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The Use of Project-Based Science Learning Model to Improve Critical Thinking Skills of Elementary School Students

Penggunaan Model Pembelajaran IPA Berbasis Proyek dalam Meningkatkan Keterampilan Berpikir Kritis Siswa SD

Echa Rizki Melani[1)*], Retno Triwoelandari[2)], Ade Irma Imamah[3)]
1,2,3) Ibn Khaldun University of Bogor

Abstract

Critical thinking skills are essential 21st-century competencies that should be nurtured from an early age. In elementary science education, approaches that actively engage students in thinking and problem-solving processes are highly needed. One learning model considered effective for this purpose is project-based learning. This study aims to examine the effectiveness of this model in enhancing students' critical thinking skills. The research employed a mixed-methods experimental design with a pretest-posttest control group. The subjects were fifth-grade students at an Islamic elementary school (SDIT) in Bogor Regency. The instruments included descriptive questions to measure critical thinking abilities and interview and observation guides to explore student and teacher responses. Quantitative analysis revealed a significant difference between the experimental and control groups, with average posttest scores of 82.5 and 74.3, respectively ($p < 0.05$). Qualitative data showed increased student enthusiasm, active discussions, and a more enjoyable learning process. This study contributes to the development of more meaningful and contextual science teaching strategies, highlighting significant differences compared to previous studies that have not deeply emphasized critical thinking skill development.
Keywords: Project-based Learning, Critical Thinking Skills, Science, Elementary School

Abstrak

Kemampuan berpikir kritis merupakan keterampilan penting di abad ke-21 yang perlu dikembangkan sejak dini. Dalam pembelajaran IPA di tingkat sekolah dasar, pendekatan yang melibatkan siswa secara aktif dalam proses berpikir dan pemecahan masalah sangat dibutuhkan. Salah satu model pembelajaran yang dianggap efektif untuk tujuan ini adalah pembelajaran berbasis proyek. Penelitian ini bertujuan untuk mengkaji efektivitas model tersebut dalam meningkatkan kemampuan berpikir kritis siswa. Metode yang digunakan adalah eksperimen dengan pendekatan campuran (mixed methods) menggunakan desain pretest-posttest dengan kelompok kontrol. Subjek penelitian adalah siswa kelas V di salah satu SDIT di Kabupaten Bogor. Instrumen yang digunakan meliputi soal uraian untuk mengukur kemampuan berpikir kritis serta panduan wawancara dan observasi untuk menggali respons siswa dan guru. Hasil analisis kuantitatif menunjukkan adanya perbedaan signifikan antara kelas eksperimen dan kelas kontrol, dengan nilai rata-rata posttest masing-masing 82,5 dan 74,3 ($p < 0,05$). Data kualitatif memperlihatkan bahwa siswa menjadi lebih antusias, aktif berdiskusi, dan merasakan proses pembelajaran yang lebih menyenangkan. Penelitian ini memberikan kontribusi dalam pengembangan strategi pembelajaran IPA yang lebih bermakna dan kontekstual, serta menonjolkan perbedaan signifikan dibandingkan penelitian sebelumnya yang belum banyak menitikberatkan pada pengembangan keterampilan berpikir kritis secara mendalam.
***Kata Kunci**: Pembelajaran Berbasis Proyek, Kemampuan Berpikir Kritis, IPA, Sekolah Dasar*

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*Corresponding author:
E-mail: echarizkimelani853@gmail.com

INTRODUCTION

Education is a process that is consciously designed and structured to build a conducive learning environment and process, so that it can support the development of students' abilities. (B. Suryosubroto, 2015) To address global challenges and the swift advancement of science and technology, 21st-century education focuses on student-centered learning and aims to cultivate essential skills such as critical thinking, communication, collaboration, and creativity.(Chusna et al., 2024;Mahrunnisya, 2023) These competencies are essential for students to succeed in today's world. Among them, critical thinking stands out as a core skill that learners must develop, especially within the context of 21st-century education, including science learning.. (Regi et al., 2025;Wahyuni & Rosana, 2025).

