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Problem-based learning enhanced by electronic textbooks: The effects on students' critical thinking abilities

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ABSTRACT

Students' critical thinking skills remain relatively low due to learning activities that are still dominated by teacher-centered approaches and the limited use of interactive learning media. This condition makes students less engaged in analyzing, reasoning, and solving problems in a deep and meaningful way. To overcome this issue, the problem-based learning model assisted by electronic textbooks was applied to promote independent, active, and contextual learning. This study aimed to investigate the impact of the PBL model, supported by electronic textbooks, on students' critical thinking skills. The research employed a quasi-experimental design with a population of 270 students, from which 60 were selected using the cluster random sampling technique. The instrument used was a critical thinking test administered during the pretest and posttest. The data were analyzed using a parametric statistical test, specifically the independent sample t-test. The results showed that the t-value (2.656) was greater than the t-table value (1.671), indicating a significant effect of PBL assisted by electronic textbooks on students' critical thinking skills. Future research is recommended to explore other innovative learning models, integrate additional learning variables, and apply these models to larger and more diverse samples across various educational levels to obtain more comprehensive and generalizable results.

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INTRODUCTION

The digital era has brought about substantial transformations in the domain of education as a consequence of the advancement in the realm of technological innovation and science. These changes include the necessity regarding the twenty-first-century competencies, which prioritize critical, creative, communicative, and collaborative thinking. Critical thinking is one of the most critical intellectual abilities possessed by students must acquire. This capacity serves as the foundation for the rational and reflective evaluation of information, problem-solving, and the decision-making process (Khusna et al., 2024; Pitorini et al., 2024; Yeh et al., 2023). In line with what Yeh et al., (2023) said, critical thinking abilities are essential competencies that students must develop to analyze problems, evaluate information logically, and generate suitable solutions.

In an academic environment, critical thinking skills are the foundation for a meaningful learning process (Nurfathurrahmah, 2018; Widayati & Khofifah, 2022). Students who think critically are not only able to understand the material conceptually but can also relate it to real contexts, formulate in-depth questions, and provide logical and argumentative solutions to a problem (Anggela et al., 2021; Aslan & Aybek, 2024). Another definition of critical thinking is the ability to reason logically, with an emphasis on making judgments regarding truth and determining appropriate courses of action (Leny et al., 2024).

Cognitive learning achievement plays a crucial role in the education system, as the core of learning activities involves developing thinking and memory skills. Critical thinking ability is a fundamental skill that students must possess. Through critical thinking, students can think logically and make appropriate decisions and choices based on the data they obtain (Sudiarti et al., 2023). Therefore, these skills are very important in compiling scientific assignments, class discussions, and completing case studies that require high-level reasoning.

In spite of the fact that abilities in critical thinking abilities are indispensable for students, the field's reality is that numerous students continue to confront a myriad of challenges as they strive to foster these abilities. One of the primary issues is the limited capacity of students to conduct in-depth analyses of information. Many students have a tendency to accept information in its current state without engaging in a process of critical reflection, clarification, or evaluation of the content and sources of the information. Another problem is the weak ability of students to formulate logical and systematic arguments. In discussions or academic writing, students often have difficulty formulating opinions that are supported by strong reasons, relevant data, and coherent reasoning structures. This shows that they are not yet accustomed to using logic and high-level thinking in processing and conveying ideas.

The learning approach, which remains focused on memorization and mastery of material, is another factor contributing to students' low critical thinking abilities. The teacher-centered learning model tends to limit students' active roles in exploring, questioning, and solving problems independently (Fahruddin et al., 2025; Susanto & Hapudin, 2024). As a result, students do not get enough opportunities to hone their critical thinking skills in a challenging and meaningful learning context. These problems indicate the need for transformation in learning strategies in higher education. Learners are required to be positioned as active participants in the learning process, actively engaged in the resolution of real-world issues, able to think reflectively, and supported by technology-based and contextual learning resources.

