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ORIGINAL RESEARCH

Implementation of problem-based learning (PBL) model assisted by electronic science worksheets to improve critical thinking skills of 8th grade students

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Abstract

This study investigates the effectiveness of the Problem-Based Learning (PBL) model, assisted by Electronic Student Worksheet, in enhancing students' critical thinking skills in science education. A pre-experimental One-Group Pretest-Posttest Design was employed, involving 34 eighth-grade students from SMPN 3 Sumber, selected through purposive sampling. A critical thinking test served as the research instrument, and the data were analyzed using descriptive and inferential statistics, including N-gain analysis and paired sample t-tests. The results indicate a moderate improvement in students' critical thinking skills, with an N-gain score of 0.54, and a significant difference ($p < 0.05$) between pretest and posttest scores. Additionally, the effect size was large ($d = 2.30$), indicating a substantial impact of the PBL model. These findings confirm that PBL, assisted by Electronic Student Worksheet, is an effective instructional strategy for enhancing critical thinking skills in science education. This study highlights the potential of technology-enhanced learning to optimize student engagement and promote higher-order thinking skills. Further research is suggested to explore the long-term impact and broader implementation of this approach in diverse educational settings.

Keywords: Critical Thinking, Problem-Based Learning, Electronic Student Worksheet, Science

INTRODUCTION

The 21st-century education emphasizes the integration of skills, knowledge, attitudes, and mastery of information and communication technology. Learning programs prioritizing these aspects are critical for educators in schools, ensuring that students can develop learning and innovation skills, the ability to use technology and media, and cooperation skills (Pratiwi et al., 2019; Ramdani et al., 2019). The characteristics of 21st-century learning include 4C skills: critical thinking, creative and innovative thinking, communication, and collaboration skills, all of which must be mastered by students (Erdoğan, 2019; Rosnaeni, 2021).

Critical thinking skills involve analyzing and evaluating problems or information in a structured way, enabling students to use their knowledge to solve problems effectively (Ennis, 2018; Nurita et al., 2024). Critical thinking skills are supported by rational arguments. A person

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who makes a rational decision about something must believe in its truth (Jamaluddin et al., 2020; Jackson 2021). Critical thinking is essential because it allows learners to analyze, evaluate, and solve complex problems effectively (Ariadila et al., 2023; Kurniawan et al., 2020). The fact is that, until now, formal education has still been more focused on training students to memorize facts, with many educators tending to use questions with low cognitive levels. In addition, the use of technology in learning is still very limited, so students have difficulty in facing and solving problems critically. This condition is certainly not in line with the objectives of science learning, which should be a means to develop critical thinking skills (Arisoy & Aybek, 2021). Research by Rosmalinda et al., (2021) stated that students' critical thinking skills were still low, with a percentage of 58.1%. Sari et al., (2024) found that the measurement of students' critical thinking ability showed that the simple explanation indicator was in the sufficient category, with a percentage value of 51%.

The indicator of building basic skills was in the sufficient category, with a percentage value of 55.6%. The concluding indicator was in the sufficient category with a percentage of 50.8%, and providing further explanation was in the sufficient category with a percentage of 57.1%. This is also reinforced by the research of Sara et al., (2020), which found that 92% of students had critical thinking skills in a very poor category.

Critical thinking skills are very important in the learning process because they allow students to more easily understand and master the material being taught, and provide the ability to solve problems effectively (Asokawati et al., 2023). Critical thinking helps individuals to analyze information more deeply, make better decisions, and solve problems creatively. In addition, this skill is also essential for learners' education, especially in facing increasingly complex challenges at higher education levels, such as secondary school (Malik et al., 2020). With critical thinking skills, learners can develop the ability to think independently and face more complicated problems in the future (Arifah et al., 2021; Sari et al., 2024). For this reason, a learning model is needed that can train students' critical thinking skills, but still focus on material concepts, one of which is the problem-based learning (PBL) learning model (Asokawati et al., 2023; Setyawan & Koeswanti, 2021).

PBL integrates real-life problems, which help learners develop problem-solving skills. This model stimulates learners to propose and solve problems, so they not only acquire knowledge but also improve critical thinking skills during the learning process (Vikayatri, 2022). In addition, PBL encourages students to think scientifically and form a mindset that is relevant to 21st-century learning needs. With this approach, learning becomes more student-centered, which allows maximum development of their abilities (Andini et al., 2022).