Critical thinking skills are a vital foundation for developing 21st-century competencies among young learners, especially when applied to solving problems.(Ngatminiati et al., 2024). This skill should be nurtured and strengthened from an early stage to help children grow into capable individuals who are ready to overcome diverse challenges.(Hujairah, 2021;Gushmanida et al., 2025) Critical thinking is a multifaceted process that includes the logical interpretation, application, synthesis, problem-solving, justification, and assessment of information. (Setiana et al., 2025). This cognitive process takes place in the brain through interpreting and evaluating received information, which is then organized into material for rational consideration.(Hasanah et al., 2024). Despite this, various studies indicate that Indonesian students generally have underdeveloped critical thinking abilities, highlighting the need for enhancement.(Fauziyyah et al., 2024) This happens because students often depend heavily on online platforms like Google to find answers, rather than doing their own thorough research and critical examination.(Dewi & Widodo, 2024) Developing critical thinking skills is a key part of education to enable students to maximize their potential when dealing with the challenges of the 21st century.

Similar conditions were observed in the fifth grade class at SDIT Al-Madinah, where the learning process is still mainly dominated by lectures and textbooks as the primary source. Students rarely get the chance to actively participate, and often, by the time they want to ask questions, the lesson time has already ended. The limited opportunities for students to express their ideas and develop an open mindset result in low critical thinking skills. This approach is less effective, especially in science learning, which ideally should focus on exploratory, interactive, and real-life experience-based activities.

Natural Sciences as a subject offers students the chance to gain hands-on experience since it includes three key elements: processes, attitudes, and outcomes. To incorporate all these elements effectively in the learning process, teachers need to allow students the freedom to actively select, explore, and solve problems on their own. This method demonstrates that teachers encourage the development of students' critical and creative thinking, leading to meaningful and deeper learning experiences (Susilowati, 2017). Science is the study that explains or describes the natural world. It involves a process or investigative method that encompasses ways of thinking, attitudes, and systematic scientific procedures to produce scientific knowledge, such as observing, measuring, creating and testing hypotheses, gathering data, experimenting, and making predictions (Rorimpandey & Modeong, 2024). Science education supports students in building scientific reasoning and equips them with problem-solving skills to face daily challenges with a constructive mindset and attitude. (Basak Erkacmaz et al., 2023). Project-Based Learning (PjBL) is a popular and proven teaching method that effectively enhances students' skills (Subekti et al., 2025). Using this approach, PjBL seeks to create a more engaging and meaningful learning experience while promoting the growth of essential skills needed in the 21st century. (Ulaini & Fitrisia, 2025). According to the Buck Institute for Education (1999), PjBL is a learning model focused on students, where they engage in problem-solving and meaningful activities, allowing them to work independently and create tangible outcomes.(Tupan et al., 2024). In the PjBL model, students not only grasp the subject matter but also build personal skills that help them function effectively in society, including communication and presentation, organization and time management, research and inquiry, self-evaluation and reflection, teamwork and leadership, as well as critical thinking.(Ndiung & Menggo, 2024). Project-Based Learning also motivates students to learn by engaging them in real-world projects that involve problem-solving, exploration, and teamwork.(Gunawan et al., 2024). Therefore, PjBL is an effective approach to enhance students' creative thinking and strengthen their 21st-century skills.

Earlier studies have shown that project-based learning can enhance students' critical thinking abilities, as it encourages them to actively seek solutions to problems.(Herlina et al., 2022). Another study revealed that the Project-Based Learning (PjBL) approach significantly impacts students' critical thinking abilities, particularly in science subjects. This positive effect is evident as the PjBL model offers structured and organized project tasks that help students actively develop their critical thinking skills.. (Khaerunissa et al., 2024). Other research

indicates that PjBL can greatly enhance students' critical thinking skills, as one of its main strengths is boosting their problem-solving capabilities. At the same time, critical thinking is recognized as a focused and organized process that can be used in various cognitive tasks, including problem-solving and decision-making. (Wahid, 2024).

