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The Effect of E-Worksheets With The Problem Based Learning Model Assisted by PhET on Global Warming Material on Critical Thinking Skills

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Abstract

The purpose of this study is to investigate the effect of students' critical thinking skills in relation to the issue of global warming when using Problem-Based Learning (PBL) e-worksheets assisted by PhET. Students from classes X2 and X4 participated in this study, which was conducted at SMA Negeri 1 Seputih Raman during the odd semester of the 2023/2024 academic year. In this non-equivalent control group research design, the dependent variable is critical thinking skills, the moderator variable is the PBL model, and the independent variable is the PBL-based e-worksheet assisted by PhET. The study results indicate that the use of PBL-based e-worksheets assisted by PhET enhances students' critical thinking skills. This is confirmed by the n-gain test results, which show that the control class obtained a low score of 0.299, while the experimental class achieved a moderate score of 0.498. Additionally, the effect size test produced a score of 1.78, which falls into the very high category. In conclusion, compared to traditional video-based worksheets, PBL-based e-worksheets assisted by PhET have been proven to be significantly more effective in improving students' critical thinking skills.

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1. Introduction

Teacher-centered learning has given way to student-centered learning in the twenty-first century. Teachers primarily serve as facilitators while using this approach, promoting student engagement and giving them lots of chances to practise critical thinking. As a result, students can think more thoroughly and logically while also becoming accustomed to using concepts, methods, evidence, and contextual factors when making decisions that involve interpretation, analysis, inference, and explanation [1], [2]. Critical thinking skills encourage students to seek solutions to the problems they encounter, providing concrete, real-life experiences that can be applied to solving similar issues in the future. This process also promotes active student involvement in teaching and learning activities [3], [4]. Such learning activities require appropriate and effective media and learning models in order to benefit both teachers and students. The PBL paradigm can help students become more adept at critical thinking. According to Watson [5], learning physics is a good fit for the PBL paradigm, which emphasises problem analysis and evidence-based solutions. PBL is grounded in a constructivist approach that emphasizes contextual and collaborative learning, metacognitive thinking, and effective problem-solving [6], [7].

Students can cultivate critical thinking abilities by applying the PBL paradigm, which will allow them to examine issues, form conclusions, and make deductions from their findings [8], [9]. As a result, including the PBL approach into instruction can successfully raise students' critical thinking abilities. To maximise the benefits of PBL, students' critical thinking abilities may be developed and the learning process improved with the use of worksheets and other relevant resources.

The worksheets has evolved from traditional printed formats to digital versions, commonly known as e-worksheets. In education, e-worksheets have a positive impact by making learning activities more interactive while also providing students with opportunities to practice and stay motivated in their studies [10], [11], [12]. Additionally, e-worksheets offer greater convenience, reduce spatial limitations, and enhance student engagement, ultimately making the learning process more effective [13]. Beyond format modifications, the content of e-worksheets has also been enhanced with advanced features such as virtual labs using PhET Simulations. By incorporating PhET Simulations, students can independently explore and develop physics concepts through interactive experimental simulations, allowing for direct investigation and deeper understanding [14], [15].

Based on data from preliminary studies conducted by researchers by distributing questionnaires using Google Form to grade 10 students, it is known that 47.7% of the student population surveyed still experience difficulties in understanding the material on global warming. In addition, 54.5% of the student population surveyed are less enthusiastic and interested in learning about global warming due to the teaching method used by the teacher, which more often relies on teaching and using learning materials such as videos taken from YouTube. Teachers at SMA Negeri 1 Seputih Raman were interviewed, and it was discovered that when implementing the physics curriculum, particularly the global warming content, the teacher still uses the teaching method and teaching media such as the teacher's handbook and videos from YouTube related to the material. The teachers at SMA Negeri 1 Seputih Raman added that the learning process and that pupils' critical thinking abilities have not improved as a result of their lack of interest and passion for learning about global warming. Thus, to increase its efficacy, the learning process should be continuously assessed and improved. Based on the background problem explanation, the electronic worksheet with a PhET-assisted PBL model offers an alternative to enhance students' critical thinking. This study examines its impact on learning about global warming

