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Problem-Based and Project-Based Learning for Enhancing Elementary Students' Science Problem-Solving and Learning Outcomes

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Abstract

Abstract

This study examined the effectiveness of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) on elementary students' science learning outcomes in energy-saving materials by considering students' Learning Styles. A quasi-experimental design with a 2×3 factorial arrangement was employed involving 52 sixth-grade elementary school students. Participants were assigned to either a Problem-Based Learning group or a Project-Based Learning group. Data were collected through a science learning achievement test and a Learning Styles questionnaire. Instrument reliability testing yielded a Cronbach's Alpha coefficient of 0.909, indicating excellent reliability. Data were analyzed using Two-Way ANOVA after meeting the assumptions of normality and homogeneity. The findings revealed that students who learned through Problem-Based Learning achieved significantly higher science learning outcomes than those who learned through Project-Based Learning. Learning Styles had a significant effect on students' learning outcomes, and a significant interaction was found between instructional models and Learning Styles. Problem-Based Learning was particularly effective in promoting inquiry engagement, conceptual understanding, scientific reasoning, and collaborative problem-solving, especially among students with experiential inquiry preferences. This study contributes to the growing discourse on adaptive inquiry-based learning by highlighting the importance of accommodating learner diversity to enhance meaningful science learning in elementary education.

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Abstrak

Penelitian ini bertujuan untuk menganalisis efektivitas Problem-Based Learning (PBL) dan Project-Based Learning (PjBL) terhadap hasil belajar Sains materi Penghematan Energi siswa sekolah dasar dengan mempertimbangkan Gaya belajar (Learning Styles) siswa. Penelitian menggunakan desain kuasi eksperimen dengan pola faktorial 2×3 yang melibatkan 52 siswa kelas VI sekolah dasar. Peserta didik dibagi ke dalam dua kelompok pembelajaran, yaitu Problem-Based Learning dan Project-Based Learning. Data dikumpulkan menggunakan tes hasil belajar dan angket Gaya belajar. Hasil uji reliabilitas instrumen menunjukkan nilai Cronbach's Alpha sebesar 0,909 yang mengindikasikan reliabilitas sangat tinggi. Data dianalisis menggunakan Two-Way ANOVA setelah memenuhi asumsi normalitas dan homogenitas. Hasil penelitian menunjukkan bahwa siswa yang belajar menggunakan Problem-Based Learning memperoleh hasil belajar yang lebih tinggi dibandingkan siswa yang belajar menggunakan Project-Based Learning. Gaya belajar berpengaruh signifikan terhadap hasil belajar siswa, dan terdapat interaksi signifikan antara model pembelajaran dan gaya Belajar. Temuan penelitian menunjukkan bahwa Problem-Based Learning lebih efektif dalam mendukung inquiry engagement, conceptual understanding, scientific reasoning, dan collaborative problem-solving, terutama pada siswa dengan experiential inquiry preference. Penelitian ini berkontribusi pada pengembangan adaptive inquiry-based learning yang menempatkan Gaya belajar sebagai karakteristik siswa yang penting dalam meningkatkan kualitas pembelajaran sains di sekolah dasar.

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1. INTRODUCTION

The transformation of twenty-first-century education has shifted the learning paradigm from teacher-centered instruction toward student-centered and inquiry-oriented learning environments that emphasize students' active participation in constructing knowledge (Gottschalk & Weise, 2023; Lee & Hannafin, 2016; Wang, 2023). This transformation is driven by the need to prepare learners with critical thinking, scientific reasoning, collaborative inquiry, and problem-solving competencies necessary to address increasingly complex real-world challenges (Banilower, 2019; Bybee, 2018). Recent systematic reviews indicate that student-centered approaches consistently improve academic achievement, learning motivation, engagement, and higher-order thinking skills in primary education (Li & Ding, 2023; Mat & Jamaludin, 2024).

