PBL Student Worksheet with PhET Simulations: Improving Cognitive Learning Outcomes on Simple Machines

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Abstract - *This study aims to analyze the cognitive learning outcomes of students before and after using PBL student worksheets assisted by PhET Simulations on simple aircraft material. This study used a quasi-experimental method with a one-group pretest-posttest design. The research subjects were 32 students of class VIII H at SMPN X Yogyakarta in the odd semester of the 2023/2024 school year which was determined by purposive sampling technique. The instrument used was a multiple choice test of 15 items that measured cognitive learning outcomes based on Bloom's cognitive taxonomy levels C2, C3, C4. The results showed a significant increase in the cognitive learning outcomes of students before and after using PBL student worksheets assisted by PhET Simulations on simple aircraft material. The pretest average score of 61.97 increased to 84.41 on the posttest, exceeding the minimum completeness criteria. The normality test shows that the data is normally distributed. The paired sample t-test produced a significance value of 0.000 ($p < 0.05$), which showed a significant difference between the pretest and posttest. The effect size value of 1.73 is in the large category, indicating a strong influence of the treatment on students' cognitive learning outcomes.*

Keywords*: Problem Based Learning; PhET Simulations; Cognitive Learning Outcomes*

INTRODUCTION

The achievement of cognitive learning outcomes in Indonesia, especially in science, is still low, as evidenced by Indonesia's PISA science score of only 383, far below the international average of 476 (OECD, 2024). This is a challenge in the era of globalization that demands 21st century skills such as creativity, critical thinking, collaboration, and communication to compete in the modern world of work (Thornhill-Miller et al., 2023). Therefore, the education system needs to produce graduates who are not only sufficient in quantity but also of high quality for Indonesia to become a competitive and innovative society (Tias, 2018).

The low achievement in science is reflected in the students' low understanding of physics material, which involves concepts, principles, laws, and theories and demands critical thinking (Suliyati et al., 2018; Verdiana et al., 2024). Due to the abstract and complex nature of physics, this material is often considered difficult and less interesting (Mayanti et al., 2022). In addition, many students find it difficult with science lessons, especially physics, because they are considered boring, complicated, and less relevant to everyday life (Hidayana et al., 2022; Rosuli et al., 2019; Saban, 2023; Yufa et al., 2024). Simple aircraft material is one of the difficult subpoints, where students often misunderstand the concepts of effort and mechanical advantage, and assume that all levers are the same and the mechanical advantage of pulleys does not vary (Laila et al., 2024; Putriardi et al., 2023).

These difficulties have a negative impact on cognitive learning outcomes and learner comprehension, inhibit the acceptance of new knowledge, and lead to low academic achievement. The achievement of cognitive learning outcomes

is closely related to the learning process followed by learners during teaching activities. Cognitive learning outcomes are not only reflected in academic grades, but also include changes or improvements in attitudes, habits, knowledge, discipline, and development in a more positive direction (Astuti et al., 2023).

The results of observations at SMPN X Yogyakarta show that most students in class VIII H have not reached the minimum completeness value on the previous physics material (work and energy), with an average score of 72, while the minimum completeness criteria for science subjects is 80, where the teacher still uses a monotonous lecture method that makes students bored, especially since science lessons are scheduled at the end of the hour. Although there has been a practicum, the student worksheets used have not been problem-based or raised everyday phenomena.

Learning activities that are still dominated by classic approaches such as lectures and question and answer are considered less effective in developing students' critical thinking skills, and often cause conceptual difficulties due to inconsistencies and errors (Suarez et al., 2020; Utami et al., 2019). In addition, the lack of use of interactive media inhibits the focus and active involvement of students in the learning process (Agus et al., 2022; Suryadi et al., 2021). The lack of innovative learning strategies contributes to the low cognitive learning outcomes of some students (Kisdiono, 2023; Su & Cheng, 2019).

One solution to improve cognitive learning outcomes is the use of Problem Based Learning (PBL) learner worksheets assisted by PhET Simulations. Learner worksheets make it easier for learners to understand learning objectives (Aulia, 2023) and encourage active involvement, both individual and group (Yufa et al., 2024), helping teachers manage learning by shifting the focus from teachers to learners (Yashinta et al., 2019). Research shows PBL learner worksheets help learners achieve optimal results and integrate new knowledge (Kristiana & Radia, 2021; Mardhatilah et al., 2022). This PBL model also improves creativity, process skills, critical thinking, and teamwork (Hidayana et al., 2022; Saban, 2023), and has proven effective on simple aircraft material (Mariana & Warsidah, 2023; Rustam et al., 2024).