Learning based on problems constitutes one of the learning models that can enhance students' critical thinking abilities. A learning model that emphasizes the importance of problems as the primary stimulus for learning is known as problem-based learning (Aziz et al., 2016; Misidawati & Sundari, 2021; Nurfathurrahmah, 2018). Through PBL, students are encouraged to learn independently and collaboratively in analyzing real problems, formulating solutions, and reflecting on the thinking process that has been gone through (Chaidam & Poonputta, 2022; Ernawati et al., 2023). In accordance with this, one of the learning methods that is considered effective in the development of critical thinking abilities is problem-based learning. This model emphasizes the use of real-world problems as the foundation for learning (Kloeg, 2023; Orhan, 2024). The presentation of problems in the Problem-Based Learning model employs real-world issues as materials for discussion during the learning process. These problems are solved by students, with the expectation that they will develop the habit of thinking critically when addressing issues based on real-life contexts (Yhonara et al., 2022). Therefore, PBL encourages students to explore knowledge, formulate hypotheses, collect data, and develop solutions to the problems faced.

According to Arends Üce & Ateş (2016), Waalkes et al., (2024) and Zeng & Ruannakarn (2023), the formal structure of the problem-based learning model typically comprises five primary steps, namely: 1) problem orientation, the lecturer presents a complex and authentic contextual problem to stimulate curiosity and build students' curiosity; 2) organize students to learn, students are grouped and directed to understand the problem, identify what is already known and what needs to be known, and plan problem-solving strategies; 3) guide individual and group investigation, students explore information, discuss, experiment, or review literature to collect relevant data; 4)

develop and present the work, students process the results of the investigation, draw conclusions, and present solutions or products to other groups; 5) examination and evaluation of the problem-solving process, as lecturers and students collaboratively reflect on the learning experience, evaluate the resultant solutions, and appraise the efficacy of teamwork and individual contributions.

The success of PBL implementation is highly dependent on the media and learning resources used. In the contemporary digital age, the utilization of electronic textbooks is a strategic decision to facilitate problem-based learning (Muga et al., 2017). Electronic textbooks can serve as an alternative learning resource to replace printed textbooks that do not adequately support student participation. This aligns with Reinita & Putri (2024), who stated that learning resources, such as printed textbooks, have not been effective in enhancing student participation and engagement during the classroom learning process. Electronic textbooks offer succinct and interactive content, enhanced by multimedia links, quizzes, and navigational tools that facilitate independent comprehension and exploration of concepts for students (Aulia et al., 2023; Riwu et al., 2018). In line with what Setyowati & Satrio (2025) said that electronic textbooks as digital learning resources that are designed systematically and pedagogically have great potential in supporting the development of students' critical thinking Moreover, electronic textbooks not only convey information in textual format but also incorporate diverse multimedia components, including images, videos, interactive simulations, and reflective quizzes (Chen et al., 2024; Riwu et al., 2018). These elements encourage students to engage with the material actively, rather than merely absorbing information passively, by evaluating, analyzing, and interpreting it.

Based on a review of relevant studies, the novelty of this research lies in the integration of the Problem-Based Learning model with electronic textbooks as interactive and contextual learning support media. This innovation offers a learning experience that encourages students to solve problems and actively develop their critical thinking skills. Unlike previous studies that generally examined the effectiveness of PBL in conventional settings, this research introduces a digital approach that aligns with current educational demands. Furthermore, the focus on prospective teachers offers a new contribution to efforts aimed at improving the quality of future educators who are critical, creative, and adaptable to developments in educational technology.

The use of electronic textbooks at the student level will increase student independence in learning anytime and anywhere because it is easier to access. This is in line with what experts have said: electronic textbooks can be accessed anytime and anywhere through various digital devices such as laptops, tablets, or smartphones. Students are able to study independently and customize their study time to suit their individual requirements (Jazuli et al., 2018). The integration of electronic textbooks into the structure of problem-based learning is anticipated to enhance cognitive engagement and deliver a more impactful learning environment for students.

According to the description, it is crucial to empirically investigate the effect of the problem-based learning model, which is facilitated by electronic textbooks, on the critical thinking abilities of students. Consequently, the objective of this investigation is to ascertain the extent to which the critical thinking abilities of students are impacted by the problem-based learning model, which is facilitated by electronic textbooks.

