

Effectiveness of Learning With PBL Model Based on E-Modules To Improve Critical Thinking Skills

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ABSTRACT

Objective: This study aims to examine the effectiveness of physics e-modules based on the Problem-Based Learning (PBL) model in improving students' critical thinking skills on static fluid concepts. The focus is to evaluate the implementation of learning, measure the improvement of students' critical thinking ability, and analyze student responses after applying the PBL-based e-modules. **Method:** The research employed a proper experimental design with a pre-test and post-test control group, conducted at MA Ma'arif Bangil, Pasuruan, Indonesia. A total sampling technique was used, with class XA as the experimental group and class XB as the control group. Data were collected using observation sheets, pre-test and post-test instruments, and student response questionnaires. Data analysis included N-Gain scores, normality and homogeneity tests, t-tests, and descriptive analysis for student responses. **Results:** The findings showed that the implementation of PBL-based e-modules reached an average of 91.8% categorized as very good. Students in the experimental class demonstrated a significant improvement in critical thinking skills, with an average N-Gain of 0.512 (moderate), compared to 0.212 (low) in the control group. Furthermore, student responses were predominantly in the "good" and "very good" categories, indicating positive perceptions of the learning approach. **Novelty:** This study highlights the integration of PBL with interactive e-modules as an innovative learning strategy that not only enhances students' critical thinking skills but also addresses the limitations of conventional print modules. It provides empirical evidence that digital-based problem-oriented instruction is highly relevant to fostering 21st-century competencies in science learning.

INTRODUCTION

Twenty first century education requires students not only to master knowledge but also to possess higher-order thinking skills, including critical thinking skills (Lombardi, 2023). These skills are considered essential in preparing young people to face global challenges, rapid technological developments, and increasingly complex societal needs (Kennedy, 2025). Critical thinking skills help students analyse information in depth, evaluate perspectives objectively, and make appropriate decisions in solving real-life problems (Calma & Davies, 2025). However, various international studies, such as the Programme for International Student Assessment (PISA), indicate that Indonesian students' science and problem-solving abilities remain below the OECD average, suggesting that their critical thinking skills have not developed optimally (OECD, 2019). This finding aligns with national research indicating that the average critical thinking ability of students is approximately 35.41%, which is classified as low (Marisda et al., 2024). To address this challenge, a learning strategy is needed that can increase student active engagement and hone their critical thinking skills. One model that has proven effective is Problem-Based

Learning (PBL). The PBL model emphasises the resolution of contextual problems as a means of developing critical thinking skills, problem-solving, and communication skills among students (Hafizah et al., 2024). Previous studies have also reported that the implementation of PBL in physics learning can improve conceptual understanding and critical thinking skills (Samadun & Dwikoranto, 2022). However, the success of PBL is greatly influenced by the media used. Conventional modules in print form still have limitations in terms of flexibility, interactivity, and visual appeal. This type of module is not yet able to facilitate the presentation of multimedia content such as animations or videos that can increase students' learning motivation (Tugtekin & Dursun, 2022).

With the development of educational technology, e-modules have become one of the innovative learning media that can support the implementation of PBL more effectively (Gunawan et al., 2024). E-modules enable the integration of interactive content, multimedia presentation, and flexible access for students (Holisoh et al., 2025). Previous studies have shown that PBL-based e-modules can improve critical thinking skills in various subjects. However, there are still limitations in achieving specific indicators, particularly in advanced clarification, supposition, and integration, which are still relatively low (Hamidah et al., 2024). Therefore, further research is needed to optimise the role of PBL-based e-modules in the context of physics learning (Arifin et al., 2024). The selection of static fluid material in this study also has specific reasons. The topic of static fluids is known to be quite complex and often causes misconceptions among students because it involves the concepts of pressure, buoyancy, and abstract laws of physics (Jamaludin & Batlolona, 2021). These difficulties often result in low learning outcomes for students in this subject (Brooks et al., 2014). Thus, the development of PBL-based e-modules integrated with static fluid material is considered relevant to address this problem while improving students' critical thinking skills (Kreijkes & Greateorex, 2024).

Based on the above description, this study aims to innovate learning by applying PBL-based physics e-modules to static fluid material. The novelty of this study lies in the combination of the PBL model with digital e-modules to optimise interactivity, increase motivation, and train students' critical thinking skills in line with the demands of 21st-century education. Specifically, the objectives of this study are to: (1) describe the implementation of learning with PBL-based physics e-modules, (2) analyse the improvement in students' critical thinking skills after the implementation of the e-modules, and (3) determine students' responses to the implementation of learning using PBL-based e-modules.

