Synergy Education: Journal of Multidisciplinary Language and Social Sciences
Vol. 1. No. 2, July 2026, pp. 55-64
ISSN: xxxx-xxx E-ISSN: 3163-3420

E-Worksheet of Problem Based Learning (PBL) Model on Physics Materials to Improve Critical Thinking Ability

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Abstract

Developing students' critical thinking skills has become an urgent priority in science education, yet conventional physics instruction often provides limited opportunities for higher-order thinking. This study investigates the effectiveness of Problem-Based Learning (PBL)-based e-worksheets in enhancing students' critical thinking skills on the topics of progressive and stationary waves. A quasi-experimental pretest-posttest control group design was employed involving two Grade XI science classes at SMAN 20 Makassar, with Class XI MIPA 1 serving as the experimental group and Class XI MIPA 2 as the control group. Data were collected through product assessment worksheets and critical thinking tests, and analyzed using normality, homogeneity, and independent-samples t-tests. The results demonstrate that the PBL-based e-worksheets significantly improved students' critical thinking skills compared with conventional instruction. This study contributes empirical evidence supporting the integration of digital PBL learning materials into physics education to promote students' higher-order thinking and active learning.

Keywords: Critical Thinking Ability, E-Worksheet, Nearpod, Problem-Based Learning, Progressive and Stationary Waves Materials.

1. Introduction

21st century learning connects science with the real world that can be understood with critical thinking ability. Critical thinking ability helps students understand the information conveyed in learning (Damayanti & Kuswanto, 2021). In addition to facing the challenges of the 21st century, critical thinking ability are one of the important abilities in the industrial era 4.0 which requires humans to act and make decisions appropriately and quickly so that everyone needs to improve their critical thinking ability (Aurum & Surjono, 2021). There are five critical thinking indicators derived from critical activities, namely (1) being able to formulate the main points of the problem; (2) able to reveal the facts needed in solving a problem; (3) able to choose logical, relevant, and accurate arguments; (4) able to detect bias based on different viewpoints; and (5) able to determine the consequences of a statement taken as a decision (Ennis, 1996). Therefore, critical thinking is needed by everyone to deal with problems in real life.

The process of critical thinking can be accepted as reflective, rational and responsible. Critical thinking is directed at deciding what to do or believe in analysing a problem and drawing conclusions (Sari et al., 2023). The low ability to

think critically is due to the fact that there is still a teacher-centred learning process which results in students becoming passive and not understanding the learning material (Arni et al., 2024). Learning that does not involve students actively tends to make students accustomed to using a small part of their potential or thinking ability and makes them lazy to think (Nabilla et al., 2021). The ability to think critically can be combined with the knowledge gained by students, it will be very useful for the future life of students.

Related to critical thinking ability, most of the physics learning materials contain abstract concepts that are difficult for students to understand. Physics is a topic that demands greater understanding due to the use of many pictures, symbols, and equations, so Physics is considered difficult by most students (Muwafiq & Nugroho, 2025). This can be seen in the 2019 National Examination results in the wave material, especially in the progressive wave reaching 54.06% and in the stationary wave reaching 35.02% (Puspendik, 2019). These results show that there is still a lack of students' understanding of the concepts presented in physics.

Physics is one of the sciences that is always evolving, with the rapid development of science and technology. However, in fact the learning process of Physics in schools still has a number of shortcomings. One example is the infrastructure of learning resources in the form of monotonous learning devices by relying on textbooks and worksheets (Purnawati et al., 2020). Students prefer to bring computers or other electronic devices instead of textbooks because they are unable to carry thick and heavy textbooks to school (Dewi et al., 2019).

Student Worksheet is a worksheet intended to help students learn physics material better. One of the benefits of using this worksheet is that it can increase the effectiveness of the teaching and learning process in the classroom by asking students to complete group or individual work activities to answer questions from the worksheets (Rani et al., 2021). In this day and age, it is very important to convert worksheets into electronic worksheets, which enable independent learning and effective communication with teachers (Ayuni & Tressyalina, 2020).

The ease of accessing the internet provides new innovations in using online learning resources, one of which is in the form of the web. Student Worksheets using the web in the teaching and learning process can help educators and students improve the quality and outcomes of the learning process (Putri et al.,

2023). One website that can be used is Nearpod. Nearpod is highly recommended to teachers because this application is easy to use and students are more stimulated to participate in learning activities so as to make students more active, and teachers can more freely monitor the progress of each student (Delacruz, 2014). Worksheets must be combined using relevant and beneficial learning models, one of which is problem-based learning (PBL).

