formulas but includes understanding concepts deeply. However, many students perceive physics as a difficult subject, negatively impacting their learning outcomes and preventing them from achieving learning goals.

Student learning success in achieving learning objectives is reflected in learning outcomes, covering cognitive (knowledge), affective (attitudes), and psychomotor (behavioral) aspects. Learning outcomes can be interpreted as the results obtained through various evaluations or tests quantified into scores given by teachers at the end of the learning period. Low student learning outcomes are evident when students fail to reach the Minimum Mastery Criterion (KKM) set (Fitri et al., 2021). Purwanto, as cited in Saputra et al. (2020), states that learning outcomes are the results achieved from the teaching and learning process aligned with educational goals. Learning outcomes should be measured to evaluate the achievement of educational objectives.

Observations conducted at SMA Negeri 1 Suwawa through interviews with physics teachers revealed that, besides using the lecture method, physics teachers had also implemented the discovery learning model. However, they faced difficulties guiding students toward optimal learning outcomes. Students were still less actively involved in problem-solving and discovering physics concepts. Moreover, limited laboratory equipment at school reduced students' opportunities for conducting experiments. This condition contrasts with the essence of physics learning, which should involve interaction with objects and the learning environment.

To address these issues, teachers are required to find ways to motivate students to learn. Teachers should develop a learning model that can enhance students' ability to explore, discover, investigate, and express their ideas in science, especially in physics. One suitable approach for this situation is the Problem-Based Learning (PBL) model. This model focuses on problems relevant to students' lives, making learning more meaningful. In this context, the teacher's role is to present problems, pose investigative questions, and facilitate student dialogue.

According to Yulianti (2019), PBL is a learning model emphasizing the steps needed to solve problems. The PBL model involves presenting authentic and significant problem situations to students, making it easier for them to conduct investigations and explorations. Ramadani & Nana (2020) explain that PBL is an approach where students engage in solving real-world challenges as part of the learning process, emphasizing critical thinking development and conceptual understanding of the subject matter.

Besides selecting an engaging learning model, utilizing learning tools also has the potential to increase students' interest in physics lessons, ultimately enhancing their understanding of physics concepts (Romlah & Andi, 2021). One such learning tool is the Physics Education Technology (PhET) virtual simulation. As described by Nabila et al. (2022), PhET simulations are technology-based learning media capable of explaining abstract or visually difficult physics phenomena.

PhET is a platform offering free downloadable physics learning simulations for group teaching in classrooms or individual learning. Kagan Jhoni et al., as cited in Puspitasari (2022), explain that PhET simulations are designed in an interactive, game-like animation format, enabling students to learn through active exploration.

Methods

This research was conducted at SMA Negeri 1 Suwawa. The study took place from September to October during the first semester of the 2024/2025 academic year. This is a quantitative study employing an experimental research method. The design used in this study is the One-Group Pretest-Posttest Design, as shown in Table 1.

Table 1
Research Design

Group	Pretest	Treatment	Posttest
Experiment	0_1	X	0_2
Replication 1	0_1	X	0_2
Replication 2	0_1	X	0_2

Infomation :

0_1	:	The Pretest was administered to the experimental and replication classes before the treatment.
0_2	:	The Posttest was administered to the experimental and replication classes after the treatment.
X	:	The treatment for the experimental and replication classes involved the use of the PBL model and PhET Simulation.

The population in this study consisted of all 93 students from the 11th-grade Physics specialization at SMA Negeri 1 Suwawa in the 2024/2025 academic year, divided into three classes. The sampling technique used in this study was total sampling. Class XI A was designated as the experimental class, Class XI C as Replication Class 1, and Class XI B as Replication Class 2, determined randomly through a lottery system. The variables in this study included the independent variable, which was the PBL model supported by PhET Simulation, and the dependent variable, which was students' learning outcomes.

The research instrument used was a learning outcome test in the form of 10 essay questions validated by three expert lecturers. The test was administered at the beginning and end of the learning process, after applying the PBL model supported by PhET Simulation. The data analysis technique involved several tests, including the normality test (Lilliefors test), hypothesis testing, and N-gain analysis.