In student-centered learning environments, students are positioned as active agents who construct knowledge through exploration, inquiry, reflection, and collaboration. Such learning environments require autonomy, scaffolding, and authentic learning experiences that encourage meaningful engagement (Lee & Hannafin, 2016). Contemporary educational technology perspectives further emphasize the importance of adaptive learning environments that accommodate learner diversity and support meaningful participation in inquiry-based learning experiences. Adaptive inquiry-based learning enables educators to design learning environments that respond to students' characteristics, interests, and learning needs while fostering scientific reasoning and problem-solving competencies required in the twenty-first century (Lee & Hannafin, 2016; Sayadi & Pangandaman, 2025).

In science education, learning is no longer viewed merely as the transmission of information but as a process of developing conceptual understanding through meaningful and contextual learning experiences (Sayadi & Pangandaman, 2025). Modern science education also emphasizes knowledge-in-use, referring to students' ability to apply scientific ideas to explain phenomena and solve authentic problems (Krajcik et al., 2021; Miller & Krajcik, 2019). Therefore, elementary science instruction should not only promote conceptual understanding but also support scientific reasoning and contextual application of scientific knowledge (Harris et al., 2015; Miller & Krajcik, 2019)

Within this perspective, Problem-Based Learning (PBL) and Project-Based Learning (PjBL) have emerged as two prominent inquiry-based instructional models. Both approaches are grounded in constructivist theory and support higher-order thinking, collaborative inquiry, critical thinking, and self-directed learning (Loyens et al., 2025; Prince; & Felder, 2006; Savery, 2006). However, they differ in instructional emphasis. PBL centered learning around authentic problems that stimulate investigation, hypothesis generation, and collaborative reasoning, whereas PjBL emphasizes the creation of projects or products through extended inquiry and experiential learning (Bell, 2010; Savery, 2006).

The effectiveness of inquiry-based learning, however, may depend not only on instructional models but also on learner characteristics. Elementary school students have differences in readiness, interests, talent, engagement preferences, and learning style ((Albanese et al., 2021; Taş & Minaz, 2024; Tomlinson, 2017) that can affect how they build conceptual understanding during the inquiry process. It is clear that in the classroom there are students who have heterogeneous characteristics (Khotimah et al., 2025; Stollman et al., 2021) that require different instructional strategies. The differentiated instruction aspect is important because students learn in different ways and require a learning experience that is responsive to learner diversity The learner characteristics that were tested for influence in this study were learning style, which was differentiated into visual learner (V), auditory learner (A), and kinesthetics learner (K). Recently, the position of learning style has been doubted by several experts, who argue that this type of learner characteristic does not affect learning outcomes. However, several studies indicate that the instructional method that proves most effective for students with one learning style is not the most effective method for students with a different learning style (Tomlinson, 2017). This study is expected to provide empirical evidence that different learning strategies (PjBL and PBL) will have different influences as a result of students having different learning styles. This research can contribute so that students with different learning styles must receive differentiated instruction (PjBl or PBL). The results of this study must accommodate learner characteristics so that students experience learning according to their needs (Darling-Hammond, 2021; Darling-Hammond et al., 2020). This study is expected to provide empirical evidence that different learning strategies (PjBL and PBL) will have different influences as a result of students having different learning styles. This research can contribute so that students with different learning styles must receive differentiated instruction (PjBl or PBL). The results of this study must accommodate students' learning style so that students experience learning according to their needs (Darling-Hammond, 2021; Darling-Hammond et al., 2020).

Although numerous studies have reported the effectiveness of Problem-Based Learning and Project-Based Learning in science education, most studies have examined these models independently (Bell, 2010; Harris et al., 2015). Comparative studies investigating both inquiry-based learning models within elementary science contexts remain limited. Furthermore, relatively few studies have examined how learner characteristics interact with inquiry-based instructional models to influence science learning outcomes (Loyens et al., 2025). Therefore, this study contributes to the growing discourse on adaptive inquiry-based learning by comparatively examining Problem-Based Learning and Project-Based Learning while considering students' learning styles in elementary science education.

