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# Physics Learning with the Problem Based Learning (PBL) Model Based on Electronic Liveworksheets to Improve Critical Thinking Skills

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**ABSTRACT**

***Objective:*** *This study aims to determine the effectiveness of the Problem-Based Learning (PBL) model based on electronic liveworksheets in improving students' critical thinking skills.* ***Method:*** *This research employed a quantitative quasi-experimental design with a pre-test and post-test control group. The study subjects were 64 eleventh-grade students from SMA Negeri 1 Bluluk, divided into an experimental class (PBL with electronic liveworksheets) and a control class (conventional PBL), each consisting of 32 students. Research instruments included learning implementation observation sheets, critical thinking skills test questions, and student response questionnaires. Data were analyzed using prerequisite tests (normality and homogeneity) and hypothesis tests (paired t-test, N-Gain, and Effect Size).* ***Results:*** *The results showed that the learning implementation reached a "Very Good" category with a percentage of 93.2%. The experimental class demonstrated a higher improvement in critical thinking skills with an N-Gain value of 0.50 (medium category) and an Effect Size of 0.70 (medium category), both of which were greater than those of the control class. Student responses to the use of electronic liveworksheets were also very positive, with all aspects receiving percentages above 85%.* ***Novelty:*** *The novelty of this research lies in the successful integration of the PBL model with electronic liveworksheets, which effectively overcomes the limitations of conventional PBL, such as time inefficiency and delayed feedback. This integration provides an interactive dimension and instant feedback that significantly increases student motivation, engagement, and critical thinking skills, making it an innovative and relevant solution for 21st-century learning.*

## INTRODUCTION

In the digital era, physics learning faces significant challenges in integrating technology into the teaching and learning process while simultaneously developing students' critical thinking skills. Technology is expected to function not only as a simple tool but also as an effective learning medium to enhance understanding of complex scientific concepts. One fundamental concept in physics that often confuses students is the difference between temperature and heat. Many students have difficulty distinguishing between these two concepts and understanding their relationship (Alwan, 2019). This emphasizes the need for a learning approach that allows students to explore real-world phenomena, critically analyze data, and apply their understanding to everyday life.

Critical thinking skills are one of the essential 21st-century competencies that need to be developed. According to Facione (2011), critical thinking encompasses several key aspects, such as interpretation, analysis, evaluation, inference, explanation, and self-regulation. This competency is crucial in understanding physics concepts, including temperature and heat, as it helps students process information systematically, draw conclusions based on evidence, and build a deeper understanding. However, research conducted by Tiruneh et al. (2018) shows that the level of students' critical thinking skills in physics learning remains low. A study conducted at SMA Negeri 1 Bluluk revealed that most students struggle to connect theoretical concepts with real-world phenomena and are less able to explain the reasoning behind a thermal phenomenon based on scientific principles. Interviews with physics teachers also revealed that most students tend to memorize formulas without understanding the physical meaning of the quantities studied. This indicates that the learning process has not optimally encouraged students to think reflectively and analytically. One contributing factor is the teaching method, which is still dominated by traditional approaches that provide limited opportunities for students to engage in complex and challenging problem-solving activities.

The PBL model is one of the effective learning models for improving students' critical thinking skills. PBL places real problems at the center of learning, encouraging students to conduct investigations, analyze various information sources, and construct their understanding independently (Savery, 2015). Various empirical studies support the effectiveness of PBL in improving critical thinking skills in physics learning. Students who learned using the PBL model showed a significant increase in analytical and evaluative abilities compared to those who used conventional methods (Nurlaela et al., 2020). In addition, research by Widiastuti et al. (2023) also showed that PBL plays a role in developing students' critical thinking skills through more in-depth problem-based learning experiences.

