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EVALUATING PROJECT-BASED LEARNING AS A PEDAGOGICAL STRATEGY TO PROMOTE ACTIVE LEARNING AND CRITICAL THINKING IN ELEMENTARY SCIENCE LESSONS

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ABSTRACT

This study aims to evaluate the effectiveness of Project-Based Learning (PjBL) in promoting active learning and critical thinking in elementary science lessons. Using a Classroom Action Research (CAR) design based on the Kemmis and McTaggart model, the study was conducted in two cycles involving 24 sixth-grade students at SDN 182 Tanjung Jabung Barat. Data were collected through observation sheets assessing visual, oral, listening, writing, and motoric activities, as well as through critical thinking tests measuring interpretation, analysis, evaluation, inference, and explanation. The findings show a substantial improvement in students' learning activeness from 56.2% in Cycle I to 87.4% in Cycle II. Similarly, students' critical thinking scores increased from 61.5 (moderate) to 83.8 (high). These improvements were achieved through iterative refinement of project activities, which provided structured opportunities for hands-on exploration, collaborative problem-solving, and reflective inquiry. Overall, the study concludes that PjBL effectively fosters a student-centered learning environment that enhances participation and higher-order thinking skills, aligning with the development of twenty-first-century competencies in elementary science education.

Keywords: Project-Based Learning, active learning, critical thinking, science education.

INTRODUCTION

Science education at the elementary level plays a pivotal role in nurturing students' scientific literacy and reasoning skills (Holbrook & Rannikmae, 2007). However, many classroom practices still rely on teacher-centered approaches that emphasize factual memorization rather than inquiry and exploration. This instructional pattern often limits students' opportunities to engage meaningfully in the learning process and develop analytical thinking. As a result, students tend to become passive recipients of information, which hinders their ability to apply scientific knowledge in daily life. Such conditions underscore the necessity for innovative pedagogical models that encourage students' active involvement and critical reflection in learning science.

Education in the twenty-first century demands learners who are not only knowledgeable but also capable of analyzing, evaluating, and solving real-world problems. The integration of higher-order thinking skills such as critical thinking, creativity, and collaboration has therefore become a central goal of contemporary curricula (Azizah et al., 2025). Active learning environments are increasingly recognized as effective means to cultivate these competencies, as they require students to engage cognitively, socially, and emotionally in their learning tasks. Through active participation, students gain ownership of their learning and become more motivated to explore and question scientific concepts.

Project-Based Learning (PBL) has been widely acknowledged as a pedagogical approach that aligns with the principles of active learning. It involves students in authentic, complex tasks that require investigation, collaboration, and production of tangible outcomes (Al-Qoyyim & Kurniawan, 2025). According to Omelianenko & Artyukhova (2024), PjBL enables learners to connect theoretical understanding with practical applications through project execution. This method encourages students to work collaboratively, engage in scientific inquiry, and reflect on their progress, three essential aspects that foster deep learning. By situating students as active agents in constructing knowledge, PjBL bridges the gap between theory and experience in science education.

Despite its potential benefits, the implementation of PjBL in elementary science education remains underexplored, particularly in contexts where traditional methods still dominate classroom practice. Many teachers struggle to design projects that effectively balance content mastery and skill development. Furthermore, limited empirical evidence exists regarding how PjBL specifically enhances active learning and critical thinking among younger learners. Therefore, evaluating the effectiveness of this approach is necessary to provide pedagogical insights and empirical validation for its broader application in elementary science classrooms.

In the context of science education, active learning involves more than physical participation; it demands cognitive engagement in observation, experimentation, and problem-solving (Cheng et al., 2019). Students are encouraged to formulate questions, test hypotheses, and interpret data to construct meaningful understanding. Such processes reflect the essence of scientific inquiry, where learners act as investigators rather than passive recipients of information. Through this engagement, students develop not only conceptual knowledge but also metacognitive awareness, recognizing how they learn and why specific methods are effective. Therefore, promoting active learning is crucial for nurturing scientifically literate citizens capable of critical reasoning.

Critical thinking, as defined by Rositawati (2019), is the process of purposeful, self-regulatory judgment that involves interpretation, analysis, evaluation, and inference. In science learning, critical thinking enables students to evaluate evidence, distinguish between facts and assumptions, and draw rational conclusions. Previous studies have demonstrated that students who participate in inquiry- and project-based activities show improved critical thinking performance compared to those taught using conventional methods (Diana & Saputri, 2021; Rahayu et al., 2025). Hence, cultivating critical thinking through Project-Based Learning is an essential pathway toward achieving the broader goals of twenty-first-century science education.