This research contributes to the development of learning innovation in higher education by implementing the Problem-Based Learning model, supported by electronic textbooks. The findings of this study are expected to help students think more critically and independently in solving problems. Practically, this research can serve as an example for other educators in designing more engaging learning processes that align with technological advancements. Furthermore, this study enhances the use of electronic textbooks as a learning medium that supports the development of students' higher-order thinking skills.

METHOD

The current research is quantitative by design and applies a quasi-experimental methodology. The objective of quasi-experimental analysis is to ascertain the effect of an implementation. On the subject of the study (Sugiyono, 2010). In this investigation, a pretest-posttest control group design was implemented. The research design is concisely summarized in the following scheme:

Table 1. Control Group Design Schematic for Pretest-Posttest

No.	Group	Pre-test	Treatment	Post-test
1	Experimental Class	O_1	X	O_2
2	Control Class	O_3	-	O_4

In the experimental class, a pretest (O1) was administered prior to the treatment, followed by the experimental treatment (X) in which students used electronic textbooks to participate in problem-based learning. Finally, students were administered a posttest (O2) following the treatment. This information is derived from the aforementioned research design. Furthermore, the control class was administered a pretest (O3) and posttest (O4) without any treatment, utilizing electronic textbooks and PBL learning.

The study population comprised 270 candidates for elementary school teaching in their sixth semester. Samples were randomly selected from the entire population utilizing the cluster random sampling method, resulting in two classes comprising a total of 60 students, with 30 students designated as the experimental group and 30 as the control group. The experimental group receives a learning intervention utilizing a problem-based learning model supplemented by electronic textbooks. The control group is one that does not receive any special treatment, engaging solely in standard learning through direct instruction.

The research instrument employed was an assessment of students' critical thinking abilities. The assessment employed a multiple-choice format comprising 20 questions, each valued at 5 points. The assessment was administered to students on two occasions: a pretest and a posttest. The pretest assessed students' initial abilities, while the posttest evaluated the outcomes the capacity for critical thinking among students following experimental treatment with a problem-based learning model supported by electronic textbooks. The grid for the students' critical thinking ability test can be seen in the following Table 2.

Table 2. Student Critical Thinking Ability Test Grid

No.	Aspect of Critical Thinking Ability	Indicators	Expected Behavior Description	Number of questions
1	Interpretation	a. Identifying problems presented in the learning context. b. Understanding the meaning of relevant concepts, terms, or data.	Students are able to explain the meaning of a concept or problem and recognize important related information.	3
2	Analysis	a. Describing relationships among concepts, ideas, or data. b. Distinguishing between facts and opinions in a statement.	Students are able to identify the structure of arguments, distinguish relevant from irrelevant information, and examine cause-and-effect relationships within a phenomenon.	4
3	Evaluation	a. Assessing the accuracy and relevance of information. b. Evaluating the logic of arguments and evidence used to support conclusions.	Students are able to judge the validity of information, weigh the strength of arguments, and determine the reliability of data sources.	3
4	Inference	a. Making assumptions or predictions based on available evidence and data. b. Formulating alternative solutions to given problems.	Students are able to draw logical conclusions from existing information and develop reasonable possible solutions.	4

No.	Aspect of Critical Thinking Ability	Indicators	Expected Behavior Description	Number of questions
5	Explanation	a. Providing logical reasons to support decisions or answers. b. Presenting the results of analysis or solutions with coherent arguments.	Students are able to explain their reasoning process rationally and support it with strong evidence.	3
6	Conclusion	a. Drawing objective conclusions based on the analyzed data. b. Reassessing conclusions to ensure consistency and accuracy.	Students are able to derive conclusions supported by evidence and sound logic while reflecting on the accuracy of their reasoning.	3

The collected data on the critical thinking abilities of learners were analyzed to reach a conclusion. The data underwent analysis through prerequisite tests, specifically the normality test and the homogeneity test. The criteria for decision-making regarding the normality test were based on significance. According to the definition, A dataset is considered to be normally distributed when the significance value exceeds 0.05. Additionally, hypothesis testing was done using an independent sample t-test. If the t-count is higher than the value shown in the t-table, the null hypothesis should be thrown out according to the rules for conducting hypothesis testing. Majority support for Ha suggests a big difference in the average level of critical thinking between the experimental and control groups. To show that there isn't a significant difference in the average critical thinking skills between the experimental and control groups, the t-count must be less than the t-table threshold. This means that the null hypothesis must be accepted and the alternative hypothesis must be rejected. Researchers used a normalized Gain test to look at how problem-based learning with electronic textbooks affected students' ability to think critically. The normalized Gain value was subsequently classified into three distinct categories: high, medium, and low, as illustrated in Table 3 below.