In practice, elementary science instruction is still frequently dominated by memorization and procedural tasks, limiting students' opportunities to develop inquiry skills, scientific reasoning, and collaborative problem-solving abilities. This issue is particularly evident in energy-saving topics, where students often struggle to connect scientific concepts with everyday phenomena. As a result, learning becomes less meaningful and learning outcomes remain suboptimal (Anoling et al., 2024).

Accordingly, this study aims to examine the effects of Problem-Based Learning and Project-Based Learning on elementary students' science learning outcomes in energy-saving materials while considering students learning styles. The findings are expected to contribute empirical evidence for the development of adaptive inquiry-based learning environments that are student-centered, contextual, and supportive of meaningful science learning in elementary education.

2. METHODS

2.1.. Research Design

This study uses a quasi-experiment design with a factorial of 2×3. The research aims to examine the influence of learning models and student learning styles on the learning outcomes of science, energy-saving materials.

2.2. Research Participants

The subjects of this study are grade 6 elementary school students who are enrolled in two classes where each class has 26 students. In accordance with the quasi-experiment design, these two classes were divided into two learning groups, namely Problem-Based Learning and 26 students in the Project-Based Learning group.

2.3. Instruments

The instruments used to collect data are tests and questionnaires. Tests to measure the results of the weaving and a questionnaire to determine the students'' Learning styles.

The preparation of learning outcome tests is carried out by teachers in accordance with the learning objectives. The items of the learning outcome test questions were first tested for consistency with the Cronbach's Alpha technique; the result was a Cronbach's Alpha value of 0.909 (Figure 1) or very high so that this test is suitable to be used to measure student learning outcomes.

Cronbach's Alpha	N of items
.909	28

Figure 1. Reliability Test

2.4. Data Analysis

Data analysis was carried out using descriptive statistics and Two-Way ANOVA. Before testing the hypothesis, a prerequisite test was carried out in the form of normality and homogeneity tests.

3. RESULTS

3.1. Descriptive Statistic

The Descriptive Statistics learner outcome analyses on Figure 2 indicate that students who used problem-based learning (PBL) outperformed those who used project-based learning (PjBL) in terms of learning outcomes related to energy-saving material science. The PBL group scored an average of 78.03, but the PjBL group scored an average of 64.57. In PBL settings, students that have a propensity for hands-on learning and active learning perform better. Students in the PBL group with kinesthetics' learner had the highest average score, at about 82 points.

Descriptive Statistics

Dependent Variable: Learning outcome

Method	Learning Styles	Mean	Std. Deviation	N
PBL	Visual	70.3333	1.52753	3
	Auditory	76.0833	2.10878	12
	Kinesthetic	82.2727	2.96954	11
	Total	78.0385	4.74536	26
PjBL	Visual	62.8182	244206	11
	Auditory	66.4615	1.94145	13
	Kinesthetic	62.0000	2.82843	2
	Total	64.5769	2.87295	26
Total	Visual	64.4286	3.89703	14
	Auditory	71.0800	5.29087	25
	Kinesthetic	79.1538	8.12246	13
	Total	71.3077	7.82790	52

Resource: SPPS

Figure 2. Descriptive Statistics learner outcome

3.2 Two-Way ANOVA Result

Before testing the hypothesis, a prerequisite test was carried out in the form of normality and homogeneity tests. The results of the normality test showed an Asymp value. Sig is 0.087 which means that the data is normally distributed. The results of the homogeneity test also showed a significance value above 0.05 so that the data was declared homogeneous (Figure 3).