Furthermore, elementary students possess natural curiosity and a strong desire to explore how things work in their surroundings (Ting & Siew, 2014). When this curiosity is channeled through well-structured projects, learning becomes meaningful and enjoyable. Topics such as parallel electric circuits provide an excellent context for PjBL because they allow hands-on experimentation and collaborative problem-solving. Students can design and construct circuit models, observe cause-and-effect relationships, and reflect on their findings, activities that directly stimulate both active engagement and critical thought. Therefore, the use of Project-Based Learning in teaching electricity not only enhances conceptual understanding but also transforms the learning process into an experience that integrates inquiry, creativity, and reflection.

Although numerous studies have examined the benefits of Project-Based Learning across various educational levels, research focusing on its practical implementation in elementary science remains limited. Most prior investigations have concentrated on secondary or higher education contexts, where students possess more advanced conceptual understanding and reasoning abilities. As a result, there is insufficient empirical evidence addressing how PjBL influences learning activeness and critical thinking among younger learners, particularly in rural or resource-limited schools. This gap underscores the need for context-specific studies that examine both the challenges and successes of implementing PjBL at the primary level, where foundational cognitive and collaborative skills are still developing.

Therefore, this study aims to evaluate the effectiveness of Project-Based Learning as a pedagogical strategy to promote active learning and critical thinking in elementary science lessons, particularly on the topic of parallel electric circuits. By employing a Classroom Action Research design, the study seeks to identify measurable improvements in students' learning activeness and critical thinking skills through iterative teaching cycles. The findings are expected to provide empirical support for integrating PjBL into elementary science education practices, offering practical implications for teachers seeking to implement student-centered, inquiry-oriented approaches aligned with twenty-first-century learning goals.

LITERATURE REVIEW

Project-Based Learning (PBL) has been widely recognized as an instructional model that aligns with constructivist learning theory, emphasizing students' active role in constructing knowledge through authentic experiences. According to Rispandi et al (2025), PjBL enables learners to engage in meaningful projects that integrate inquiry, problem-solving, and collaboration, resulting in deeper conceptual understanding and transferable skills. In science education, this model bridges theoretical knowledge and real-world application by allowing students to explore natural phenomena through experimentation and investigation. Zubaidah (2016) emphasizes that project-oriented learning cultivates autonomy, creativity, and reflection, key characteristics of effective learners in the twenty-first century. Thus, PjBL offers a pedagogical framework that fosters both cognitive and affective dimensions of learning.

Active learning is an instructional approach closely related to PjBL, focusing on students' engagement through participation and interaction rather than passive reception of information. Brame (2016) defines active learning as any instructional method that involves students in doing things and thinking about what they are doing. This approach promotes higher retention and understanding, as learners become co-constructors of knowledge rather than recipients. Sarudin et al. (2024) further highlight that active learning strategies, such as discussion, simulation, and experimentation, help students develop critical and analytical skills. In the context of science education, active learning transforms the classroom into a dynamic environment where inquiry, exploration, and collaboration replace memorization and routine tasks.

Critical thinking, another key construct in this study, refers to the ability to interpret, analyze, evaluate, and infer information in a reasoned manner (Lai, 2011). It is considered a cornerstone of scientific literacy and intellectual growth. Zahroh & Yuliani (2021) argue that critical thinking encompasses disciplined reasoning and intellectual standards such as clarity, accuracy, and fairness. Developing these skills from the elementary level is crucial to preparing learners to become reflective and responsible decision-makers. Research by Robbani (2025) confirms that critical thinking can be effectively developed through inquiry- and project-based pedagogies that encourage students to question assumptions, test hypotheses, and evaluate outcomes. Therefore, integrating critical thinking objectives into PjBL provides a dual benefit: content mastery and intellectual empowerment.

The theoretical foundation of this study is also supported by constructivism and social learning theory, which underpin the principles of Project-Based Learning. Piaget's constructivism posits that learners actively construct their own understanding through interaction with the environment, while Vygotsky's social constructivism emphasizes the role of collaboration and scaffolding in cognitive development. In PjBL contexts, these theories manifest through group-based projects that require negotiation of meaning, division of tasks, and shared reflection. Studies by Arofah (2024) and Azizah et al. (2024) demonstrate that social collaboration during project work enhances both academic achievement and socio-emotional growth. Consequently, the theoretical alignment between PjBL and constructivist principles strengthens the rationale for applying this model in elementary science learning.