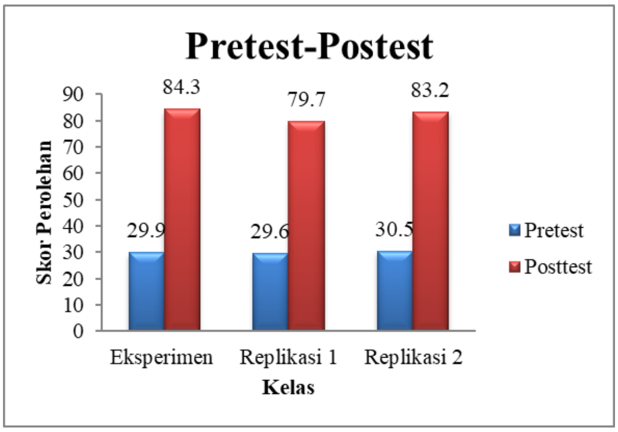
Result and Discussions

Before implementing the physics learning treatment using the PBL model supported by PhET Simulation in the experimental, Replication 1, and Replication 2 classes, a pretest was administered to each class. The pretest aimed to measure students' prior knowledge of the parabolic motion concept. Afterward, each class underwent the learning process with the same treatment for two meetings. After the treatment, a posttest was administered to each class to measure the extent of students' learning improvement. The average learning outcome scores of the experimental and replication classes are presented in Table 2.

Table 2
Average Pretest and Posttest Score

Class/Sample	Pretest Score	Posttest Score
Experiment	29.9	84.3
Replikasi 1	29.6	79.7
Replikasi 2	30.5	83.2

Figure 1
Diagram of Improvement in Student Learning Outcomes in Experimental Class and Replication Class



Based on Table 2 and Figure 1, there is a noticeable difference in the average pretest and posttest scores between the experimental and replication classes. The average pretest score for the experimental class was 29.9, while the average posttest score was 84.3. For Replication Class 1, the average pretest score was 29.6, and the average posttest score was 79.7. Similarly, for Replication Class 2, the average pretest score was 30.5, and the average posttest score was 83.2. These results indicate that the average posttest scores for all classes, including the experimental and replication classes, were higher than their respective pretest scores.

Before conducting the hypothesis test, a normality test was performed to determine whether the data were normally distributed. The normality test used in this research was the Liliefors test, with the results presented in Table 3.

Table 3
Data Normality Test Results

Liliefors Test			
Test	L_{count}	L_{table}	Status
Experimental Posttest	0,1575	0.159	Normal
Replikasi 1 Posttest	0.1059	0.1559	Normal
Replikasi 2 Posttest	0.1009	0.1559	Normal

Based on Table 3, the normality test data for all three classes show that the calculated L-value (Lhitung) was less than or equal to the critical L-value (Ltabel) at a significance level of $\alpha = 0.05$. Thus, the null hypothesis (H_0: the sample is normally distributed) was accepted, and the alternative hypothesis (H_1: the sample is not normally distributed) was rejected. Therefore, it can be concluded that the research data were normally distributed in both the experimental and replication classes.

After confirming that the samples were normally distributed, the hypothesis testing was conducted. The purpose of this test was to determine whether the use of the PBL model supported by PhET Simulation had a positive effect on students' learning outcomes in the experimental and replication classes. The results of the one-tailed t-test hypothesis testing are presented in Table 4.

Table 4
Hypothesis Test Results

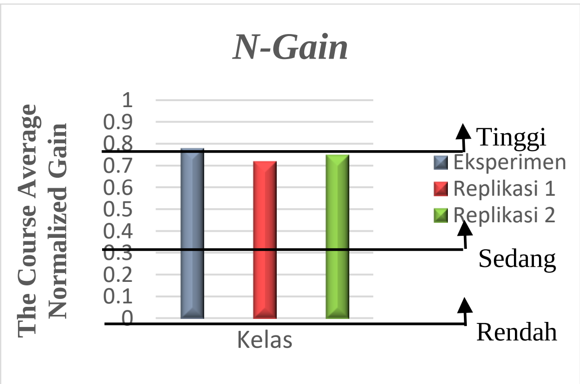
Test	t_{count}	t_{table}	Status
Experiment Posttest	9,3	1.699	H_0 accepted
Replication 1 Posttest	7.388	1.697	
Replication 2 Posttest	8.534	1.697	

Based on Table 4, all sampled classes obtained a calculated t_{hitug} greater than the critical t_{tabel} ($t_{hitug} \geq t_{tabel}$) at a significance level of α=0.05. This indicates that H_0 (having an effect) was accepted, while H_1 (having no effect) was rejected. The results showed that the average learning outcome scores were equal to or higher than the minimum passing criterion (KKM) of 70, suggesting that the implementation of the PBL model supported by PhET Simulation had a positive effect on students' learning outcomes.
To measure the extent of the effect on students' learning outcomes, an N-gain analysis was conducted, as shown in Table 5.