RESEARCH METHOD

This study employed a quasi-experimental design (rather than an actual experimental design) with a pre-test and post-test control group design (Muse & Baldwin, 2021). This design was chosen because it allows for a comparison of learning outcomes between the experimental group, which received treatment in the form of e-module-based Problem-Based Learning (PBL), and the control group, which only used conventional PBL (Asih

et al., 2022). This design model also offers the advantage of controlling external variables that may influence the research results, thereby enabling the effectiveness of the treatment to be measured more accurately (Johnson et al., 2009).

Table 1. Control group design with pre-test and post-test

Group	Pre-test	Treatment	Post-test
Experiment	O ₁	X	O ₂
Control	O ₁	-	O ₂

In this study, O₁ is the initial observation or pre-test conducted before students received the learning treatment. Next, O₂ is the final observation or post-test given after students received the learning treatment. The symbol X indicates learning activities using physics e-modules based on Problem-Based Learning (PBL) applied in the experimental class. Meanwhile, the symbol represents learning activities using the conventional PBL model with printed modules applied in the control class. Additionally, the research was conducted at MA Ma'arif Bangil, Pasuruan, East Java, with tenth-grade science students as the subjects. The sampling technique employed was total sampling, which included all students in the designated class as research respondents. Class XA was selected as the experimental group, which received PBL-based e-module learning, while Class XB served as the control group with PBL-based printed module learning. The entire research stages are presented in Figure 1.

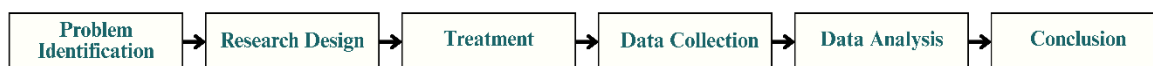


Figure 1. Research methods

The research instruments used included three types, namely critical thinking skills tests in the form of pre-tests and post-tests, learning implementation observation sheets, and student response questionnaires (Tian et al., 2025). The critical thinking skills tests were compiled based on indicators developed by Facione, which included interpretation, analysis, evaluation, inference, and explanation skills (Mastuti et al., 2022). The observation sheets were used to assess the implementation of learning according to the PBL syntax. In contrast, the student response questionnaires, in the form of a 1–4 Likert scale, were used to determine students' perceptions of learning with PBL-based e-modules (Evendi & Verawati, 2021). All instruments were validated by expert judgment and tested for reliability using Cronbach's Alpha formula, with a reliability criterion of α greater than 0.70.

The research procedure was conducted in four stages: preparation, implementation, evaluation, and analysis. In the preparation stage, the researcher developed a PBL-based e-module, prepared research instruments, and conducted validity and reliability tests on the instruments (Aladin et al., 2024). The implementation stage began with administering a pre-test to both groups, followed by treatment in the form of applying PBL-based e-

modules in the experimental class and conventional learning in the control class (Sikumbang et al., 2025). During the learning process, observers observed the implementation of activities using observation sheets. The evaluation stage was carried out by administering a post-test to measure critical thinking skills and distributing questionnaires to students. Finally, the analysis stage was carried out to process and interpret the research data. Data analysis was conducted using several techniques, where the learning implementation data were analyzed using the percentage of observation scores categorized by type (Huang et al., 2020).

Data on the improvement of critical thinking skills were analysed using the Normalised Gain (N-Gain) formula (Hadi et al., 2018), with criteria of high if $g > 0.7$, moderate if $0.3 \leq g \leq 0.7$, and low if $g < 0.3$. Before conducting the hypothesis test, prerequisite tests were first conducted, including normality using the Kolmogorov-Smirnov test and homogeneity using Levene's Test. A hypothesis test was conducted using an independent sample t-test to determine whether there was a significant difference in improvement in critical thinking skills between the experimental and control classes. Meanwhile, student response data were analyzed descriptively by calculating the percentage of answers for each questionnaire item, which were then categorized according to Arikunto's criteria, as shown in Table 2 (Aisyah, 2020).

Table 2. Categories of student responses

Interval of Student Responses	Pre-test
$80\% \leq Na < 100\%$	Very Good
$60\% \leq Na < 80\%$	Good
$40\% \leq Na < 60\%$	Fair
$20\% \leq Na < 40\%$	Poor
$Na < 20\%$	Very Poor

To ensure the validity of the research results, instrument triangulation was used, which included tests, observations, and questionnaires (Hussein, 2009). In addition, the e-modules used in learning have also been validated by experts in the field of physics education and learning media development. Thus, the results of this study are scientifically credible and are expected to make a meaningful contribution to enhancing the quality of physics learning, particularly in developing students' critical thinking skills.