In recent years, numerous empirical studies have demonstrated the positive impact of Project-Based Learning on students' engagement and learning outcomes in science education. A study by Eswaran (2024) found that PjBL enhances students' scientific reasoning and collaborative skills by engaging them in authentic investigations that mirror real-world scientific practices. Similarly, Hendranti et al (2025) reported that PjBL increased students' motivation, participation, and curiosity toward scientific phenomena, leading to a more sustained understanding of complex concepts. These findings confirm that integrating project-based activities encourages learners to take ownership of their learning, fostering both cognitive and behavioral engagement. Consequently, PjBL represents an evidence-based strategy that supports active participation and the development of inquiry-oriented mindsets among young learners.

Several studies have also emphasized the close relationship between Project-Based Learning and the enhancement of critical thinking. Research by Nuraini et al. (2020) found that students involved in project-based activities demonstrate significant improvement in analytical and evaluative thinking compared to those in traditional instruction. This occurs because PjBL encourages learners to question assumptions, examine evidence, and make reasoned judgments based on investigation results. In a similar vein, Nuun et al (2016) argue that the collaborative nature of project work nurtures metacognitive reflection and argumentation skills, two key indicators of critical thinking. Thus, when students engage in collective construction and testing of ideas, they internalize higher-order thinking processes that are essential to science learning.

Within the elementary education context, PjBL provides a developmentally appropriate means to introduce inquiry and experimentation. Young learners tend to learn best through direct experience, manipulation of materials, and social interaction. PjBL accommodates these needs by offering opportunities for students to explore phenomena, design prototypes, and present findings in collaborative settings. In the topic of electricity, for instance, students can design parallel circuits, predict outcomes, and analyze energy flow patterns. These hands-on experiences are critical for transforming abstract concepts into concrete understanding, while simultaneously enhancing active learning and critical reflection. Moreover, the sense of accomplishment derived from completing projects strengthens intrinsic motivation and long-term engagement in science.

Despite its documented advantages, the application of Project-Based Learning in elementary classrooms remains inconsistent due to various constraints such as limited teacher readiness, time management, and resource availability. Many teachers express uncertainty about how to design projects that effectively balance content mastery with skill development. This research seeks to address that gap by providing empirical evidence on how PjBL can be implemented effectively in the context of elementary science, particularly on the topic of parallel electric circuits. By examining changes in students' activeness and critical thinking across iterative cycles of classroom action research, this study contributes to the growing body of literature validating PjBL as a transformative pedagogy. The findings are expected to reinforce theoretical perspectives and offer practical implications for improving science learning at the foundational level.

METHODOLOGY

This study employed a Classroom Action Research (CAR) design based on the Kemmis and McTaggart model, which emphasizes a cyclical process of planning, acting, observing, and reflecting. The research aimed to evaluate the effectiveness of Project-Based Learning (PBL) in improving students' activeness and critical thinking within elementary science lessons. The study was conducted at SDN 182 Tanjung Jabung Barat, Indonesia, during the first semester of the 2025/2026 academic year. The participants consisted of 24 sixth-grade students (13 boys and 11 girls) with diverse academic abilities. The CAR approach was selected because it allows teachers to systematically implement and reflect on pedagogical innovations in a real classroom setting while directly addressing instructional challenges.

Data were collected using a combination of observation sheets, student worksheets, and critical thinking tests. The observation sheets were used to record students' active learning behaviors based on the indicators proposed by Diedrich, covering visual, oral, listening, writing, and motoric activities. Meanwhile, students' critical thinking skills were assessed through written tests designed according to the dimensions of interpretation, analysis, evaluation, inference, and explanation outlined by Mohammadi et al. (2022). In addition, field notes and documentation such as project reports and photographs were gathered to ensure data triangulation and enhance validity. Each data source was analyzed collaboratively by the teacher and researcher to minimize subjective bias and confirm the reliability of the observations.

The collected data were analyzed using descriptive quantitative and qualitative techniques. Quantitative data from observations and test results were processed by calculating mean scores and percentage improvements across cycles to determine the degree of change in students' activity and critical thinking. Qualitative data from reflections and student feedback were analyzed through thematic interpretation to identify patterns of engagement and learning behaviors. The criteria for success were established when the class average for learning activeness reached at least 80% (active category), and the average critical thinking score reached ≥75 (high category). This mixed analysis approach ensured that both measurable outcomes and contextual insights were considered in evaluating the overall effectiveness of Project-Based Learning implementation.