Table 3. Normalized Gain Score Criteria

No.	Criteria	Normalized Score
1	High	Gain ≥ 0.7
2	Medium	$0.7 >$ Gain ≥ 0.3
3	Low	Gain < 0.3

The Normalized Gain score is classified as high if it exceeds 0.7, medium if it is between 0.3 and 0.7, and low if it is less than 0.3, as shown in the table above. The procedures employed in this investigation are as follows: 1) defining the problem and establishing research objectives; 2) analyzing theories related to problem-based learning, electronic textbooks, and critical thinking skills; and formulating hypotheses. 4) ascertaining the employed research design; 5) identifying the population and sample of the study; 6) developing a tool to assess students' critical thinking abilities; 7) testing the control and experimental groups' critical thinking skills beforehand; 8) treatment group with a combination of problem-based learning and electronic textbooks, and a control group that only received traditional lectures and class discussions; 9) administering a posttest to both groups to evaluate critical thinking skills following the intervention; 10) acquiring and analyzing data through statistical methods; 11) reviewing the data to ascertain whether the two groups (experimental and control) differ significantly; 12) analyzing results in relation to established theories and prior research; 13) briefly outlining the study's conclusions.

RESULTS AND DISCUSSION

Results

The analysis utilized test results, particularly pretest and posttest scores from both the experimental and control classes, to assess the critical thinking abilities of prospective elementary school teachers. The students in the control group received more traditional forms of direct

instruction and discussion, whereas those in the experimental group used an online textbook to supplement a problem-based learning approach. Figure 1 presents the average scores from pre-tests and post-tests for the control and experimental classes.

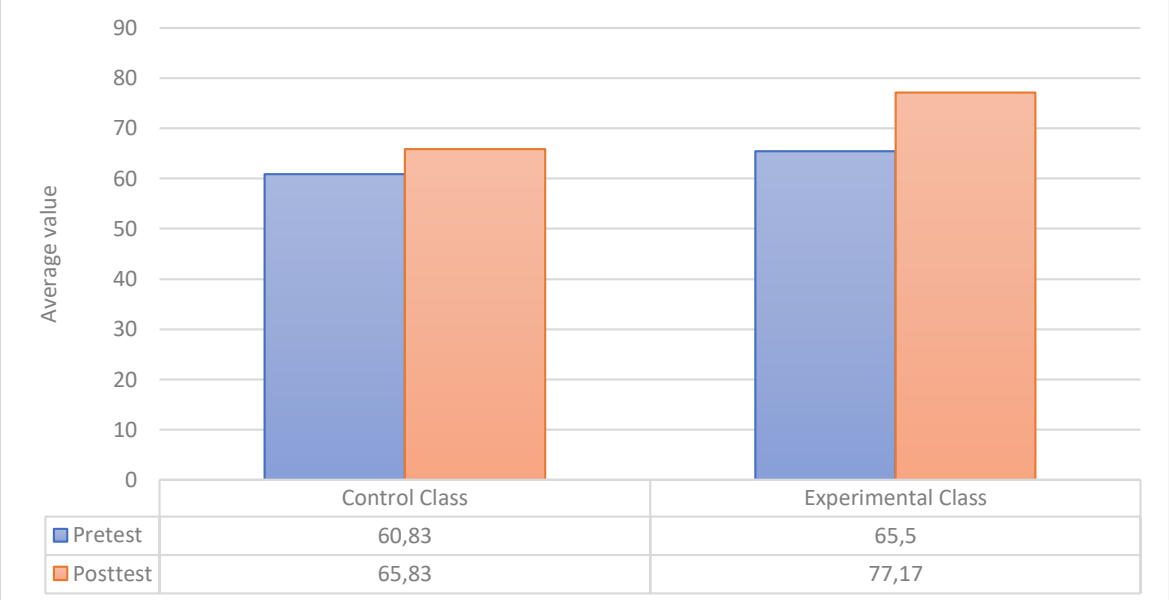

Figure 1. Analysis of Average Pre-test and Post-test Values between Experimental and Control Groups

Figure 1 illustrates that the mean posttest score surpasses the mean pretest score for both the experimental and control groups. The experimental group demonstrated a greater enhancement in students' critical thinking skills compared to the control group.