The model includes the use of real-life issues as a learning guide to hone and train students' ideas in order to develop cognitive capacity which aims to help students develop self-help ability when solving problems in the PBL model so that they can understand the problem-solving process (Bahri, 2021). Problem Based Learning (PBL) is a learning model designed so that students gain important knowledge, in order to make them proficient in solving problems, and have their own learning model and have the skills to participate in teams (Kemendikdasmen, 2025). In its application in learning, PBL involves small group discussions and presentations, where students learn to use authentic real-world problems, guided by educators with the aim of dynamic interactions among students for the success of this learning model (Abdul Ghani et al., 2022) (Ghani, et al, 2022). There are five strategies in using the problem-based learning model (PBL), namely: (1) problems as a study, (2) problems as an exploration of understanding, (3) problems as examples, (4) problems as an inseparable part of the process, and (5) problems as a stimulus for authentic activities. This paper discusses the effectiveness E-Worksheet of Problem Based Learning (PBL) to improve the critical thinking ability of the students of SMAN 20 Makassar.

2. Research Method

This study used a quasi-experimental design method, which uses existing groups rather than random assignments. While E-Worksheet is the independent variable in this study. The dependent variable is the students' critical thinking ability.

The design in this study used a pretest-posttest control group design. This design uses two groups, namely the experimental group and the control group (Creswell & Creswell, 2023). The subjects used in this study were students of class XI MIPA which were divided into two groups, Class XI MIPA 1 as the experimental group and Class XI MIPA 2 as the control group. At the beginning

of the E-Worksheet trial, students were given a pre-test to determine the students' initial abilities. Then the two groups received different treatment, the experimental group received the E-Worksheet treatment based on Problem-based learning, while the control group received the Package Book treatment with the lecture method. After the treatment was completed, both groups received a posttest which aims to determine the ability of the students after the treatment.

The obtained results were analyzed using independent-test homogeneity and normality tests. Before analyzing the data using the independent t-test, the homogeneity and normality tests were performed as independent t-test. This is due to fact that the independent t-test includes parametric statistical tests.

To find out more about the effect of critical thinking ability in the experimental class and control class, the data were analyzed using the following equation.

$$NP = \frac{R}{SM} \times 100\%$$

Information:

NP = Percentage Score

R = indicator Score

SM = Maximal Score

The results of the Critical Thinking Ability that have been obtained are then categorized based on Table 1.

TABLE 1. Categorization of critical thinking ability

Percentage (%)	Categorization
$81 < X$ 100	Very Well
$61 < X \leq 80$	Well
$41 < X \leq 60$	Average
$21 < X \leq 40$	Low
$0 < X \leq 20$	Very Low

3. Results

This research uses E- Worksheet which is linked to the web, namely Nearpod. On Nearpod there is a filter that is connected to the PhET Simulator that is adapted to the Worksheet. This E-Worksheet has been developed by previous research and the focus of this research is to improve students' critical thinking

ability. The E- Worksheet and wen Nearpod displays used in this study are shown in Figure 1, Figure 2, Figure 3 and Figure 4.

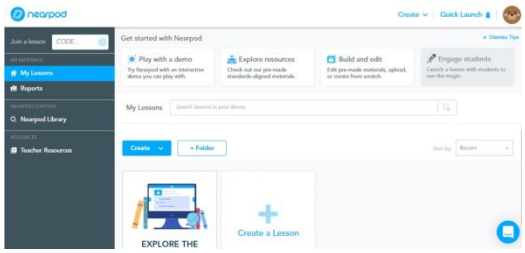

Figure 1. Initial view of Nearpod on teacher account

Figure 2. PhET simulation feature display on Nearpod

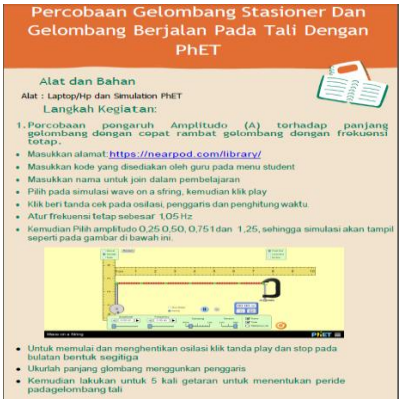

Figure 3. Stationary and progressive wave material Experiment Display on E-Worksheet

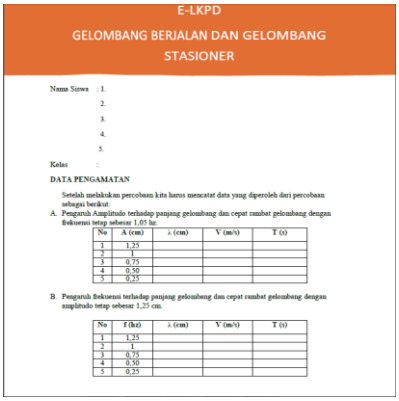

Figure 4. Student observation data sheet on E-Worksheet

The research continues with trials in the experimental and control classes to improve students' critical thinking ability. Indicators of critical thinking ability that are measured include generalizing data, analyzing data, investigating data and concluding data. The analysis was carried out using an independent t-test to see the difference in critical thinking ability in the experimental class which was taught using e-modules and the control class which was taught using commonly used media. The research design is a posttest only control group. This is because the critical thinking ability data is only obtained from the posttest conducted.