RESULTS AND DISCUSSION

Results

The research results obtained are descriptive quantitative data covering the implementation of learning, prerequisite tests, pre-test and post-test results, N-Gain analysis, and student responses. These data were obtained through a series of systematic research stages, starting from the observation process, test data collection, and analysis of learning outcomes. The presentation of the results aims to provide a comprehensive

overview of the effectiveness of the learning model used, both in terms of classroom activity implementation and student learning outcomes. In the following section, the research results are presented in detail based on the aspects studied, starting with the implementation of learning.

Implementation of learning

Based on observations of teacher and student activities, all aspects of learning implementation were rated as Very Good (VG). Details of the results are shown in Table 3.

Table 3. Tables and figures should be valuable, relevant, and visually attractive

Aspect	Teacher		Students	
	%	Criteria	%	Criteria
Phase 1	94.7	VG	90.6	VG
Phase 2	90.6	VG	94.7	VG
Phase 3	90.6	VG	90.6	VG
Phase 4	89.5	VG	93.0	VG
Phase 5	94.7	VG	93.0	VG

Table 3 explains that problem-based learning is implemented through five main phases. In the first phase, teachers orient students to the problems to be studied, so that they have an initial understanding of the context and the challenges to be faced. Next, in the second phase, the teacher organises students to learn, either by forming groups or providing guidance on the steps to be taken. The third phase is guiding individual or group investigations, where the teacher acts as a facilitator to help students find information, analyse data, and formulate solutions. In the fourth phase, students develop and present their solution designs or findings systematically. Finally, the fifth phase emphasizes the analysis and evaluation of the problem-solving process, allowing students to reflect on the strengths, weaknesses, and successes of the strategies they have used.

Normality and Homogeneity Tests

The prerequisite test results indicate that the learning outcome data are typically distributed and homogeneous, as shown in Table 4.

Table 4. Normality test and homogeneity test

Aspect	Class	Normality Test	Homogeneity Test
		Sig.	Sig.
Pretest	Exp	0.181	0.305
	Con	0.135	
Posttest	Exp	0.083	0.254
	Con	0.067	

Pre-test and post-test results

Table 5 shows an increase in the average score from the pre-test to the post-test in both classes, with a higher increase in the experimental class.

Table 5. Average results of pre-test and post-test

Class	Test Type	
	Pretest	Posttest
Experiment	48.83	72.00
Control	47.42	60.38

N-Gain Results

The N-Gain calculation indicates an increase in students' critical thinking skills in the moderate category for the experimental class and a low increase for the control class, as presented in Table 6.

Table 6. Average N-gain results

Class	Mean	Category
Experiment	0.512	Moderate
Control	0.212	Low

Student Responses

Data on student responses to learning using PBL-based e-modules indicate that most students gave ratings of good to very good. Detailed data are presented in Table 7.

Table 7. Data on the percentage of student responses

Question	Percentage (%)	Category
1	76.7	Good
2	81.7	Very Good
3	80.8	Very Good
4	80.8	Very Good
5	79.2	Good
6	84.2	Very Good
7	81.7	Very Good
8	85.0	Very Good
9	82.5	Very Good
10	93.3	Very Good

Discussion

The results of the study indicate that the implementation of learning with e-modules based on PBL can be highly effective. Observations in each phase of PBL, from problem introduction to evaluation of the problem-solving process, all received a rating of 'very good' with an average implementation score of 91.8. This indicates that the integration of e-modules with PBL can be implemented consistently by the specified syntax. Optimal implementation not only demonstrates the readiness of teachers and students in adopting

this model but also shows how digital media can support problem-based learning more effectively. These findings align with the views of Sun et al. (2008), who suggest that high implementation is a crucial indicator of a learning model's effectiveness, as it reflects active interaction, high student participation, and teacher involvement in guiding the investigation process.

The results of the prerequisite tests, specifically normality and homogeneity tests, confirm that the research data are typically distributed and homogeneous, allowing for the valid use of parametric tests. This aspect is crucial because it ensures that the differences in critical thinking skills between the experimental and control classes are truly the result of the treatment, not confounding variables. Thus, the research findings have strong internal validity. A comparison of pre-test and post-test results reveals an increase in critical thinking skills in both groups; however, the increase in the experimental class is more pronounced than in the control class. The average N-Gain of the experimental class was in the moderate category (0.512), while the control class was only in the low category (0.212). These results confirm that the use of PBL-based e-modules can lead to better improvement in students' critical thinking skills compared to learning with printed modules. These findings are consistent with the research by Purnamasari et al. (2020), which showed a significant increase in students' critical thinking skills with the use of PBL-based e-modules in physics, even reaching the high category. Thus, this study strengthens the empirical evidence that PBL e-modules are an effective medium for improving higher-order thinking skills.