RESULT AND DISCUSSION

The implementation of Project-Based Learning (PjBL) in elementary science lessons occurred over two cycles, each comprising the stages of planning, action, observation, and reflection. The main objective of the intervention was to increase students' engagement and critical thinking skills through hands-on, inquiry-based learning activities on parallel electric circuits. During the initial observation prior to Cycle I, it was found that most students were passive during lessons and relied heavily on teacher explanations. This limited participation reflected a lack of engagement in scientific inquiry, which is essential for developing higher-order thinking skills. The application of PjBL was therefore designed to transform the learning environment into one that encouraged exploration, collaboration, and problem-solving.

In Cycle I, students were divided into small groups and assigned projects to design and construct simple parallel circuits using recycled materials. The teacher acted as a facilitator, providing guidance and questioning strategies to provoke critical reasoning. Although the activity successfully increased students' curiosity, several challenges emerged, including unequal participation among group members and limited time for discussion. Some students still hesitated to express ideas or evaluate group decisions. Reflection after Cycle I indicated that more structured guidance and clear task distribution were required to ensure balanced involvement. Consequently, modifications were made in Cycle II to improve collaborative mechanisms and expand opportunities for student-led inquiry.

The results from both cycles showed a marked improvement in students' learning activity. Observational data revealed that students became more engaged not only in physical activities but also in verbal participation and problem analysis. The level of interaction during discussions increased significantly, and students began to demonstrate greater initiative in proposing experimental designs and interpreting outcomes. These findings are consistent with previous studies by Rubino (2024) and Rehman et al (2024), which confirmed that PjBL enhances classroom engagement by positioning students as active constructors of knowledge. In this study, the gradual increase in activeness also reflected the growing sense of ownership students felt toward their learning projects.

Table 1 presents the quantitative results of students' activeness observed throughout both cycles. The data show a steady increase in the mean scores of all five observed indicators: visual, oral, listening, writing, and motoric activities. The average overall activeness improved from 56.2% (moderate category) in Cycle I to 87.4% (very active category) in Cycle II, surpassing the predetermined success criterion of 80%.

Table 1. Students' Learning Activeness Results

Indicator	Cycle I (%)	Cycle II (%)	Improvement (%)	Category (Cycle II)
Visual Activity	58.0	86.5	+28.5	Very Active
Oral Activity	52.3	85.2	+32.9	Very Active
Listening Activity	60.1	88.0	+27.9	Very Active
Writing Activity	55.7	87.0	+31.3	Very Active
Motoric Activity	54.8	90.3	+35.5	Very Active
Average	56.2	87.4	+31.2	Very Active

The improvement in students' learning activeness across cycles can be attributed to the experiential and collaborative nature of Project-Based Learning. Through direct involvement in constructing and testing circuit models, students not only observed scientific phenomena but also interpreted their learning outcomes through discussion and reflection. This aligns with the constructivist perspective, which asserts that knowledge is best internalized when learners actively engage with real-world problems (Piaget, as cited in Schunk, 2020). The transition from teacher-centered to student-centered learning allowed students to explore and question, fostering a classroom culture that valued curiosity and shared responsibility. As participation became more evenly distributed among group members, motivation and confidence in expressing scientific ideas also increased.

The analysis of students' critical thinking test scores revealed significant progress between the two cycles. In Cycle I, students' average score was 61.5, categorized as moderate. Many students initially struggled to formulate hypotheses and evaluate experimental outcomes, indicating limited analytical reasoning. However, after refining the PjBL process in Cycle II, which emphasized deeper inquiry and reflective discussion, the mean score rose to 83.8, indicating a high level of engagement. This improvement demonstrates that project-based instruction not only encouraged active participation but also enhanced students' ability to think logically, make inferences, and justify their conclusions.

Table 2 summarizes the quantitative results of students' critical thinking assessments across both cycles. The most significant improvement occurred in the indicators of *analysis* and *evaluation*, suggesting that the revised instructional design in Cycle II successfully encouraged learners to critique and refine their own understanding.