Although many previous studies have demonstrated that the project-based learning (PjBL) model effectively enhances students' critical thinking skills, most have relied on either quantitative or qualitative methods alone, which limits a full understanding of how these skills develop during learning. Additionally, there is still a lack of research applying the PjBL model in elementary science education using a mixed-methods approach (sequential explanatory) that combines both quantitative and qualitative data for a more thorough insight. Critical thinking skills are essential competencies for tackling the complex information and problems of the 21st century. However, these skills have not been a primary focus in school learning processes. Therefore, fostering critical thinking from an early age is crucial to help students become accustomed to analyzing, evaluating, and solving problems independently. One effective way to develop these abilities is through the PjBL model, which encourages students to actively engage with and solve real-world problems. In science education, this method is particularly relevant because it allows students to directly observe natural phenomena, engage in discussions, and draw conclusions based on their observations, enabling critical thinking skills to grow naturally and meaningfully.

Critical thinking skills are often overlooked in the learning process, even though they are essential for tackling the complex information and challenges of the 21st century. These skills need to be developed early so students become familiar with analyzing, evaluating, and solving problems independently. An effective way to build critical thinking is through project-based learning, which encourages students to actively explore and solve real-world problems. In science education, this method is particularly relevant because it involves students directly observing natural phenomena, participating in discussions, and drawing conclusions based on their observations. This enables critical thinking to develop naturally and meaningfully.

Given these issues, the researcher is interested in conducting a study at SDIT Al-Madinah, an elementary school known for actively applying various learning approaches. However, traditional, teacher-centered methods are still commonly used in practice. This leads to students being less engaged in the learning process, particularly in science

subjects, which ideally should promote critical thinking through exploration and problem-solving activities. Therefore, the researcher considers it important to implement the project-based learning (PBL) model to enhance students' critical thinking skills at this school. Furthermore, SDIT Al-Madinah has shown positive support for the research, making it an ideal setting to examine the effectiveness of this learning model in elementary science education.

RESEARCH METHODS

This study employs a Mixed Method approach using a Sequential Explanatory design, which sequentially integrates quantitative and qualitative data. This method was chosen to provide a more comprehensive and detailed understanding of how effective project-based learning is in enhancing students' critical thinking skills. The sampling process used purposive sampling by selecting two classes with similar characteristics from the population of fifth-grade students at SDIT Al-Madinah. These similarities include students' ages within the same range, comparable socio-economic status, similar past academic performance, class size, and alike facilities and learning environments. Class VF (Class F - Fifth Grade) was assigned as the experimental group receiving project-based learning, while class VG (Class G - Fifth Grade) served as the control group with traditional learning methods. This class selection aims to reduce differences between groups, ensuring that the results are more valid and that any observed differences are truly due to the applied learning treatments.

Quantitative data were gathered using a critical thinking skills test that included both multiple-choice and descriptive questions. This test was designed based on critical thinking indicators such as analyzing information, evaluating arguments, solving problems, and synthesizing data. It was administered as both a pretest and posttest to assess the students' critical thinking development before and after the intervention. Meanwhile, qualitative data were collected through interviews and observations. Interviews aimed to understand students' experiences and reactions to the project-based learning implementation and the critical thinking processes during lessons. Observations used checklists focusing on critical thinking behaviors like student interaction, problem-solving, and collaboration.

The instruments used in this study underwent a validation process by both content and instrument experts to ensure the questions were appropriate and at the right difficulty level. The reliability of the critical thinking skills test was evaluated using Cronbach's Alpha, with a minimum acceptable value set at 0.7. The interview guide and observation checklist were

validated through discussions with the supervisor and a small-scale trial to confirm their ability to gather relevant data. To enhance the reliability of the qualitative data, techniques such as source and method triangulation were applied, along with member checking by verifying interview results with the participants. These steps were taken to ensure the accuracy and trustworthiness of the research findings.