However, although PBL has many advantages, there are some limitations in its implementation in the classroom. These include the need for a longer time, the burden on teachers to facilitate group discussions, and the challenge of providing comprehensive and timely feedback to all students. In this context, the development of digital technology offers a potential solution through the use of electronic liveworksheets as an interactive learning medium that can complement the weaknesses of PBL. Electronic liveworksheets are digital-based worksheets that allow students to interact directly with learning materials and receive instant feedback (Maharani & Hamid, 2024). This medium not only increases the flexibility of learning but also supports the principle of independent learning, which is at the core of the PBL approach. Electronic learning worksheets in physics learning can increase students' motivation and engagement (Mahliatussikah, 2022). Rusdan & Mulya (2023) found that students who used this interactive medium were more active in the learning process and showed a better increase in conceptual understanding compared to those who used conventional worksheets. Thus, the integration of PBL and electronic live worksheets becomes a strategic combination to optimize the development of critical thinking skills in the digital learning era.

Although electronic liveworksheets have great potential in increasing the effectiveness of learning, research on the application of electronic liveworksheets with the PBL model to improve critical thinking skills in temperature and heat learning is still limited (Suryantika & Aliyyah, 2023). Most of the digital worksheets currently available do not apply the PBL model and are not explicitly designed to improve students' critical thinking skills (Khastini et al., 2023). Therefore, electronic live worksheets with the PBL model are a strategic step in integrating digital technology with a more interactive and practical learning model in encouraging students' critical thinking skills.

Electronic live worksheets with the PBL model for temperature and heat topics are expected to create a more dynamic and interactive learning environment, facilitate a deeper understanding of concepts, and help students analyze, evaluate, and solve problems independently. This innovation is not only a solution for more effective physics learning but also contributes to the development of critical thinking skills, which are a primary need in 21st-century education.

## RESEARCH METHOD

This study used a quantitative research method with a quasi-experimental pre-test post-test control group design. This design involves a comparison between a control class and an experimental class (Creswell, 2021). The research design is illustrated as follows in Table 1.

**Table 1.** Research design

| Class | *Pre-test* | Treatment | *Post-test* |
|---|---|---|---|
| **Eksperimen** | $O_1$ | $X_1$ | $O_2$ |
| **Kontrol** | $O_1$ | C | $O_2$ |

Information :

$X_1$ = Experimental class treatment (PBL Model with Electronic Liveworksheets)

C = Control class treatment (PBL Model with printed worksheets)

$O_1$ = Pre-test before treatment is given

$O_2$ = Post-test after treatment is given

This research was conducted in April 2025 at SMA Negeri 1 Bluluk. The population of this study was all students of grade XI. The sample selection was carried out using a purposive sampling technique based on the recommendations of the subject teachers at SMA Negeri 1 Bluluk. Purposive sampling is a sampling method that allows researchers to select participants based on certain criteria that are in accordance with the research objectives (Creswell, 2022). The data analysis techniques used in this study include are, first analysis of learning implementation observation, the score for this implementation assessment has a range from 1 to 4 with the following in Table 2.

**Table 2.** Score categories

| Score | Category |
|---|---|
| 0.00 – 1.49 | Poor |
| 1.50 – 2.49 | Sufficient |
| 2.50 – 3.49 | Good |
| 35.0 – 4.00 | Very Good |

(Jatmiko et al., 2018)

The percentage of learning implementation can use as shown in Table 3.

**Table 3.** Percentage category rating scale

| Percentage | Category |
|---|---|
| 0% - 20 % | Very Poor |
| 21% - 40 % | Poor |
| 41% - 60 % | Sufficient |
| 61% - 80 % | Good |
| 81% - 100 % | Very Good |

Analysis of the Improvement of Students' Critical Thinking Skills. The prerequisite tests used were the normality test and the homogeneity test. Hypothesis tesring, this difference test analysis was performed using a paired parametric t-test, provided that the data were normally distributed. If the data were not normally distributed, a non-parametric test was performed to measure the significance of the difference between two paired groups. $H_0$ is accepted if the significance value (p-value) < 0.05, which means there is a significant difference between the pre-test and post-test scores. To find out the level of increase in pre-test and post-test scores, it can be analyzed in the N-Gain test.