A hypothesis test was performed to evaluate the impact of the problem-based learning model, implemented with electronic textbooks, on students' critical thinking abilities. The initial step was to administer a prerequisite test that included a homogeneity and normality test. The SPSS software was employed to analyze the normality and homogeneity tests. The data on critical thinking skills of prospective elementary school teachers underwent tests for normality and homogeneity. The outcomes are as follows.

Table 4. Importance of Homogeneity and Normality Assessments

No.	Class/Group	Sig. Normality (Kolmogorov-Smirnov)		Sig. Homogeneity (Levene Statistic)
		Pretest	Postest	
1	Experiments	0.235	0.142	0.891
2	Controls	0.536	0.432	

Table 4 reveals that the pretest exhibits a significance value of 0.235 in the experimental class, whereas the posttest shows a significance value of 0.142. The significance value for both the pre-test and post-test in the experimental class exceeds 0.05, indicating that the data in this class adheres to a normal distribution. The control class shows a pretest significance of 0.536 and a posttest significance of 0.432. The value is greater than 0.05, suggesting that the control class data adheres to a normal distribution. The Levene statistic test produced a significance value of 0.891, which is above the 0.05 threshold. This suggests that both the experimental and control classes demonstrate identical data variance, indicating a homogeneity in the data.

The outcomes of the normality and homogeneity assessments were employed to perform a hypothesis test utilizing parametric statistics and an independent sample t-test, contingent upon meeting the necessary criteria. Data on the critical thinking skills of prospective elementary school teachers were input into SPSS software to perform the independent sample t-test. The results of the t-test for independent samples are presented here.

Table 5. Outcomes of the Independent Samples Test

No.	Variables	t-count value	t-table value	Sig. (2-tailed)
1	Critical Thinking Skills	2.656	1.671	0.010

The t-test calculation with the independent sample test type is represented in the table above. These findings indicate that the t-count value (2.656) exceeds the t-table value (1.671), and the sig. Value: 0.010 < 0.05 (2-tailed). This signifies a disparity in the means observed between the experimental and control groups. The problem-based learning model, augmented by electronic textbooks, substantially affects students' critical thinking abilities. An analysis utilizing the Normalized Gain was performed to ascertain the average enhancement in critical thinking skills among prospective elementary school teachers. The subsequent table illustrates the outcomes of the N-Gain score calculation.

Table 6. Results of the Normalized Gain Test for the Experimental and Control Classes

No.	Group	Normalized Gain Criteria			Normalized Gain Average
		Low	Medium	High	
1	Experiments	13	12	5	0.34
2	Controls	28	2	-	0.13

As shown in Table 6, the majority of the gain values in the experimental class were in the medium gain category and were higher than those in the control class, which were predominantly in the low gain category, according to the results of the normalized Gain test. This implies that the learning process is more effective when facilitated by electronic textbooks and the problem-based learning model than when learning is conducted through regular discussions. This is also evident in the average N-gain score, which indicates that the experimental group is in the medium category with a score of 0.34, whereas the control group has an average N-gain score of 0.13, placing it in the low category.

Discussion

This study's results demonstrate that students' critical thinking skills are markedly enhanced when the problem-based learning model is utilized in conjunction with electronic textbooks. The results of statistical tests indicate that the t-count value (2.656) exceeds the t-table value (1.671). In problem-based learning, students are prompted to examine authentic issues that enhance their critical thinking abilities. According to the pertinent theory, problem-based learning offers a genuine problem context that motivates students to analyze, evaluate, and devise solutions both independently and collaboratively (Treepob et al., 2023; Widayati & Khofifah, 2022). Furthermore, problem-based learning is a learning model that involves students as active participants in the resolution of intricate contextual issues (Pitorini et al., 2025; Simanjuntak et al., 2021). In this process, students not only remember information but are required to identify problems, analyze data, formulate arguments, and evaluate solutions, all of which are indicators of critical thinking skills (Indriani et al., 2023; Rofiq, 2019).