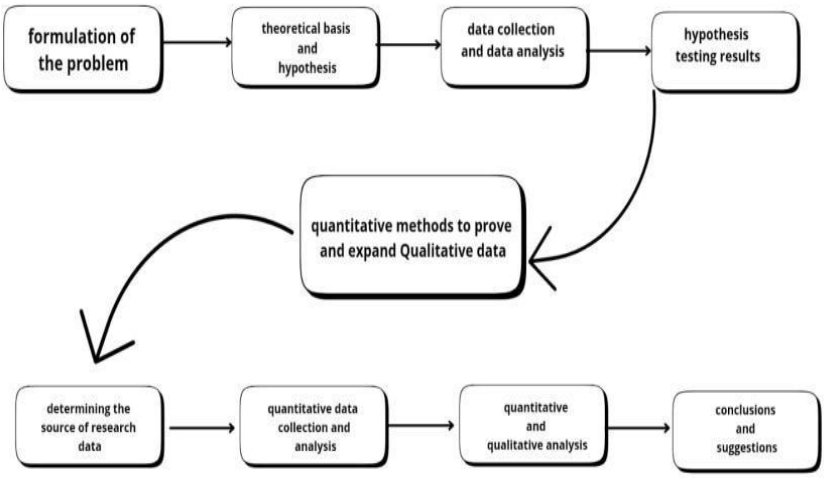

Figure 1. Research Steps

The instrument used in this study consisted of descriptive questions aimed at assessing students' critical thinking skills based on five indicators from (Fatmarani & Setianingsih, 2022) giving basic explanations, developing foundational skills, drawing conclusions, offering further explanations, and identifying strategies and tactics. These questions were systematically arranged and validated by experts to ensure alignment with the targeted indicators. Validity was confirmed through expert review and trial testing, while reliability was assessed using the Cronbach's Alpha coefficient, indicating strong internal consistency. Additionally, qualitative instruments such as observation and interview guides were employed to complement the quantitative data. Quantitative data collection involved administering pretests and posttests using the descriptive questions. The data analysis included descriptive statistics to provide an overview of student learning outcomes, as well as inferential tests like normality testing (e.g. Kolmogorov-Smirnov), homogeneity testing (Levene's Test), and independent t-tests to identify significant differences between the experimental and control groups.

Observation and interview protocols were carefully developed and then reviewed by experts to ensure they effectively collected data aligned with the research objectives. An initial trial was conducted to assess the clarity, completeness, and usefulness of the

protocols in gathering information about the learning process and the development of students' critical thinking skills. The qualitative data from interviews and observations were analyzed descriptively through data reduction, data presentation, and drawing conclusions. To enhance the validity and trustworthiness of the qualitative data, interview findings were supported and corroborated by direct observation data collected during the learning process. This method helps confirm that the interview information accurately reflects the actual conditions in the field. By providing a detailed explanation of the instruments, analysis methods, and validation of qualitative data through observational support, this study aims to be more transparent and facilitate easier understanding, evaluation, and replication by future researchers.

RESULTS AND DISCUSSION

The data for this study were collected from science learning outcomes before and after applying the project-based learning (PjBL) model in both the experimental and control classes. Both classes took a pretest and a posttest. Students' critical thinking skills were evaluated using observations and the posttest, focusing on indicators such as basic explanations, foundational skills, drawing conclusions, and providing further explanations. The results from both observations and posttests were combined to assess the impact of PjBL on enhancing students' critical thinking abilities.