The N-Gain value is used to determine the magnitude of the average increase in pre-test and post-test scores in the experimental and control classes as shown in Table 4.

**Table 4.** N-Gain interpretation categories

| Score | Category |
|---|---|
| 0.7 < (g) | High |
| 0.3 < (g) < 0.7 | Medium |
| (g) < 0.3 | Low |

(Hake, 2002)

The effect size analysis is based on Cohen's d using calculating the effect size using Cohen's d, the higher the value, the greater the difference between the experimental class and the control class (Cohen, 1988). The category intervals for the effect size are as follows in Table 5.

**Table 5.** Effect size category intervals

| Score | Category |
|---|---|
| Effect size > 0.80 | High |
| 0.51 – 0.80 | Medium |
| 0.21 – 0.50 | Low |
| 0 – 0.20 | Very Low |

(Cohen, 1988)

Next is analysis of student response questionnaire sheets with student response categories. The table of student response categories is shown in Table 6.

**Table 6.** Student Response Categories

| Criteria | Score |
|---|---|
| **Strongly Agree** | 1 |
| **Agree** | 2 |
| **Disagree** | 3 |
| **Strongly Disagree** | 4 |

## RESULTS AND DISCUSSION

### *Results*

*1. Learning Implementation*

Based on the results of the learning implementation observation conducted by two observers over two meetings, the following data were obtained as shown in Table 8.

**Table 8.** Recapitulation of learning implementation results

| Aspect | PA 1 | PA 2 | Average | Percentage (%) | Category |
|---|---|---|---|---|---|
| **Introduction** | 4.0 | 4.0 | 4.0 | 100.0 | Very Good |
| **Phase 1** | 3.5 | 3.5 | 3.5 | 87.5 | Very Good |
| **Phase 2** | 3.6 | 3.6 | 3.6 | 90.8 | Very Good |
| **Phase 3** | 3.6 | 3.6 | 3.6 | 90.8 | Very Good |
| **Phase 4** | 3.5 | 3.5 | 3.5 | 87.5 | Very Good |
| **Phase 5** | 3.8 | 3.8 | 3.8 | 95.8 | Very Good |
| **Conclusion** | 4.0 | 4.0 | 4.0 | 100.0 | Very Good |
| **Overall Average** | 3.7 | 3.7 | 3.7 | 93.2 | Very Good |

Based on Table 8, it shows that the learning implementation with the PBL model based on electronic liveworksheets reached an average score of 3.7 on a scale of 4.0, with a percentage of 93.2%, which is included in the "Very Good" category. The phase that obtained the highest score was Phase 5 (Analyzing and evaluating the problem-solving process) with a score of 3.8 (95.8%), while the phases that obtained the lowest scores were Phase 1 and Phase 4, with scores of 3.5 (87.5%) each.

*2. Pre-test and Post-test Results*

*a. Descriptive Statistics Data*

**Table 9.** Descriptive statistics of pre-test and post-test results

| Class | Test | Mean | N | Std.Deviation | Min | Max |
|---|---|---|---|---|---|---|
| **Experiment** | Pre-test | 49.75 | 32 | 4.103 | 40 | 56 |
| **Experiment** | Post-Test | 74.94 | 32 | 2.994 | 70 | 81 |
| **Control** | Pre-test | 45.50 | 32 | 3.610 | 40 | 51 |
| **Control** | Post-Test | 63.13 | 32 | 3.319 | 58 | 71 |

Based on Table 9, the experimental class had an average pre-test score of 49.75 and a post-test score of 74.94, while the control class had an average pre-test score of 45.50 and a post-test score of 63.13. The increase in the average score in the experimental class was 25.19, while in the control class it was 17.63.

b. *Prerequisite Test*

**Table 10**. Normality test results

| Class | Statistic | df | Sig. | Conclusion |
|---|---|---|---|---|
| **Pre-test Experiment** | 0.118 | 32 | 0.200 | Normal |
| **Post-test Experiment** | 0.147 | 32 | 0.075 | Normal |
| **Pre-test Control** | 0.131 | 32 | 0.178 | Normal |
| **Post-test Control** | 0.146 | 32 | 0.081 | Normal |

Based on Table 10, the normality test results show that all data have a significance value > 0.05, which means the data are normally distributed and meet the requirements to perform a parametric test.