The use of electronic textbooks as supporting media in the PBL model provides an important contribution. Electronic textbooks can be accessed and used flexibly, and the presentation of materials is interactive (Chen et al., 2024). Electronic textbooks can facilitate students to explore information in more depth according to problem-based learning needs. This is in line with the opinion of Aulia et al., (2023) that the digital generation tends to learn with a visual approach and technology that supports speed and flexibility. Relevant opinions also say that electronic textbooks allow the presentation of materials visually, interactively, and easily accessible at any time (Jazuli et al., 2018; Setyowati & Satrio, 2025).

The enhancement of students' critical thinking skills is evidenced by their capacity to identify problems, interpret information, evaluate arguments, and propose logical solutions (Amhar et al., 2022; Suhirman et al., 2021). Students' active involvement in group discussions, searching for additional learning resources, and reflecting on the solutions proposed in each problem scenario are important parts of forming critical thinking patterns (Net et al., 2024). Furthermore, these results are consistent with numerous prior studies that have demonstrated the efficacy of PBL in enhancing

critical thinking and other advanced cognitive abilities (Aziz et al., 2016; Nurfathurrahmah, 2018; Rofiq, 2019; Widayati & Khofifah, 2022). Thinking skills, or activities that help students gain understanding, process information, and conclude, are factors that can support them in learning more effectively. Critical thinking refers to an individual's ability to examine thoughts or concepts more precisely, applying their skills and relevant information (Baharuddin et al., 2022).

The results of this study are also consistent with those of Leny et al., (2024), who found that the use of electronic teaching materials presenting content in an engaging, real-world, and interactive manner helps enhance critical thinking skills. The incorporation of digital media, including electronic textbooks, aligns with the findings of the study by Jazuli et al., (2018), which indicates that technological utilization in education can enhance student engagement and comprehension. The integration of the PBL approach with electronic textbooks fosters a learning environment that promotes active, reflective, and significant learning, thereby enhancing students' critical thinking abilities. In line with the statement of Leny et al., (2024), the teaching materials and learning models used in the learning process play a crucial role in supporting effective learning.

This study has several strengths, including the integration of the Problem-Based Learning model with an interactive electronic textbook, creating an engaging, modern learning experience aligned with the needs of students in the digital era. This approach provides empirical evidence that integrating technology into learning can significantly enhance students' critical thinking skills. Furthermore, the electronic textbook used in this study functions not only as a learning resource but also as a medium that guides students to analyze and solve problems independently. The implications of this research suggest that educators can use it as a reference for designing more engaging and student-centered learning experiences. For students, implementing this model can foster independence and enhance critical thinking skills.

This study has several limitations that should be noted. First, the research was conducted within a single study program with a limited sample size, making it difficult to generalize the findings to broader contexts or other fields of study. Second, the study focused solely on one dependent variable, critical thinking skills, without considering other factors such as motivation, creativity, or collaborative learning, which may also influence learning outcomes. Based on these limitations, it is recommended that future research involve larger and more diverse samples to produce more representative results. Additionally, subsequent studies could include other variables such as learning motivation, creativity, or collaborative skills to provide a more comprehensive understanding of the effectiveness of the Problem-Based Learning model supported by electronic textbooks in improving the quality of higher education learning.

CONCLUSION

Based on the findings, it can be concluded that the implementation of the Problem-Based Learning (PBL) model supported by electronic textbooks has a significant effect on improving students' critical thinking skills. This finding indicates that problem-based learning integrated with interactive digital media can foster a more active, reflective, and meaningful learning experience for students. The novelty of this study lies in the integration of the Problem-Based Learning model with a contextually and interactively designed electronic textbook, offering a new approach to instructional development in the digital era. The results of this study have implications for the future of higher education, promoting a transformation toward more innovative, digital, and student-centered learning. Therefore, these findings can serve as a foundation for lecturers and educational developers to continue integrating technology into teaching practices that nurture students' higher-order thinking skills.

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