To determine the effect of the PjBL model, a comparison of the pretest and posttest results was carried out on the experimental and control classes. The pretest measures students' initial abilities, while the posttest measures achievement after learning. The following graph presents a comparison of the scores of the two classes as a basis for analyzing the effectiveness of PjBL implementation:

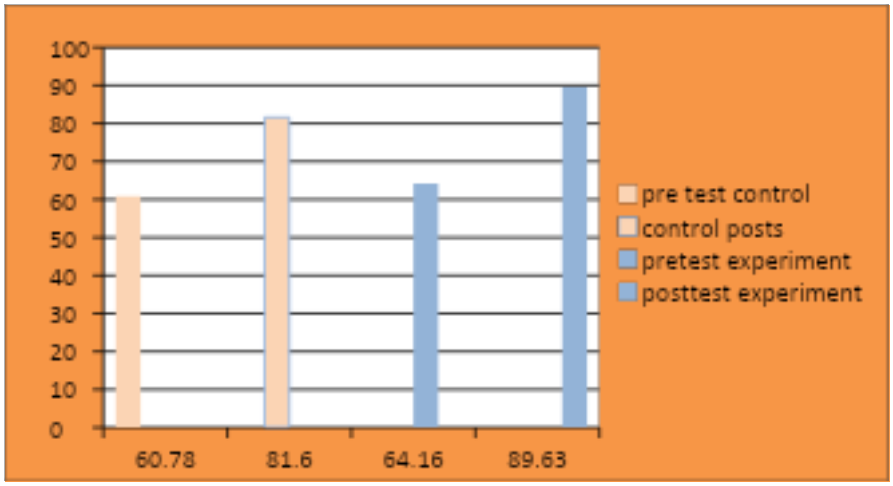

Figure 2. Graph of Control and Experimental Classes

The graph shows that posttest scores for students' critical thinking skills improved in both groups, but the group that used project-based learning experienced a greater increase.

Table 1. Results of the Normality Test of Critical Thinking Ability

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Pretest Control Class	,130	30	,200	,956	30	,240
Posttest Control Class	,130	30	,200	,936	30	,073
Pretest Experimental Class	,125	30	,200	,950	30	169
Posttest Experimental Class	,157	30	,056	,941	30	,099

The normality test is performed to check if the collected data follows a normal distribution, which is a prerequisite for using parametric statistical tests like the t-test. A commonly used method for normality testing, especially when the sample size is below 50, is the Shapiro-Wilk test. In this test, the data is deemed normally distributed if the p-value (significance level) exceeds 0.05.

Based on Table 1, the results of the analysis using SPSS version 26 for Windows, the significance values were 0.240 for the control class pretest, 0.073 for the control class posttest, 0.169 for the experimental class pretest, and 0.099 for the experimental class posttest. Since all values exceed 0.05, it indicates that the data from all four groups are normally distributed, fulfilling the criteria for conducting further parametric statistical tests. It also shows that students demonstrate varying levels of critical thinking skills throughout the learnng process.(Kholilah et al., 2024). This is evident from the normality test results for each group. According to the Shapiro-Wilk test, all significance values for both the pretest and posttest in the control and experimental classes exceed 0.05, indicating that the data is normally distributed and suitable for further statistical analysis.

Table 2. Results of the Homogeneity Test of Students' Critical Thinking Skills

Test of Homogeneity of Variances					
		Levene Statistics	df1	df2	Sig.
Hasil	Based on Mean	,001	1	58	,972
	Based on Median	,007	1	58	,932
	Based on Median and with adjusted df	,007	1	56,468	,932
	Based on trimmed mean	,002	1	58	,967

The homogeneity test aims to ensure that the variance of the data from the compared groups is the same or homogeneous. This is important so that parametric statistical analysis, such as the t-test, can be carried out validly. The homogeneity test is

usually assessed from the significance value (Sig.) in the Levene test, where the data is considered homogeneous if the Sig. value is greater than 0.05.

Referring to the outcomes of the homogeneity test in Table 2, the Sig. value for the control group's pretest is 0.972, and for the experimental group, it is 0.932. Meanwhile, the posttest Sig. values are 0.932 for the control group and 0.967 for the experimental group. Since all significance values exceed 0.05, it indicates that the data across both groups have equal variance. Therefore, the results fulfill the criteria necessary to proceed with the subsequent parametric statistical analysis.