PBL presents contextual problems to help understand physics in a structured way. As a learner-centered model, the teacher's role is important in fostering scientific attitudes. Effective learning occurs when learners actively solve problems (Suindhia, 2023). In addition, PhET Simulations learning media facilitates understanding of physics concepts through interactive virtual experiments, and significantly improves creative thinking skills and cognitive learning outcomes (Yani & Widiyatmoko, 2023), with a positive impact on students' cognitive learning outcomes (Nurhayati et al., 2014). Virtual laboratory-based student worksheets are also effective in helping students understand the material (Firdaus & Wilujeng, 2018).

RESEARCH METHODS

This research is a quasi-experimental research with a one-group pretest-posttest design. The research subjects were 32 students of class VIII H SMPN X Yogyakarta in the odd semester of the 2023/2024 academic year, which were selected using purposive sampling technique. In this design, students were given a pretest to measure cognitive learning outcomes before being given treatment. The treatment in question is the application of

PBL student worksheets assisted by PhET Simulations simple aircraft material. After treatment, students are given a posttest to determine the increase in cognitive learning outcomes.

Table 1. One Group Pretest-Posttest Design

Pretest	Treatment	Posttest
O_1	X	O_2

Description:
O_1 : before treatment
O_2 : after treatment
X : application of treatment

Data collection techniques are used with test techniques. The test used is a test to measure the cognitive learning outcomes of students on simple aircraft material. The research instruments included 15 multiple choice pretest and posttest questions on simple aircraft material which were arranged based on Bloom's Taxonomy cognitive levels C2 (understanding), C3 (applying), C4 (analyzing).

Data analysis was carried out using descriptive statistical analysis techniques to calculate the comparison of the average pretest and posttest scores, normality test and paired sample t-test using SPSS version 25, and effect size to determine the effect of treatment on students' cognitive learning outcomes.

Table 2. Cohen's d Interpretation Criteria

d Value	Interpretation
0,8≤d≤2,0	Large
0,5≤d≤0,8	Medium
0,2≤d≤0,5	Small

RESULTS AND DISCUSSION

This study aims to analyze the cognitive learning outcomes of students before and after using PBL student worksheets with the help of PhET Simulations on simple aircraft material. The research was conducted at SMPN Yogyakarta in class VIII H with 32 students as research subjects. The research was conducted in the odd semester of the 2023/2024 school year. The material used in this study is simple aircraft material which includes levers, pulleys, and inclined planes. Learning is done using PBL student worksheets assisted by virtual laboratory PhET Simulations.

Before receiving learning treatment using PBL student worksheets supported by PhET Simulations, students were first given a pretest to measure the initial ability of cognitive learning outcomes. After the treatment is given, a posttest is conducted to determine the final ability of students. Measurement of cognitive learning outcomes is based on learning objectives that have been formulated, with a focus on understanding, applying, and analyzing the concept of simple aircraft, which are arranged referring to the cognitive level of Bloom's Taxonomy C2 (understanding), C3 (applying), and C3 (analyzing).

Results

Based on the application of PBL student worksheets assisted by PhET Simulations, there is an increase in the average cognitive learning outcomes of students. This can be seen from the comparison of the average pretest and posttest scores, where the pretest average score was 61.97, while the posttest average score increased to 84.41. This increase shows that the average value has been above the minimum completeness criteria. Thus it can be concluded that learning with the integration of PhET Simulation on PBL student worksheets has succeeded in meeting the minimum completeness criteria for science subjects.

Table 3. Average of Pretest and Posttest

		Mean	N
Pair 1	Pretest	61.97	32
	Posttest	84.41	32

The results of the normality test are to ensure that the data obtained meet the assumptions of normal distribution. The results of the Shapiro Wilk normality test on pretest data are Sig (2-tailed=0.141) ≥ α (0.05) and posttest data Sig (2-tailed=0.071) ≥ α (0.05), so it can be concluded that the pretest and posttest data are normally distributed. The results of the normality test can be seen in Table 4.