Table 5
Data Normality Test Results

Kelas	N-gain	Kriteria
Experiment	0,78	Tinggi
Replication 1	0,72	Tinggi
Replication 2	0,75	Tinggi

Figure 2
Diagram of N-Gain Test Results in Experimental Class and Replication Class



Based on Table 5 and Figure 2, the N-gain for the experimental class was 0.78, indicating a high criterion. The N-gain for Replication Class 1 was 0.72, also in the high criterion, while Replication Class 2 scored 0.75, falling within the high criterion as well. It can be concluded that the improvement in students' learning outcomes in both the experimental and replication classes was categorized as high.

The learning activities were conducted over two meetings per week in each class, with each session lasting 2×45 minutes. The first meeting focused on the characteristics of parabolic motion and its physical quantities, while the second meeting discussed the highest and farthest points of parabolic motion. All classes were taught using the PBL model supported by PhET Simulation. According to Edison (2021), PBL is a learning model that presents real-world problems as learning materials, encouraging students to solve these problems. This approach fosters critical thinking, analytical skills, and motivates students to become independent learners. Similarly, Erviana et al. (2022) argued that problem-based learning is an effective approach for teaching higher-order thinking skills. This aligns with Buhungo et al. (2023), who emphasized the importance of connecting learning materials with real-life situations to enhance long-term retention and internalization of information.

Setyabudi et al. (2021) highlighted the need for effective and efficient media in teaching physics, citing PhET simulations as suitable alternatives to laboratory experiments. PhET Simulations provide interactive visualizations that aid in understanding physics concepts. In the context of PBL, PhET helps students explore concepts independently and answer key questions during problem-solving, promoting active learning and motivation. This finding aligns with the study by Abdjul & Ntobuo (2019), which demonstrated that students taught using PhET-based virtual laboratory media achieved better learning outcomes than those using simple teaching aids.

The research data showed that the average pretest scores for the experimental, Replication 1, and Replication 2 classes were 29.9, 29.6, and 30.5, respectively. The low pretest scores were due to the students' lack of prior exposure to the parabolic motion material. After implementing the PBL model supported by PhET Simulation, the average posttest scores for the experimental, Replication 1, and Replication 2 classes increased to 84.3, 79.7, and 83.2, respectively.

The results indicate that the average posttest scores in all three classes were significantly higher than the pretest scores, surpassing the minimum passing criterion (KKM). This improvement is attributed to the PBL model with PhET Simulation, which created a learning environment that encouraged active student engagement and the development of essential scientific skills. This finding aligns with Supartin (2022), who demonstrated that PBL positively affects students' learning outcomes. Similarly, Rahayu (2023) reported that students taught with PBL supported by PhET Simulation had higher concept mastery than those taught without it. Nurhayati (2020) also found that PBL enhances students' critical thinking skills and conceptual understanding, particularly in abstract physics subjects.

The hypothesis test showed that the calculated t-value was greater than the critical t-value at a significance level of α=0.05, leading to the acceptance of H_0 and rejection of H_1. This indicates a significant positive effect of the PBL model with PhET Simulation on students' cognitive learning outcomes in the parabolic motion topic. While the treatment produced consistent results across all classes, a few students scored close to or below the minimum passing criterion. This was due to their lack of attention during lessons and insufficient involvement in problem identification, discussions, and solution development, limiting their full benefit from the PBL and PhET Simulation model. This finding supports Nurfadillah (2023), who demonstrated that PBL supported by PhET positively impacts students' scientific process skills and cognitive learning outcomes. Similarly, Suharto et al. (2021) found that PBL with technology integration enhances students' motivation in learning physics. As Wulandari (2020) concluded, PBL improves learning outcomes because students with better problem-solving skills tend to achieve optimal learning results.

Conclusions

Based on the research results obtained from data analysis and hypothesis testing, it can be concluded that the implementation of the PBL model supported by PhET Simulation on the topic of parabolic motion has a significant effect on improving the cognitive learning outcomes of Grade XI students at SMA Negeri 1 Suwawa. This significant effect was demonstrated through the one-tailed hypothesis test results, where $t_{hitung} > t_{tabel}$. This indicates that the average scores of students in the experimental class, Replication Class 1, and Replication Class 2 consistently exceeded the school's established Minimum Passing Criterion (KKM) of 70.

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