2. Methods

This study using a non-equivalent control group design and a quantitative experimental methodology. It uses two sample classes, X-2 and X-4, and is carried out at SMA Negeri 1 Seputih Raman. Table 1 presents the entire research design, were a quantitative data collected through a test instrument consisting of 20 essay questions covering global warming material. The instrument's validity and reliability were analyzed using SPSS version 26.0. A pre-test was given prior to the learning session, and a post-test was given following the conclusion of the learning process in order to collect data. After all study data was gathered, data analysis was done to assess the hypotheses and provide answers to the research questions. The study using the SPSS version 26.0 and included tests for homogeneity and normality. The hypothesis was then assessed using parametric statistical methods, including the n-gain test, independent sample t-test, and effect size test.

Table 1. Non-Equivalent Control Group Design Experiment Design

Pre-test			
Topic	**Meeting**	**Treatment**	
		K_A	K_B
T_1	P_1	X_1	X_2
T_2	P_2	X_1	X_2
T_3	P_3	X_1	X_2
T_4	P_4	X_1	X_2
Post-test			

Information: K_A: Class A (P_1: Session 1), K_B: Class B (P_2: Session 2), T_1: Learning Topic 1 (P_3: Session 3), T_2: Learning Topic 2 (P_4: Session 4), T_3: Learning Topic 3 (X_1: Learning treatment using the PBL model assisted by PhET), T_4: Learning Topic 4 (X_2: Learning treatment using video-assisted PBL model). Data analysis of pre-test and post-test results using N-gain for control and experimental classes; this method measures student's quantitative data using a normalised N-gain score. As indicated in Table 2, the efficacy of the n-gain values acquired in this investigation is interpreted according to particular standards [16].

Table 2. Interpretation of N-gain Effectiveness

N-gain range	***Interpretation***
$0{,}7 \leq n\text{-}gain \leq 1{,}0$	Height
$0{,}3 \leq n\text{-}gain < 0{,}7$	Avarag
$0 \leq n\text{-}gain < 0{,}3$	Low

The independent sample t-test was used to statistically assess the data on students' critical thinking skills. SPSS software was used to conduct this test at a 5% significance level. The data must have homogenous variance and be regularly distributed in order to be used with the independent sample t-test. Before the learning process began, a pretest was given, and then a posttest. The criteria for interpreting the independent sample t-test results in this study are in interval Sig (*2-tailed*) < 0,05 with Ho accepted criteria and Sig (*2-tailed*) ≥ 0,05 with H_0 not accepted criteria [17]. The effect size test was also used to evaluate the applied learning technique's impact on the study sample. The range of values that can be interpreted from the effect size test that was employed in this study; $0{,}2 < d \leq 0{,}5$ is low category, $0{,}5 < d \leq 0{,}8$ average or medium category, and $0{,}8 < d \leq 1{,}0$ is height category [18].

3. Results and Discussion

PBL-based e-worksheet is designed to encourage students to explore real problems related to global warming, such as the increase in earth temperature, the greenhouse effect, and the impact on the environment. With the help of PhET interactive simulations, students can observe the physical processes that occur, such as how solar radiation is absorbed and reflected by the atmosphere and the effects of greenhouse gases in increasing the earth's temperature. The results showed that students who learned with PBL-based e-worksheet assisted by PhET were more active in analyzing data and drawing conclusions compared to conventional learning methods.

Table 3. Pre-test and Post-test Results Data for Experiment Class

Parameter	Experimental Class		Control Class	
	Pre-test	Post-test	Pre-test	Post-test
Number of students	30	30	30	30
Mean	42.77	71.30	42.40	59.67
Highest score	52.00	86.00	51.00	70.00
Lowest value	29.00	58.00	30.00	50.00

Students became more critical in understanding the factors that contribute to global warming, such as carbon emissions, deforestation, and fossil fuel use. In addition, through interactive simulations, they can explore scenarios to see how environmental changes can impact global temperatures, thus increasing awareness of the importance of mitigation and adaptation efforts to climate change.