This learning model involves students in problem-solving efforts through several stages of the scientific method, so students are expected to learn knowledge relevant to the problem while developing problem-solving skills. PBL-based learning uses real situations as a context for students to practice critical thinking and hone problem-solving skills (Asmara & Septiana, 2024; Qomariyah et al., 2019). In addition to using learning models, educators must be creative and innovative in designing effective and engaging learning experiences by using teaching materials and other media that align with curriculum and technological developments in the learning process (Marta, 2019). One of the steps that can be taken is to provide learning media in the form of electronic E-Worksheet based on problem-based learning.

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Electronic E-Worksheet is a guide to work steps in digital form that can be accessed via Android devices, notebooks, or computers, making it easier for students to achieve learning goals (Hamzah et al., 2022; Nurzaman et al., 2021). E-Worksheets can be prepared and adjusted to the conditions and situations of learning activities. Teachers must also be able to provide clear instructions so that the basic competencies designed can be achieved (Nurhayati et al., 2024). The use of E-Worksheets makes the learning process more efficient and engaging for both teachers and students because students can easily access material and understand problems through smartphones. In addition, the use of E-Worksheets encourages students to be more active in finding information related to the learning delivered by the teacher (Sinaga et al., 2024).

This electronic E-Worksheet can be accessed through the Live Worksheet application, which is integrated with real problems by following the steps of the Problem-Based Learning (PBL) model (Islamiati et al, 2024; Samsudin & Raharjo, 2023). These steps help create a structured learning flow with the provision of electronic E-Worksheets, from an initial understanding of the problem to reflection, which makes it easier for teachers to guide the learning process and ensure students are active at every stage (Kusno, & Setyaningsih, 2021; Yaacob et al, 2021; Kim, 2024). This is in line with the research conducted by Qatrunada et al., (2023) which shows that E-Worksheets based on Problem-Based Learning improve students' critical thinking skills.

In addition, the problem-based learning model is highly influential on students' critical thinking, and students also have a different experience in the learning process because they are required to solve problems during learning (Munir et al., 2022; Setyawan & Koeswanti, 2021). Based on this background, learning with PBL, supported by electronic E-Worksheets, is expected to enhance students' critical thinking skills. Therefore, it is necessary to conduct a study titled "Implementation of Problem-Based Learning Model Assisted by Science Electronic E-Worksheets to Improve Critical Thinking Skills of Grade VIII Students.

METHODS

The type of research used is experimental research with a One-Group-Pretest-Posttest Design research design (Creswell & Creswell, 2017). The population of this study were all students in grade VIII of SMPN 3 Sumber in the 2024/2025 academic year. The sampling technique in this study used purposive sampling. The sample used was 1 class, namely class VIII B with a total of 34 students. The tests used were pretest and posttest. In this study, the test used to obtain data on student’s critical thinking skills was a written test in the form of multiple choice questions of 15 questions which contained indicators of explaining simple explanations, building basic skills, concluding, providing further explanations and organizing strategies and tactics (Mukarromah et al, 2024; Torkzadeh, 2021). Data obtained through pretest and posttest, then the data obtained will be analyzed using descriptive and inferential statistical analysis with the help of the SPSS 22.0 for windows applications.

Descriptive statistical analysis was used to describe the critical thinking skills scores of students who were taught using the problem-based learning (PBL) model assisted by IPA electronic LKPD. The N-Gain results were then classified according to the following criteria.

Table 1. N-Gain Score Criteria

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Value Interval	Category
N-gain ≥ 1.0	High
0.3 ≤ N-gain < 0.7	Medium
N-gain < 0.3	Low

Source: (Lestari et al., 2021)

The inferential analysis consists of normality tests and hypothesis testing. The normality test is used to determine the condition of the data - whether the data is normally distributed or not. Normally distributed data conditions are a requirement for testing hypotheses using statistics. The normality test used in this study is the Shapiro-Wilk test. The Shapiro-Wilk test was carried out with the help of the SPSS version 22.0 program. Furthermore, the hypothesis testing used in this study is the Paired Sample T Test test with the help of SPSS 22.0. The Paired Sample T Test test aims to determine whether there is a difference in the average of two samples (two groups) that are paired or related. The basis for making decisions on hypothesis testing is if the Sig value. (2-tailed) <0.05 then H0 is rejected and H1 is accepted and vice versa if the Sig value. (2-tailed) < 0.05 then H0 is accepted and H1 is rejected and the effect size analysis is used to find the magnitude of the effect caused by the application of the problem-based learning (PBL) learning model assisted by IPA electronic LKPD to improve students' critical thinking skills. The effect size results are then classified according to the following criteria.