**Table 11.** Homogeneity test results

| Test of Homogeneity | Levene Statistic | df1 | df2 | Sig. | Results |
|---|---|---|---|---|---|
| **Based on Mean** | 1.556 | 2 | 124 | 0.204 | Homogeneous |

Based on Table 11, the homogeneity test results show a significance value of 0.204 > 0.05, which means the data variance is homogeneous and meets the requirements to perform a parametric test.

c. *Hypothesis Testing*

**Table 12.** Paired t-test result

| Pair | Mean Difference | Std. Deviation | t | df | Sig.(2-tailed) | Conclusion |
|---|---|---|---|---|---|---|
| **Pre-test Experiment - Post-test Experiment** | -25.188 | 4.185 | -34.048 | 31 | 0.000 | Significant |
| **Pre-test Control - Post-test Control** | -17.625 | 3.329 | -29.952 | 32 | 0.000 | Significant |

Based on Table 12, the results of the paired t-test show that there is a significant difference between the pre-test and post-test scores in both the experimental and control classes ($p < 0.05$).

d. N-Gain Analysis

Based on the results of the N-Gain calculation, the following results were obtained:

**Table 13.** N-Gain results

| Class | N-Gain | Category |
|---|---|---|
| **Experiment** | 0.50 | Medium |
| **Control** | 0.32 | Medium |

Based on Table 13, although both classes are in the medium category, the experimental class shows a higher increase compared to the control class.

e. Effect Size

**Table 14.** Effect size analysis results

| Class | Effect Size | Category |
|---|---|---|
| **Experiment** | 0.70 | Medium |
| **Control** | 0.50 | Low |

Based on Table 14, the Effect Size value for the experimental class is in the medium category with a value of 0.70. Meanwhile, the control class is in the low category with a value of 0.50.

3. *Student Responses*

**Tabel 15.** Student response questionnaire results

| Statement | Total Score | Ideal Score | Percentage (%) | Criteria |
|---|---|---|---|---|
| **1** | 109 | 128 | 85.16 | Very Good |
| **2** | 110 | 128 | 85.94 | Very Good |
| **3** | 110 | 128 | 85.94 | Very Good |
| **4** | 115 | 128 | 89.84 | Very Good |
| **5** | 113 | 128 | 88.28 | Very Good |
| **6** | 120 | 128 | 93.75 | Very Good |
| **7** | 114 | 128 | 89.06 | Very Good |
| **8** | 109 | 128 | 85.16 | Very Good |
| **9** | 113 | 128 | 88.28 | Very Good |
| **10** | 116 | 128 | 90.63 | Very Good |

Based on Table 15, the results of the student response questionnaire show that all statements obtained a percentage above 85% with the "Very Good" category. The statement with the highest response was statement number 6 with a percentage of 93.75%, while the statements with the lowest responses were statements number 1 and 8 with a percentage of 85.16%.

***Discussion***

The implementation of the Problem-Based Learning (PBL) model based on electronic live worksheets has shown very positive results. Observations showed that this model was implemented very well, with a percentage of 93.2%. These results are consistent with research by Maharani & Hamid (2024), which stated that electronic liveworksheets increase learning flexibility and independence. The high score in the "Analyzing and Evaluating the Problem-Solving Process" phase (95.8%) indicates explicitly that this interactive medium is highly effective in encouraging students to conduct in-depth analysis and evaluation. This effectiveness is reinforced by the ability of electronic liveworksheets to provide instant feedback, which, according to Rusdan & Mulya (2023), increases student engagement in the learning process.