This study also showed an increase in students' learning motivation. They felt more interested in the material because they could conduct virtual simulations and experiments without having to rely on physical laboratory equipment. The results of the pre-test and post-test conducted in this study indicated an increase in students' conceptual understanding of global warming, including how energy moves and how to mitigate climate change.

This study used instruments in the form of pre-tests and post-tests to measure students' critical thinking skills so that the results were obtained in the form of average scores for the control group and the experimental group as shown in **Error! Reference source not found.**. The research result in Table 3 shows that students' early critical thinking skills were nearly equal in the two groups, with the experimental class's average pre-test score at 42.77 and the control class's at 42.40. However, the average of experimental class's post-test score increased to 71.30, where are the control class's score was 59.67. This suggests that the experimental class's critical thinking abilities were enhanced by the intervention more successfully than those of the control group. The gap between the pre-test and post-test results for the experimental and control class shows the extent to which the students' critical thinking skills have advanced. Based on the test data for the control class and experimental class after being given learning using PBL and PhET-based e-worksheet on global warming material, the experimental class obtained an n-gain score of 0.498 in the medium category and for the control class obtained an n-gain score of 0.299 in the low category. The complete data for the calculation of n-gain scores for each critical thinking indicator can be presented in Table 4.

Table 4. N-gain Critical Thinking Score for Experimental and Control Class

Critical Thinking Skills Indicator	Experimental Class		Control Class	
	N-gain	Category	*N-gain*	Category
CTS1	0,392	Medium	0,256	Low
CTS2	0,399	Medium	0,348	Medium
CTS3	0,462	Medium	0,265	Low
CTS4	0,567	Medium	0,276	Low
CTS5	0,609	Medium	0,317	Medium

Table 5. Independent t-test Post-test Results

Class	*N*	*Mean*	*S.d*	*T*	*Sig.(2-tailed)*
Eksperiment	30	71,30	7,183	6,923	0,000
Control	30	59,67	5,756		

To determine experimental and control group critical thinking abilities, post-test findings were subjected to an independent sample t-test, shows on Table 5. An effect size test was conducted following the n-gain and independent sample t-tests, given Cohen's d is 1.78, into the interpretation is very high (Table 6). According to the effect size analysis results, the implementation of the PBL paradigm, enhanced by PhET with electronic worksheets, has improved students' critical thinking skills.

Table 6. Effect Size Test

Class	*N*	*Mean*	*S.d*	*Cohen's d*	Interpretation
Eksperiment	30	71,30	7,183	1,78	Very high
Control	30	59,67	5,756		

This study aims to determine the use of e-worksheet with PhET - PBL on global warming material to improve students' critical thinking skills. Based on the previously data, this research was conducted using samples from class X-2 which utilized e-worksheets and class X-4 which used conventional video-based PBL worksheets. This research has been implemented for 1 month according to the physics learning schedule at SMA Negeri 1 Seputih Raman, where three stages in conducting research the preparation, implementation and final stages. Thus, research that uses the right stages can make the research good and accountable [19].

The study was conducted in four sessions for both the experimental and control classes using the identical lesson design and PBL methodology. While the control group received regular worksheets with video aid, the experimental class received PhET-assisted e-worksheets. The n-gain test results were obtained after confirming that the pretest and posttest data from both classes met the normality and homogeneity conditions. The critical thinking skills of experimental class's improved more than the control group, according to the n-gain data, demonstrating the superiority of PhET-assisted PBL e-worksheets over traditional video-assisted worksheets. PhET-assisted PBL e-worksheets significantly enhance students' critical thinking skills, as shown by the experimental class's average n-gain of 0.498 (medium) and the control class's 0.299 (low) effect size of 1.78 (very high).