Table 2. Effect Size Classification

Value Interval	Category
0 < *d* < 0.2	Small
0.2 ≤ *d* < 0.5	Medium
0.5 ≤ *d* < 0.8	Great
d > 0.8	Very Large

RESULT AND DISCUSSION

The results of the descriptive statistical analysis provide an overview of the critical thinking skills of the students during the pretest and posttest. The following table presents the descriptive statistics for both the pretest and posttest, including the minimum, maximum, mean, and standard deviation values.

Descriptive Statistical Analysis

The results of the descriptive statistical analysis provide an overview of the critical thinking skills of the students during the pretest and posttest. The following table presents the descriptive statistics for both the pretest and posttest, including the minimum, maximum, mean, and standard deviation values.

Table 3. Descriptive Statistical Analysis

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	34	2	10	6.29	2.125
Posttest	34	8	14	10.64	1.612

The results of the descriptive statistical analysis provide an overview of the critical thinking skills of the experimental class of SMPN 3 Sumber before and after being taught using the Problem-Based Learning (PBL) learning model assisted by electronic E-Worksheets. The

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results of the study were then analyzed descriptively to determine the maximum score, minimum score, average score, and standard deviation. Based on the data obtained, the following table presents the results of the descriptive analysis of critical thinking skills scores. Based on Table 3, shows that the total number of samples is 34 students. The pretest results of students' critical thinking skills in the research sample obtained an average score of 6.29 students with a standard deviation of 2.125. The highest score obtained was 10 and the lowest score was 2 with an ideal score of 15. While the posttest results obtained an average score of 10.64 with a standard deviation of 1.612. The highest score obtained was 14 and the lowest score was 8 with an ideal score of 15. The data from the N-Gain analysis of critical thinking skills can be seen in Table 4.

Table 4. Results of N-Gain Analysis of Student Critical Thinking Skills Data

Class	N	N-Gain	Description
Experimental Class	34	0,54	Medium
Control Class	34	0,65	High

Based on Table 4, shows that the average N-Gain of students' science literacy skills is in the medium category with an average N-Gain of 0.54. This means that students critical thinking skills score increased after treatment. The results of the N-Gain analysis for each critical thinking skills indicator can be seen in Table 5.

Table 5. Results of N-Gain Analysis of Each Indicator of Students Critical Thinking Skills

No	Indicators	Items	N-Gain	Category
1	Explaining Simple Explanations	4	0,42	Medium
2	Building Basic Skills	3	0,38	Medium
3	Summarizing	2	0,34	Medium
4	Providing Advanced Explanations	3	0,32	Medium
5	Organizing Strategy and Tactics	2	0,26	Low

Based on Table 5, it shows that there is an increase in critical thinking skills in each indicator, the highest increase in indicators is the indicator of explaining simple explanations with an N-Gain of 0.42 in the medium category and the lowest increase is the indicator of organizing strategies and tactics with an N-Gain of 0.26 in the low category.

Inferential Statistical Analysis

Normality Test

The normality test was carried out using the Shapiro-Wilk test with the provision of a significance level> 0.05 for normally distributed data using the SPSS 22.0 for Windows program.

Table 6. Shapiro-Wilk Pretest Posttest Normality Test Analysis Results with SPSS 22.0

	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest	.954	34	.167
Posttest	.939	34	.159

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Based on Table 6, the Pretest significance value (Sig.) is 0.167 and the Posttest significance value (Sig) is 0.157 The Pretest and Posttest significance values obtained through the Shapiro-Wilk test are greater than 0.05 so it can be concluded that the data is normally distributed.

Hypothesis Test

The hypothesis test used is Paired Sample T-Test. This data analysis was calculated with the help of SPSS version 22.0 for Windows. The criteria for testing the hypothesis of the Paired Sample T-Test Test is to compare the sig. (2-tailed) value on the Paired Sample T-Test with the value $\alpha = 0.05$. With the test criteria if the Sig value. (2-tailed) < 0.05 then H0 is rejected and H1 is accepted. Meanwhile, if the value of Sig. (2-tailed) > 0.05 then H0 is accepted and H1 is rejected. The hypothesis test with Paired Sample T-Test through the SPSS 22.0 application is presented in Table 7 below.

Table 7. Analysis Results of Paired Sample T-Test Hypothesis Test with SPSS 22.0

		Paired Differences		t	df	Sig. (2- tailed)
		Mean	Std. Deviation			
Pair 1	Pretes Postets	-4.35294	2.15860	-11.758	33	0.000

Based on Table 7, shows the sig. (2-tailed) value < 0.05 or 0.00 <0.05. This means that H0 is rejected and H1 is accepted, so it can be concluded that there is a significant difference in the average score of critical thinking skills of SMPN 3 Sumber students before and after the implementation of the problem-based learning (PBL) learning model assisted by electronic LKPD.