The main advantage of e-modules over printed modules is their ability to provide interactive content in the form of text, graphics, animations, and videos that can visualise abstract concepts such as static fluids. Static fluid material often causes misconceptions among students due to its abstract nature, such as the concepts of hydrostatic pressure and buoyancy. With the help of digital visualisation, students find it easier to understand the relationships between concepts while being trained to analyse contextual problems. This supports the statement by Pramestika et al. (2020) that the integration of digital media in PBL learning can improve critical thinking skills and problem-solving skills through more concrete and meaningful learning experiences. In addition, student responses also provided a positive picture of the effectiveness of PBL-based e-modules. The majority of students stated that they strongly agreed that this learning helped them understand the material, increased their motivation, and fostered their interest in learning physics. These responses indicate a match between the preferences of the digital native generation and interactive and flexible learning media. Thus, PBL e-modules not only play a role in improving cognitive learning outcomes but also support students' affective aspects, such as motivation, interest, and positive attitudes toward science. This aligns with the concept of 21st-century education, which emphasises the integration of cognitive, affective, and psychomotor competencies in the learning process (González-Pérez & Ramírez-Montoya, 2022).

Conceptually, the results of this study reinforce the constructivist theoretical framework, which emphasises that knowledge is actively constructed through contextual

learning experiences. PBL provides an authentic context in the form of real-world problems, while e-modules provide digital facilities that enrich the representation of these problems. The combination of both creates a more meaningful learning environment where students not only receive knowledge but also construct understanding through critical, analytical, and reflective thinking processes. Thus, this study contributes to the literature by affirming the importance of integrating problem-based learning models with digital media as an effective strategy in developing 21st-century skills. From a practical perspective, this study has implications for science teachers, particularly physics teachers, to utilise PBL-based e-modules as an alternative learning innovation. Teachers can design more contextual, collaborative, and real-world problem-based learning, thereby focusing not only on mastering concepts but also on developing students' critical thinking skills. However, this study also has limitations. The limited sample size, restricted to a single school, reduces the generalizability of the findings. Additionally, the study focused solely on critical thinking skills without exploring other 21st-century skills such as creativity, collaboration, and communication. Time constraints also posed challenges in assessing the sustainability of learning outcomes.

For further research, it is recommended that the sample be expanded to include schools from various regions and backgrounds to increase external validity. Furthermore, additional research is required to investigate the impact of PBL-based e-modules on other 21st-century skills, such as creativity, communication, and collaboration. Longitudinal studies are also necessary to evaluate the long-term sustainability of the impact of PBL-based e-modules. With this approach, future research findings are expected to provide a more comprehensive understanding of the effectiveness of integrating e-modules and PBL in enhancing the quality of science education in secondary schools.

CONCLUSION

Fundamental Findings: This study proves that the use of Problem-Based Learning (PBL)-based physics e-modules is efficacious in improving students' critical thinking skills. Observations of the implementation of learning showed an average of 91.8 (very good category), while test results showed a significant increase with an average N-Gain of 0.512 (moderate category). This confirms that the integration of PBL with interactive e-modules is a 21st-century learning innovation capable of fostering higher-order thinking skills. **Implication:** These findings have implications for the development of science learning in secondary schools. PBL-based e-modules not only strengthen critical thinking skills but also increase student engagement. Teachers can use them to design more contextual, collaborative, and real-world problem-based learning that is oriented towards analysis and reflection, rather than mere mastery of concepts. **Limitation:** This study has several limitations, including a limited sample size from only one school, which limits generalisability; a focus on critical thinking skills without assessing other 21st-century skills; and a relatively short study period, which does not reflect long-term impacts. **Future Research:** Further research is recommended to expand the sample size,

involve schools from diverse backgrounds, and investigate the impact of PBL-based e-modules on additional skills, such as creativity, collaboration, and communication. Longitudinal studies are also necessary to evaluate the sustainability of the long-term impact of PBL-based e-modules on improving the quality of science learning.

AUTHOR CONTRIBUTIONS

Aulia Betha Novianti was responsible for developing the conceptual framework, drafting the manuscript, and coordinating data collection. **Budi Jatmiko** contributed to the development of the research methodology, provided supervision throughout the study, and validated the findings. **Binar Kurnia Prahani** conducted the literature review. **Riski Ramadani** performed data analysis, and critically revised the manuscript. **Noer Risky Ramadhani** was involved in sourcing relevant references, editing, and enriching the discussion with theoretical insights. All authors have reviewed, revised, and approved the final version of this submission.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest, whether financial, academic, or personal, that could have influenced the content, analysis, or conclusions presented in this study.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies fully with the principles of research and publication ethics. The authors affirm that the work presented is original, carried out with academic integrity, and free from unethical practices, including plagiarism, data fabrication, or duplicate submission.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors confirm that no AI-based technologies or digital writing tools were used in the preparation of this manuscript. All parts of the research, analysis, and writing were conducted solely by the authors.

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