Table 4. Normality Test

Class	Statistic	df	Sig.
Pretest	.950	32	0.141
Posttest	.939	32	0.071

The paired sample t-test results show that the Sig. (2-tailed) value of 0.000, smaller than ½ α (0.025). Therefore, H_0 is rejected, which shows that there is a difference in pretest and posttest cognitive learning outcomes after the application of PBL student worksheets with PhET Simulations on simple aircraft material. The results of the paired sample t-test can be seen in Table 5.

The effect size test results show a value of 1.73, this means that it is included in the large category. This shows that the PBL student worksheet assisted by PhET Simulations has a strong influence on the cognitive learning outcomes of students on simple aircraft material. This large effect indicates that the learning treatment provided is effective in supporting students' understanding of the simple aircraft concepts taught.

Table 5. Paired Sample T-Test

		Mean	Std. Deviation	t	df	Sig. (2-tailed)
Pair 1	Pretest-posttest	-21.438	12.334	-9.832	31	.000

Discussion

Learning with PBL student worksheets is carried out through experimental activities using the PhET Simulations virtual laboratory. In the learning process, the teacher raises phenomena or problems in everyday life related to simple aircraft tools. Learning that presents a variety of real problems as a source and means of learning aims to help students improve their critical thinking and problem-solving skills, build knowledge independently through learning activities at school, and relate it to real life without putting aside mastery of concepts or knowledge as the main goal of learning (Faturrahman, 2020; Sembiring & Arisetya, 2023).

The problem in lever material, the teacher raises the phenomenon of two children playing seesaw, students are asked to determine the balance point based on three variations of data that have been provided. Furthermore, they calculate the mechanical advantage to understand the working principle of the lever and the relationship between weight, force, power arm, and load arm. A similar approach is applied to pulley and inclined plane materials. The problem with pulleys is that learners are asked to find the right solution for someone who draws water using only a rope and bucket. Meanwhile, in the context of inclined planes, learners are asked to determine the most effective inclined plane to move an iron barrel onto a truck, taking into account mechanical advantage.

The use of PBL learner worksheets is very effective in creating learner-centered learning. Learner worksheets provide instructions for conducting experiments that help students learn independently, while the teacher acts as a facilitator (Dari et al., 2024). The preparation of learner worksheets must consider the characteristics of students and the material being taught

because it affects the course of the learning process (Amali et al., 2019). PBL models that focus on problem solving have proven effective in developing students' critical thinking and analysis skills (Mariana & Warsidah, 2023). By applying the steps of the scientific method in solving problems, learners not only improve science process skills, but also scientific attitudes that make learning more meaningful and relevant. In addition, PBL is also able to increase learners' creativity and knowledge in solving problems (Saban, 2023).

The use of virtual laboratory PhET Simulations contributes significantly to the understanding of abstract physics concepts. This simulation allows learners to conduct virtual experiments that support interactive learning and facilitate understanding of the relationship between theory and practice. Thus, students become more motivated to learn physics (Verawati et al., 2022; Zaturrahmi et al., 2020). PBL-based learning supported by virtual laboratory PhET Simulations has proven effective in improving students' cognitive learning outcomes in physics material. PBL encourages students to be active in the learning process through the presentation of real problems that must be solved. This is in line with findings that show PBL can improve students' critical thinking skills, creativity, and learning outcomes in science subjects (Gede Swiyadnya et al., 2021; Makhrus & Wahyudi, 2020). In addition, the use of virtual laboratory-based student worksheets on mteri has also proven effective in improving student learning outcomes (Mahardika et al., 2022). This is in line with the research of Firmasari et al., (2019) that there is an effect of PBL learning model assisted by PhET Simulations on students' physics learning outcomes.

CONCLUSION

This study shows that the use of PBL student worksheets assisted by PhET Simulations significantly improves the cognitive learning outcomes of students on simple aircraft material. This is evidenced by an increase in the average score from 61.97 (pretest) to 84.41 (posttest). The paired sample t-test results show a significance value of 0.000 ($p < 0.05$), which means there is a significant difference between before and after treatment. In addition, the calculation of effect size of 1.73 is included in the large category, indicating that the learning treatment has a strong influence on increasing students' understanding. Therefore, it is recommended that teachers apply PBL student worksheets assisted by PhET Simulations in physics learning to increase students' involvement and conceptual understanding.

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