Effect Size

Effect Size aims to determine the effect size of mini solar panel props with guided inquiry models in the learning process. The effect size test measurement refers to the Cohen effect size test. The results of the analysis are as follows:

Table 8. Effect Size Results.

Class	N	Effect Size	Description
Class Experiment	31	2.30	Very Large
Control Class	31	1.10	Medium

Based on Table 8, the effect size is 2.30 in the experimental class is categorized as very large, while the control class shows an effect size of 1.10, which is considered medium. This analysis shows that the implementation of the Problem-Based Learning (PBL) model, assisted by electronic Worksheets, has a very large effect on the critical thinking skills of junior high school students, compared to the control group.

DISCUSSION

This research was conducted at SMPN 3 Sumber. This research was conducted by giving a pretest before entering the beginning of learning and giving a posttest after the final learning meeting. The research conducted was intended for how much the improvement of critical thinking skills of SMPN 3 Sumber students after the implementation of the problem-based

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learning (PBL) learning model assisted by electronic Worksheets, whether there was a difference in the average score of significant improvement in critical thinking skills of SMPN 3 Sumber students before and after the implementation of the problem-based learning (PBL) learning model assisted by electronic Worksheets and how much the effect size of the problem-based learning (PBL) learning model assisted by electronic Worksheets to improve critical thinking skills of SMPN 3 Sumber students. The sample in this study consisted of class VIII B with a total of 34 students. This study uses 5 indicators of students' critical thinking skills.

The results of different. This can be seen from the increase in the pretest average score of 6.29 to 10.64 on the posttest. This shows that learning by implementing the Problem Based Learning Model Assisted by Electronic Worksheets in junior high school science learning can improve students' critical thinking skills.

The increase in the average N-Gain score of critical thinking skills was in the moderate category with an N-Gain of 0.54. The results of the N-Gain average score indicate that students at SMPN 3 Sumber have good critical thinking skills, as evidenced by student's scores in the moderate category. This shows the Problem-Based Learning Model assisted by Electronic Worksheets. This is in line with research conducted by Sinaga et al., (2024), stating that the PBL model assisted by E- Worksheets student's critical thinking skills. According to Istni et al., (2022), the use of the PBL model assisted by Worksheets is proven to have an influence on critical thinking skills, because the process emphasizes the development of student's critical thinking skills in solving problems. In this learning, students are trained to actively think, communicate, search and process data, and finally draw conclusions. Learning activities are directed to solve problems by applying their thinking.

PBL learning involves the presentation of a problem that will encourage investigation, questioning and dialog. The problem studied is a contextual problem faced by students in everyday life. Problem solving in this learning requires the application of various concepts and principles that are simultaneously discussed and covered in learning (Rosita, 2022). In addition, students will learn to apply important concepts while developing critical thinking and problem solving skills and creating meaningful learning experiences. The stages of PBL in this study include: 1) orienting students to the problem, 2) organizing students to learn, 3) guiding group investigations, 4) developing and presenting work and 5) analyzing and evaluating the problem-solving process. The implementation of this model is combined with electronic Worksheets which has been adjusted to direct students to think critically. The PBL model assisted by E-Worksheets can encourage the development of high-level thinking skills and increase student learning independence because E- Worksheets facilitates students to take an active role in the learning process (Sinaga et al., 2024). PBL with electronic Worksheets involves student inquiry in problem-solving. Worksheets guides students in terms of investigation to solve problems. According to Istni et al., (2022), the use of electronic Worksheets can stimulate student activeness so that students are challenged in solving problems. The use of electronic Worksheets also received good responses from students because students looked excited during the learning process.

Based on the results of the N-Gain analysis of critical thinking skills indicators presented in Table 4, which consists of five indicators. In the first indicator, namely explaining simple explanations that are in the medium category with an N-Gain of 0.42. In this indicator, students analyze sub-indicators of critical thinking skills in the form of constructing students' ability to

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be able to focus on questions and analyze arguments from a problem. In this indicator, students are expected to be able to formulate problems that require explanation that are related to the syntax of the PBL model, namely orienting students to problems on electronic Worksheets. Qatrunada et al., (2023), revealed that students develop critical thinking skills gradually through trained habits, such as formulating problems and providing answers that require explanation. These skills can be honed by getting students used to working on problem-solving model questions, which in turn can increase the understanding possessed by students (Astuti et al., 2020).