Both the experimental and control groups' critical thinking skills have improved according to the results of the n-gain test. One factor that has contributed to this increase is the use of the PBL paradigm, which provides a structured approach or sintax of problem-solving. Students oriented to an issue, planning learning activities, directing investigations (individually or in groups), presenting findings, and assessing and analysing the problem-solving process are all important steps in the PBL sintax. Students' critical thinking abilities are fostered by these actions. Student's has demonstrated that the PBL approach successfully improves critical thinking abilities, as seen by better learning results for students [8], [20]. Therefore, combining the PhET-assisted PBL approach with e-worksheets to help students hone their critical thinking skills can significantly improve learning efficacy and engagement.

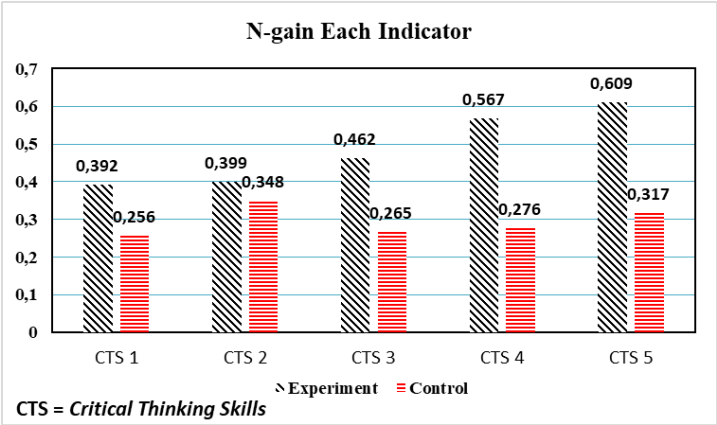

Figure 1. Student's Critical Thinking Ability

Studies on critical thinking skills in students generally contain four indicators of critical thinking proposed by Ennis [21], [22] as assumption and integration, inference, advanced clarification, fundamental clarification, and the foundation for a choice. In this study, research subjects were given tests for the experimental group and control group using the same test questions both pre-test and post-test. In order to determine the impact of the treatment on students' critical thinking skills, the n-gain score of the two tests was calculated (see Figure 1). Higher scores in the experimental class are revealed by the results of the n-gain exam, which contrasts the gains in students' critical thinking abilities between the experimental and control courses for each indicator. The experimental class received a score of 0.392 on CTS 1 (basic clarity), whereas the control group had a score of 0.256. The experimental class scored 0.399 on CTS 2 (decision-making), whereas the control group scored 0.348. For CTS 3 (inference), the equivalent scores were 0.462 and 0.265. The experimental class received a score of 0.567 on CTS 4 (advanced clarification), whereas the control group had a score of 0.276. Finally, in CTS 5 (supposition and integration), the experimental class did better than the control class, obtaining 0.609.

Using PhET-assisted PBL-based e-worksheets, the experimental class saw a greater improvement in critical thinking abilities **than** the control class, which used traditional video-assisted worksheets. In particular, both classes' CTS 2 and CTS 5 indicators were assigned to the same category, which is medium. The significant difference in n-gain scores between the experimental and control groups demonstrates this, the experimental class's critical thinking skills improvement was superior to the control class's. Additionally, subject teachers and facilitators can successfully increase students' critical thinking abilities by incorporating PBL-based e-worksheets into their teaching methods [23]. By compared traditional video-assisted worksheets and PhET-assisted e-worksheets not only improves learning outcomes but also makes learning more dynamic and interesting. PhET simulations are interactive, due to their increased motivation and enthusiasm in learning about global warming, students are better able to understand concepts and participate more actively in class activities [15], [24].