Analysis of pre-test and post-test data further corroborates these findings. The average score increase in the experimental class (25.19) was significantly higher than that in the control class (17.63), indicating that the integration of electronic liveworksheets with the PBL model has a greater positive impact. This aligns with research by Nurlaela et al. (2020), which found that the PBL model can improve analytical skills. The use of electronic liveworksheets adds an interactive dimension, allowing students to explore problems in greater depth.

Hypothetically, the N-Gain analysis showed that the experimental class experienced a higher improvement (0.50) than the control class (0.32), although both were in the moderate category. This confirms that electronic live worksheets are effective in enhancing the PBL model for developing critical thinking skills. This significant impact was also evident in the Effect Size analysis, where the experimental class fell in the moderate category (0.70) and the control class in the low category (0.50), supporting Mahliatussikah's (2022) view on the role of interactive media in increasing student motivation and engagement. Student responses were also very positive, with all questionnaire items receiving a "Very Good" rating (above 85%). This indicates that electronic learning worksheets are not only effective in improving learning outcomes but also in increasing motivation and learning satisfaction, in line with the findings of Rusdan & Mulya (2023).

The results of this study also highlight that electronic liveworksheets can overcome the limitations of conventional PBL, such as time efficiency, limited feedback, and lack of interactivity, consistent with Savery (2015) and Khastini et al. (2023). This integration significantly contributes to the development of critical thinking skills, particularly in the aspects of interpretation, analysis, evaluation, and inference, which is consistent with Facione's (2011) concept of critical thinking. Thus, this learning model is not only practical but also relevant to the demands of 21st-century learning, as emphasized by Tiruneh et al. (2018), making it an effective solution for improving students' critical thinking skills. For future research, it is recommended to explore the long-term impact and identify the specific features of electronic liveworksheets that contribute most to student learning outcomes and engagement.

## CONCLUSION

**Fundamental Findings:** This study concludes that the integration of the Problem-Based Learning (PBL) model with electronic liveworksheets is a highly effective instructional approach, particularly in enhancing students' critical thinking skills. The research shows a significant improvement in learning outcomes for the experimental group, as evidenced by a higher N-Gain score (0.50) and a larger Effect Size (0.70) compared to the control group. These values not only prove the model's academic effectiveness but also demonstrate a substantial impact on the learning process. Furthermore, the model's implementation was rated very well (93.2%) and received strong positive responses from students, indicating that electronic liveworksheets are not only beneficial but also engaging and motivating for learners. **Implications:** The implications of this research are highly relevant for modern educational practices. The integration of electronic liveworksheets was shown to successfully overcome several limitations of conventional PBL, such as time inefficiency and delayed feedback. **Limitations:** By providing instant feedback and supporting interactive, independent learning, this model creates a dynamic learning environment crucial for developing the critical thinking skills required in the 21st century. However, it is important to note the study's limitations, including its narrow focus on a specific subject and a limited time frame, which may restrict the generalizability of the results. **Future Research:** It is Recommended to conduct long-term studies to measure skill retention and to replicate this research across different subjects and educational levels to test its generalizability.

## AUTHOR CONTRIBUTIONS

**Sri Dewi** contributed to the conceptual framework, research design, and validation process; **Khoirun Nisa'** handled data management, project coordination, and manuscript drafting. All listed authors have reviewed and approved the final version of this submission.

## CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest, either financial or personal, that may have influenced the content or outcome of this study.

## ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

## STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of digital tools, including AI-based technologies, as support in the research and writing stages of this article. Specifically, Grammerly for a writing aid that offers various advantages, especially in terms of improving the quality and clarity of writing in English. All outputs generated with digital assistance were critically evaluated and revised to ensure academic rigor and ethical standards were upheld. The final responsibility for the manuscript rests entirely with the authors.

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