The Implementation of the Problem-Based Learning (PBL) Model Using a Virtual Lab to Improve Students' Learning Outcomes on Potential and Kinetic Energy Material

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Sections Info	ABSTRACT
	Objective: *This study aims to evaluate the effectiveness of implementing the Problem Based Learning (PBL) model in improving students' learning outcomes on the topic of potential and kinetic energy in Class X at SMK Putra Perdana Indonesia.* ***Method:*** *The research was conducted through two learning cycles using an innovative PBL approach integrated with virtual lab activities. Data were collected through pretests and posttests, observations, and analysis of student presentations.* ***Results:*** *The results showed an increase in the average score from 50.3 (pretest) to 70 (posttest), indicating percentage of 28.57% improvement in student learning outcomes. In addition, students' motivation and participation also increased during the learning process. Challenges such as time management and uneven student understanding were successfully addressed through thorough planning, individual guidance, and the use of heterogeneous group systems.* ***Novelty:*** *Therefore, it can be concluded that PBL is effective in enhancing students' conceptual understanding of physics and their critical thinking skills.*

INTRODUCTION

Discussing Education is not separate from the main activity, namely learning. The success of learning is highly dependent on the learning strategies, methods and models applied in teaching and learning activities [1]. In learning activities, educators play a very crucial role and are the key to the success or educators design, implement and evaluate learning outcomes [2]. Therefore, various learning models are used to make it easier for students to understand the material delivered by educators [3].

Learning physics is often considered difficult by students because of its abstract nature and requires a deep understanding of concepts [4]. One of the strategies that can be used to overcome this is the application of the Problem Based Learning (PBL) learning model, which is a real problem-based learning approach that encourages students to be active in the problem-solving process [5], [6].

Based on initial observations at SMK Putra Perdana Indonesia, students tend to be passive and less interested in learning physics, especially on the topic of potential and kinetic energy. Therefore, learning innovations are needed that can improve their interest and learning outcomes. From the brief description above, the author will analyze the effectiveness of the application of the PBL model in improving student learning outcomes and identify challenges and solutions in the implementation of PBL-based learning assessments [7].

RESEARCH METHOD

This research is a classroom *action research* that is carried out in two cycles. Each cycle consists of planning, implementation, observation, and reflection [8]. The subjects of the study were 16 students of class X majoring in Computer and Network Engineering at SMK Putra Perdana Indonesia.

This study uses a quantitative approach with a quasi-experimental method. The design used is *The Nonequivalent Posttest-Only Control Group Design* [9], which is described as follows:

Table 1. Research design.

Group	Treatment	Post - test
Experiment (postest)	x_1 (PBL Model)	T_1
Control (pretest)	x_2 (without treatment)	T_2

Sampling was carried out using *the Simple Random Sampling technique* from the population. One class was selected as the experimental group that received the PBL model treatment, and the control group did not receive the PBL model treatment.

Before learning starts, students have completed a pretest and motivational observation sheet. The learning process using PBL began with the provision of contextual problems related to potential and kinetic energy, followed by group discussions, exploration using *virtual labs,* and presentation of results [10].

RESULTS AND DISCUSSION

The homogeneity test is performed to ensure that the variants of the pretest and posttest scores are the same or not significantly different. However, because this is *paired data*, the homogeneity test is actually not mandatory, but it can still be done [11].

Since this data is a pretest and a posttest of the same subject, the proper statistical test is the Paired Sample T-Test [12].

Table 2. Paired samples statistics.

Variable	Mean	N	Standard Deviation
Pretest	50.31	16	13.55
Posttest	70.00	16	6.85

Table 3. Paired samples correlations.

N	Correlation	Sig. (2-tailed)
16	0.72	0.002

From the data above, it is known that there is a positive and significant relationship between *the pretest* and *the posttest.*

Table 4. Paired samples test.

Mean Diff.	Std. Dev.	Std. Error Mean	95% CI Lower – Upper	T-Value	DF	Sig. (2-tailed)
-19.69	11.56	2.89	-25.85 to -13.53	-6.81	15	0.000

The results of the paired sample t-test showed that there was a significant mean difference between the pretest and the posttest (t = -6.81, p < 0.001). The average learning outcome increased from 50.3 (SD = 13.55) to 70 (SD = 6.85), with an increase of 28.57%. This shows that the application of the Problem Based Learning (PBL) learning model is effective in improving student learning outcomes [13]. In addition, the results showed that there was a significant difference between the abilities of the experimental group and the control group.

The learning model applied in the classroom greatly affects the learning outcomes of students [14]. The *Problem Based Learning* (PBL) learning model has a positive influence on student learning outcomes. This refers to the research of Zainuddin, et al in his journal showing that *the Problem Based Learning* (PBL) learning model with an inquiry approach can improve student learning outcomes [4], [6], and with the application of this model student learning outcomes are higher than using conventional learning models. This improvement in learning outcomes is in line with the research results of Mutiasih, Wahyuningtyas & Minarti, and Gulo, which stated that PBL is effective in improving science/physics learning outcomes through a contextual and collaborative approach.

CONCLUSION

Fundamental Finding : Based on the results of the learning assessment analysis, it can be concluded that the application of the PBL learning model is effective in improving students' learning outcomes on potential and kinetic energy materials. There is a significant difference in problem-solving skills between students who are taught using the Problem Based Learning (PBL) model and students who have not received the Problem Based Learning (PBL) model treatment. The Problem Based Learning (PBL) model has been shown to be more effective in improving students' mathematical problem-solving skills. **Implication :** The findings suggest that the PBL model not only enhances conceptual understanding in physics but also strengthens students' ability to solve mathematical problems effectively. This indicates that the integration of PBL into classroom instruction could be a valuable strategy for educators aiming to promote deeper learning and higher-order thinking skills across various scientific domains. **Limitation :** While the results highlight the effectiveness of PBL, the study focuses primarily on specific physics content — potential and kinetic energy — which may limit the generalizability of findings to other subject areas or broader curricula. Additionally, the scope of student motivation and participation, though noted to increase, was not deeply

analyzed in terms of long-term impact or specific contributing factors. **Future Research :** Future studies should explore the application of the PBL model across different subject areas and grade levels to test its broader applicability. Further investigation into the mechanisms behind increased student motivation and participation, as well as longitudinal studies on sustained learning gains, would also enrich the current findings and offer deeper pedagogical insights.

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