Normality and homogeneity tests have different but complementary purposes. The normality test is used to see if the distribution of data in each group approaches a normal distribution, while the homogeneity test is used to ensure that the variance between the groups being compared is uniform. Both are important prerequisites in parametric statistical analysis, because if the data is not normal or not homogeneous, then parametric tests, for example the t-test, cannot be applied validly. Therefore, the outcomes of both assessments demonstrate that the dataset satisfies the fundamental requirements for accurately applying parametric statistical methods in the next stage of analysis.

Table 3. Paired Samples Test Experimental class

Paired Samples Test								
		Paired Differences						
		Mean	Std. Deviation	Std. Error Mean	Confidence interval at the 95% level for the difference		t	Sig. (2-tailed)
					Lower	Upper		
Pair 1	PrettestEksperimen - PosttestEksperimen	-25,467	13,579	2,479	-30,537	-20,396	-10,272	,000

A paired samples t-test was conducted to examine whether the implementation of project-based learning led to a significant difference in students' critical thinking skills within the experimental group. This statistical test compares the mean scores of the pretest and posttest taken by the same participants.

The analysis results presented in Table 3 show a significance value (2-tailed) of 0.000, which is lower than the threshold of 0.05. Consequently, the null hypothesis (H_0), stating that there is no difference in critical thinking skills before and after the implementation of project-based learning, is rejected. The alternative hypothesis (H_a) is therefore accepted, indicating a

significant improvement in students' critical thinking skills following the application of the project-based learning model.

This finding is further supported by the fact that the data met the assumptions required for parametric testing, specifically normal distribution and homogeneous variance. As a result, the application of the paired samples t-test is deemed appropriate and reliable for statistically analyzing the changes in students' critical thinking skills within the experimental group

Table 4. Paired Samples Test Control Class

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair	PrettestKontrol - Posttestkontrol	-13,800	10,896	1,989	-17,869	-9,731	-6,937	29	,000

The paired samples t-test was used to determine whether there was a significant difference in the critical thinking skills of students in the control class between the pretest and posttest. This test compares the average scores before and after treatment in the same group.

Based on the results of the analysis in Table 4, the significance value (2-tailed) obtained was 0.000, which means it is less than 0.05. Thus, the null hypothesis (H0) which states that there is no difference in students' critical thinking skills in the pretest and posttest is rejected, and the alternative hypothesis (Ha) is accepted. This shows that there is a significant difference in the critical thinking skills of students in the control class between before and after treatment.

The findings suggest that while students in the control group showed some improvement in their critical thinking abilities following the learning process, the improvement was not as substantial as that observed in the experimental group that implemented the project-based learning model. The slight progress in the control group may be attributed to conventional learning activities that still offered some cognitive stimulation, even though they were not intentionally structured to enhance critical thinking skills. These results further emphasize the greater effectiveness of the project-based learning approach in fostering students' critical thinking. Moreover, the use of this test is considered valid as the data satisfied

the assumptions for parametric testing, namely normal distribution and homogeneous variance, ensuring the reliability of the statistical findings.

Table 5. Independent Samples t-test

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
						Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.	t	df				Lower	Upper
Nilai	Equal variances assumed	,001	,972	-3,989	58	,000	-8,033	2,014	-12,064	-4,002

The independent samples t-test was conducted to assess whether a significant difference existed between the posttest scores of students in the experimental and control groups. This test is suitable for comparing two distinct groups using interval or ratio data, provided that the assumptions of normality and homogeneity are fulfilled.

The analysis results presented in Table 5 show a significance value (Sig. 2-tailed) of 0.000, which is below the 0.05 threshold. This indicates that the null hypothesis (H0) is rejected, and the alternative hypothesis (Ha) is accepted. Therefore, there is a significant difference in the posttest critical thinking skills scores between students in the experimental and control groups. This finding suggests that implementing the project-based learning model has a meaningful impact on enhancing students' critical thinking abilities.