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Table 2. Students' Critical Thinking Results

Indicator	Cycle I (Score)	Cycle II (Score)	Improvement	Category (Cycle II)
Interpretation	63.2	82.6	+19.4	High
Analysis	59.8	85.2	+25.4	High
Evaluation	60.5	86.0	+25.5	High
Inference	61.0	83.1	+22.1	High
Explanation	62.9	82.0	+19.1	High
Average	61.5	83.8	+22.3	High

The data in Table 2 indicate that students became more capable of analyzing problems, comparing alternatives, and interpreting evidence to support scientific conclusions. This pattern corroborates findings by Ramadhan & Hindun (2025), who noted that critical thinking can be significantly enhanced when students are provided with opportunities to construct and evaluate their own projects. During Cycle II, students demonstrated a notable shift from descriptive to analytical reasoning. They began to justify why specific circuits failed or succeeded based on their understanding of electrical flow and resistance, reflecting the internalization of scientific principles through inquiry.

Moreover, classroom observations supported the quantitative findings. Students exhibited greater independence in managing project tasks, and peer discussions became more substantive, focusing on problem-solving rather than merely completing tasks. Teachers reported that students' questions evolved from procedural inquiries to conceptual ones, such as predicting outcomes or identifying variables affecting current flow. These behavioral indicators indicate that critical thinking has become embedded in students' learning process. The reflective discussions conducted at the end of each project further allowed students to evaluate their strategies and make reasoned judgments about improvements, demonstrating metacognitive growth.

The findings from this study provide clear evidence that Project-Based Learning effectively enhances both active participation and critical thinking among elementary students. The steady increase in activeness and critical thinking scores between cycles demonstrates that structured project activities create opportunities for learners to explore, test, and articulate their understanding of scientific concepts. Students who initially depended on teacher guidance gradually became more autonomous in designing and conducting experiments. This behavioral transformation reflects the positive impact of PjBL in promoting intrinsic motivation and learner agency. The combination of group collaboration, guided inquiry, and reflective feedback enabled students to internalize scientific reasoning and apply it meaningfully in their projects.

Another important finding concerns the dynamic classroom atmosphere observed during PjBL implementation. The learning environment evolved into a collaborative and dialogic space where students learned through interaction, experimentation, and shared reflection. Such conditions align with the principles of social constructivism, which hold that learning occurs through meaningful engagement and peer collaboration. The role of the teacher shifted from a transmitter of knowledge to a facilitator and co-investigator, guiding students through questioning and scaffolding. This change not only fostered deeper understanding but also contributed to positive social-emotional outcomes such as confidence, responsibility, and mutual respect. These results are consistent with Krajcik & Czerniak's (2018) statement that project-based learning promotes both cognitive and interpersonal development in science classrooms.

From a theoretical standpoint, the outcomes of this study validate the constructivist view that learning is most effective when students actively construct knowledge through authentic experiences. By engaging in projects that required planning, experimentation, and evaluation, students moved through all stages of Bloom's revised taxonomy: remembering, understanding, applying, analyzing, evaluating, and creating. The improvement in analytical and evaluative skills observed in Cycle II reinforces the notion that Project-Based Learning bridges the gap between theory and practice. Furthermore, the emphasis on reflection after each cycle aligns with Kolb's experiential learning theory, which holds that knowledge is continuously refined through cycles of action and reflection. Thus, this research not only supports the theoretical foundations of PjBL but also extends its applicability to younger learners in the context of elementary science.

In the broader educational context, these findings resonate strongly with the goals of the Indonesian Kurikulum Merdeka and the Framework for 21st-Century Skills, which emphasize creativity, critical thinking, communication, and collaboration as essential learning outcomes. The integration of Project-Based Learning fosters these competencies by allowing students to experience scientific inquiry as an interconnected process rather than as fragmented content. Moreover, the study provides practical implications for educators seeking to align classroom practices with the *Profil Pelajar Pancasila,* developing learners who are independent, reflective, and collaborative problem-solvers. Therefore, the successful implementation of PjBL in this study not only contributes to pedagogical innovation but also exemplifies how elementary science education can serve as a foundation for lifelong learning and global competence.

CONCLUSIONS

This study concludes that Project-Based Learning (PBL) effectively improves students' activeness and critical thinking in elementary science lessons. The structured project activities fostered engagement, collaboration, and analytical reasoning, as shown by increased scores across research cycles. These findings reinforce constructivist and experiential learning theories, highlighting that knowledge is best developed through authentic, inquiry-based experiences. Practically, the study recommends integrating PjBL into the Kurikulum Merdeka to promote 21st-century skills, critical thinking, creativity, collaboration, and communication, while cultivating independent and reflective learners ready for lifelong learning.

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