The second indicator improvement is building basic skills which is in the medium category with an N-Gain of 0.38. In this indicator, students are analyzed for critical thinking skills, such as assessing the credibility of a source and researching and evaluating research results. It is expected that students can carry out experiments according to procedures and solve problems by using relevant information or prior knowledge that comes from reliable sources. This is in line with PBL syntax because students begin to understand the problem and obtain basic information needed for problem-solving. This skill allows students to test the truth of statements received, as well as convey rational thoughts, observations, and opinions (Lismaya, 2019).

The third indicator improvement is concluding which is in the moderate category with an N-Gain of 0.34. The concluding indicator consists of sub-indicators of inducing and assessing induction and determining conclusions. In this indicator, students are expected to be able to observe and relate the problems given so that they can conclude using the basis of the thinking process to analyze arguments, and develop insight into the meaning and interpretation that exists, to produce conclusions that are reliable, concise, and convincing. This is related to the PBL syntax which involves analysis and evaluation in the problem-solving process (Hidayati et al., 2021; Qatrunada et al., 2023)

The fourth indicator improvement is providing further explanations which are in the moderate category with an N-Gain of 0.32. In this indicator, students are expected to be able to understand and identify terms that are not understood from the problem, and formulate problems using their own words clearly and convincingly. This is related to PBL syntax, students develop further critical thinking by providing further explanations that involve the development and presentation of work results. The skill of providing further explanations is constructing students' abilities to be able to define terms assess the results of the definition and identify assumptions (Sari et al., 2024)

The fifth indicator improvement is managing strategies and tactics which is in the low category with an N-Gain of 0.26. In this indicator, students analyze critical thinking skills in the form of the ability to decide on the right action and interact with others. In the learning process with PBL, students are invited to conclude and analyze the entire problem-solving process that has been carried out. They also evaluate the effectiveness of the strategies used. Skills such as assessing strategies and tactics and providing further explanations are needed for reflection and evaluation of the results of the investigation. The improvement of this indicator which has the lowest n-gain, is due to the inability of students to use reasoning power to analyze, evaluate, and review based on the knowledge they have to find the right solution in designing strategies and tactics. This inability arises due to a lack of insight and difficulty in understanding the problems in the questions (Qatrunada et al., 2023; Sari et al., 2024).

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Strengthening the results of the descriptive analysis, inferential analysis was carried out through normality tests and hypothesis tests. The normality test aims to test the distribution of score data, and if the data is normally distributed, hypothesis testing can be continued. Based on the results of the normality test using Shapiro-Wilk, the significance value (Sig.) of the pretest-posttest shows that the data is normally distributed, so that hypothesis testing can be done using the t-test. Inferential analysis of scientific literacy skills was carried out through hypothesis testing using the Paired Sample T-Test. The results of this test show a significance value of 0.000 (<0.05) which means that there is a significant difference in the average score of students' critical thinking skills before and after learning with the Problem-Based Learning Model Assisted by electronic Worksheets. This is in line with the research of Sinaga et al (2024), which states that the problem-based learning model assisted by electronic Worksheets is applied not only as relevant but also effectively in improving the quality of science learning, especially critical thinking. The PBL model assisted by electronic Worksheets stimulates students to be more active in discussing and arguing so that they are able to develop their critical thinking skills. The results of the effect size analysis show that the effect size value of critical thinking skills is 2.30 with a very large category. So it can be concluded that implementing of the problem-based learning (PBL) learning model assisted by electronic Worksheets has a very large effect on the critical thinking skills of junior high school students

CONCLUSION

Based on the data analysis, it can be concluded that the increase in critical thinking skills of students at SMPN 3 Sumber, with the implementation of the problem-based learning (PBL) model assisted by electronic worksheets, shows a moderate effect with a score of 0.54. There is a difference in the average score of the increase in critical thinking skills of students at SMPN 3 Sumber before and after the implementation of the PBL learning model assisted by electronic worksheets. The Effect Size analysis of students after the implementation of the PBL learning model assisted by electronic worksheets in the learning process shows a very large effect size of 2.30.

The results show that the implementation of the PBL learning model assisted by electronic worksheets can improve students' critical thinking. The suggestions from this research focus on strengthening the indicators that are still low, such as setting strategies and tactics for implementation time. Further research is needed to explore the use of electronic worksheets, which utilize similar devices and instruments, with the goal of achieving better results. It is hoped that future researchers will also examine other variables, such as problem-solving, scientific literacy, and the use of other learning models.

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