These results strengthen the finding that project-based learning is able to provide a greater contribution to improving students' critical thinking skills compared to conventional learning. The validity of the results of this Independent test is also supported by the fulfillment of the parametric test requirements, namely normally distributed data and homogeneous variance, so that the conclusions obtained can be statistically trusted.

The qualitative data collected from observations and interviews in the fifth-grade class at SDIT Al-Madinah indicate that the implementation of Project-Based Learning (PjBL) positively influences students' critical thinking abilities. The qualitative analysis involved organizing and describing findings from both observation and interview data, with interview insights being supported by observational evidence to ensure the consistency and reliability of the information. This method helps guarantee that the

interpretations of student behaviors and reactions during project-based learning are accurate and can be scientifically validated. Observations revealed that students in the experimental group were more actively engaged in learning activities such as asking questions, participating in discussions, and collaborating to solve problems, which reflected improvements in critical thinking skills, particularly in areas like basic explanations, drawing conclusions, and providing detailed explanations. These findings were supported by teacher interviews, where educators noted that PjBL increased students' enthusiasm, independence, and active participation in learning—especially during lessons on electrical energy. Teachers also acknowledged that while PjBL was effective in promoting critical thinking and fostering a meaningful learning environment, challenges such as limited time and the need for thorough preparation were present. As one teacher expressed,

> "Project-based learning is a fun learning process that is very popular with children so that in its implementation children are very enthusiastic and not bored, besides that the project also requires students to be able to think critically and work together with their peers."

The results of this study show that implementing the Project-Based Learning (PjBL) model can enhance students' critical thinking abilities. This finding supports previous research by (Musa'ad et al., 2024) Which revealed that PjBL boosts students' critical thinking by encouraging greater involvement in questioning and problem-solving. Similarly, a study by Umayroh et al., 2024) also demonstrates that PjBL enhances students' critical thinking abilities in spatial geometry topics at the elementary school level. Therefore, it can be concluded that PjBL is an effective method for developing students' critical thinking skills.

Compared to previous research, the findings of this study align with Umayroh's study, which revealed that PjBL enhances students' critical thinking skills. Additionally, this study indicates that PjBL can boost critical thinking abilities across a variety of subjects.

The findings of this study imply that PjBL can serve as an effective learning strategy to enhance students' critical thinking skills. Teachers are encouraged to adopt PjBL as an alternative teaching method that promotes more engaging and interactive learning. Moreover, the study highlights that PjBL can boost students' motivation and interest in the learning process. Consequently, further research is necessary to expand and apply PjBL across different educational settings.

Based on the study's findings, it can be concluded that applying project-based science learning enhances the critical thinking abilities of fifth-grade students at SDIT Al-Madinah. This learning approach motivates students to be more active, independent, and engaged by working on projects related to electrical energy and its applications. Through this process, students have the opportunity to explore, analyze, and solve problems in a logical and systematic way, which leads to a better development of their critical thinking skills compared to traditional methods. Therefore, project-based learning can be considered an effective alternative for fostering critical thinking in elementary school science education.

Based on the study's findings, it can be concluded that implementing project-based science learning effectively enhances the critical thinking skills of fifth-grade students at SDIT Al-Madinah. This approach promotes active, independent, and engaged learning by having students complete projects related to electrical energy topics. Quantitative results indicate a significant improvement in students' critical thinking abilities following the application of this model, while qualitative data reinforces these results by revealing positive shifts in students' learning behaviors and attitudes. The study suggests that project-based learning is a promising alternative strategy for fostering critical thinking in elementary education. Further research is recommended to expand and adapt this model across various learning settings.

CONCLUSION

Based on the results of the study, it can be concluded that the implementation of project-based science learning can improve critical thinking skills of fifth grade students of SDIT Al-Madinah. Project-based learning encourages students to be more active, independent, and directly involved in the learning process through completing projects related to electrical energy and its uses. This process provides space for students to explore, analyze, and solve problems logically and systematically, so that their critical thinking skills develop better compared to conventional learning. Thus, this learning model can be an effective alternative in developing students' critical thinking skills in science learning in elementary schools.

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