The PBL based and PhET assisted e-worksheets is in line with the syntax of the learning process. The syntax used includes: a) phase 1 presenting the problem; b) phase 2 planning the investigations; c) phase 3 conducting the investigations; d) phase 4 demonstration learning; e) phase 5 reflecting and debriefing [25]. The e-worksheets is applied to each PBL phase or syntax to the learning process. Student's activities also serve as a marker for the PBL learning model's syntactic application, both experimental and control class by presenting the problem orienting or problem offering the subject and learning objectives target at the students is the first PBL syntax.

The students activity react to problems given in the form of questions related to global warming material and solve a problem. The e-worksheets' questions encourage students to develop theories to find answers to the activity's challenges. In the learning process, students engage actively by focusing on PhET simulations in the first PBL syntax, where they directly explore concepts and then develop problem-solving hypotheses. This strategy is in line with the PBL model's usage of e-worksheets, which improve students' capacity for methodical problem-solving and assist them in developing hypotheses [26]. The second PBL syntax is planning the investigations, in this activity organizing students into study groups to conduct discussions between students. After getting the topic of the problem of global warming, students are guided to freely discuss and make decisions in order to get the best solution in solving the problem. This activity also makes the learning process more effective because the class atmosphere is more active and students are not bored while learning. In this activity, students are directed to define the questions previously given regarding global warming phenomena. To keep students becoming disinterested or bored during the learning process, teachers must create lessons that are both effective and captivating. By incorporating interactive elements, such as group discussions and hands-on experiments, educators can foster a dynamic environment where students feel engaged and motivated to explore the topic further. This approach not only enhances understanding but also encourages critical thinking and collaboration among students [27].

The third syntax of PBL is conducting the investigations, after forming a study group to conduct discussions. Students continue the activity, namely carrying out investigations using global warming animations on PhET, guided by the teacher as facilitator. After conducting discussions, students begin to compile answers in activities on e-worksheets and later end by compiling conclusions as a form of problem solving that will be displayed or presented later. In this activity in the third syntax, students are more motivated to organize the results of their discussions because using PhET helps them solve problems. Learning in class goes well and the teacher also guides each group to avoid misconceptions and helps students reach good conclusions. This is in line with good learning which is lively learning both individually and between learning groups so that problems can be solved [12], [28].

The fourth syntax of PBL is demonstration learning, after conducting group discussions and conducting investigations, students make presentations by presenting the results of the discussions they conducted and present them in front of the class. This also aims to ensure that discussion groups can absorb information from each other so that each group can be compared. During the presentation the teacher also allows questions and answers between groups so that the delivery of information between groups runs well. Additionally, allowing students to express their opinions based on reliable learning resources can significantly enhance their critical thinking skills, particularly in developing deeper explanations related to the material they have studied. This aligns with the principles of effective learning, which emphasize the importance of group discussions when presenting their findings [29].

The final activity in PBL syntax is reflecting and debriefing, after making a presentation, presenting the results of the discussion. The final activity in the classroom learning process involves evaluating students' progress, with the teacher acting as a facilitator in assessing their learning outcomes. The teacher also facilitates reflection sessions with students, ensuring that each discussion result is synthesized into a final conclusion. This process helps students consolidate their problem-solving outcomes and assess how well they have achieved the learning objectives. In reflection, the teacher also relates apperception at the beginning of learning and guides students to use the results of problem solving to relate it to the actual conditions that occur in the surrounding environment. At the end of each learning process, it is essential for teachers to conduct evaluation and reflection to ensure that the learning activities align with the intended learning objectives [30].

4. Conclusion

Test results, discussions, and research findings all support the idea that e-worksheets and the PhET-assisted PBL paradigm significantly enhance students' critical thinking skills when it comes to global warming subject. The experimental class is moderate category and the control class is low category on the n-gain test, which supports this. On the n-gain indicator exam, the experimental class consistently did significantly better than the control class in areas like basic clarification, decision-making, inference, advanced clarification, assumption, and integration. Additionally, the effect size test produced a very high score of 1.78. These results clearly indicate that compared to traditional video-assisted worksheets, PhET-assisted PBL-based e-worksheets are significantly more successful in enhancing students' critical thinking abilities.

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