Homogeneity and normality tests were carried out first as a prerequisite test before the data were analyzed using independent t-test. This is because the

independent t-test includes parametric statistical tests. The analysis result data is displayed as in table 2.

TABLE 2. Normality Test Results

Tests of Normality

Group		Kolmogorov-Smirnov [a]			Shapiro-Wilk		
		Statistics	Df	Sig.	Statistics	df	Sig.
Ability Results Think Critical	Experiment Class	.143	15	.200 *	.955	15	.605
	Control Class	.100	15	.200 *	.958	15	.659

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on Table 2, that is possible to conclude that the data are normally distributed. This may be observed from the score importance to class experiment and class control that has a score greater than 0.05. That is between 0.955 and 0.958. The following homogeneity test was performed, as shown in the table 3.

TABLE 3. Homogeneity test and Independent t-test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Critical Thinking Ability Results	Equal variances assumed	.043	.837	2.218	28	.035	8.800	3.968	.672	16.928
	Equal variances			2.218	27.893	.035	8.800	3.963	.670	16.930

not

assumed

This indicates that the significance of the column Levene's Test is 0.837, which is more than 0.05. As a result, the data has the Fulfill condition for tested usage independent t-test. The results of data analysis using independent t-tests show that there is a significant difference between ability think critical of class control and class experiment, with score significance in the column sig.(2-tailed) less than 0.05. To find out more about the effect of critical thinking ability on the experimental and control classes, the data were analyzed using the following equation.

Based on the posttest findings, it was determined that the scatter Critical thinking ability participant teach in class experiment performed better than the class control. This was shown in the Figure 5.

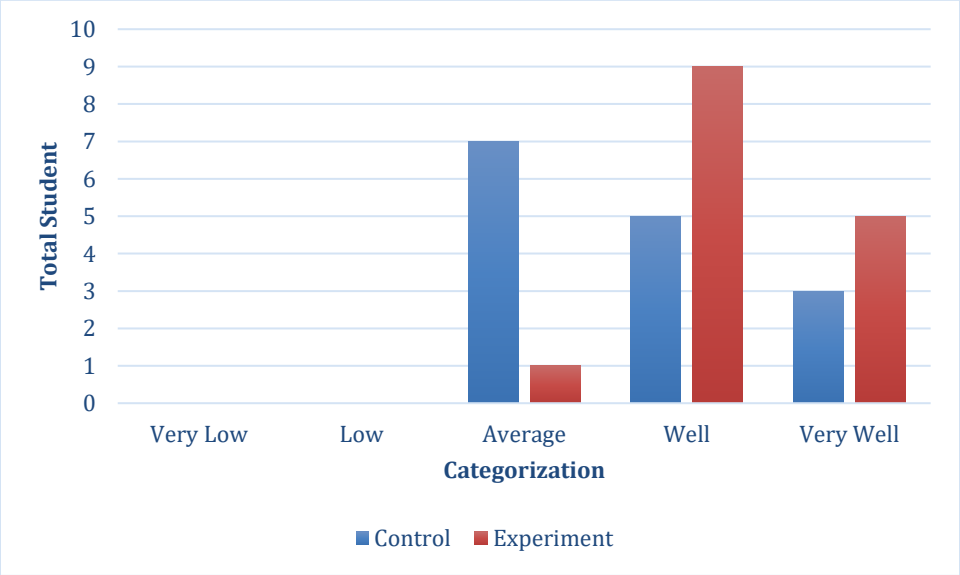

FIGURE 5. Distribution of Critical Thinking Ability in both implementation classes

Based on Figure 5, there are more students in the very good category from the experimental class with 5 people compared to the control class with 3 people. In the good category also more than the experimental class with a number of 9 people compared to the control class with a number of 5 people. In the

medium category the number of students was more than the control class which found 7 people compared to the experimental class which opened 1 person. This proves that E-Worksheets with the web can improve students' thinking skills. This is with various studies that have been done previously that worksheets that integrate critical thinking skills with problem-based learning using everyday life themes as problems to be solved can motivate students to be actively involved in problem solving activities. Presentation of problems makes students think and assume problem solving from their experiences (Murni et al., 2020). Worksheets based on learning problems in the learning process can help students understand the material faster and direct students to play an active role in learning and be involved in learning (Hakim & Sukardi, 2022).

4. Discussion

The results of the study can be concluded that the effectiveness of E-Worksheet based on problem-based learning (PBL) to improve critical thinking ability student participant in class experiment performed better than the class control. There is a significant effect on the effectiveness of problem-based learning (PBL)-based E-Worksheet to improve critical thinking ability student. It can be seen from the results of the homogeneity and normality test using the independent t-test which shows that there are differences in the results of the experimental class and the control class.

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