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Learning outcome	Base on Mean	2.804	1	50	.100
	Base on Median	2.838	1	50	.098
	Base on Median and with adjusted df	2.838	1	48.610	.098
	Base on trimmed mean	2.820	1	50	.099

Resource: SPPS

Figure 3. Test of Homogeneity Test

As for the results of the normality test, the data are shown in figure 4 as follows:

One-Sample Kolmogorov-Smirnov Test

			Unstandardized Residual
N			52
Normal Parameters[a,b]	Mean		.0000000
	Std. Deviation		6.09190982
Most Extreme Differences	Absolute		.114
	Positive		.101
	Negative		-.114
Test Statistic			.114
Asymp. Sig. (2-tailed)[c]			.087
Monte Carlo Sig. (2-tailed)[d]	Sig.		.083
	99% Confidence Interval	Lower Bound	.076
		Upper Bound	.090

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

d. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 334431365.

Figure 4. Test of Normality

After meeting the statistical requirements, namely the homogeneity test and the normality test, the hypothesis test was followed by a two-way variance analysis or Two Way ANOVA. This test is used to test the influence of learning models and learner characteristics on students' science learning outcomes. Test results are shown in Figure 5 as follow:

Test Between-Subjects Effects

Dependent Variable: Learning outcome

Source	Type III Sum of Squares	df1	Mean Square	F	Sig.
Corrected Model	2870.445[a]	5	574.089	103.711	<,001
Intercept	150053.486	1	150053.486	27107.562	<,001
Method	1190.637	1	1190.637	215.092	<,001
Learning Styles	177.143	2	88.572	16.001	<,001
Method*Learning Styles	185.866	2	02.933	16.789	<,001
Error	254.632	46	5.535		
Total	267534.000	52			
Corrected Total	3125.077	51			

a.R Squared= .919 (adjusted R Squared==.910)

Figure 5. Two Way ANOVA Result

The results of the analysis showed that the statistical model used had an R Squared value of 0.919 with an *Adjusted R Squared value* of 0.910. This value shows that about 91% of the variation in the learning outcomes of energy-saving materials can be explained by a combination of learning model variables, learning styles, and interactions between the two.

From Figure 5, The results of the Two-Way ANOVA analysis indicated that the learning model had a significant effect on the learning outcomes of Energy Saving Material Science with an F value of 215.092 and a significance below 0.001. Student learning characteristics also have a significant effect on learning outcomes with an F value of 16.001 and significance below 0.001.

In addition, a significant interaction was found between the learning model and learner characteristics with an F value of 16.789 and a significance below 0.001. The findings show that the effectiveness of the learning model is influenced by the diversity of learning styles.

4. DISCUSSION

The results of the study indicate that problem-based learning (PBL) is more effective than project-based learning (PjBL) in improving the learning outcomes of energy-saving science materials for elementary school students. These findings support the constructivist view that knowledge is actively constructed through a collaborative process of inquiry, investigation, and problem-solving (Piaget & Barbel, 2000; Vygotsky, 1978). PBL learning provides an environment where students are directly involved in contextual problems related to energy so that they are able to connect scientific concepts with real situations.

The stronger performance of PBL may be associated with the intensive inquiry processes embedded in PBL environments. Students are continuously engaged in problem identification, hypothesis generation, evidence evaluation, and conceptual reflection. Compared with PjBL, PBL appears to provide more focused opportunities for scientific reasoning within a shorter instructional duration. Consequently, students may achieve stronger conceptual understanding before progressing to product-development activities (Loyens et al., 2025; Yew & Schmidt, 2012) .

The advantages of PBL in this study are also supported by the suitability with the characteristics of the subject matter. Energy-saving material that is contextual and demands scientific reasoning. Students in PBL learning are encouraged to analyze problems, discuss alternative solutions, and reflect on scientific concepts collaboratively. These activities support a deeper conceptual understanding and strengthen student involvement in problem-solving (Miller & Krajcik, 2019; Savery, 2006).

The findings of this study indicate that the learning outcomes of students who study with Project are lower than students who study with PBL. One of the reasons is the time factor, where project activities require longer implementation time and more structured scaffolding so that students' conceptual understanding can develop optimally (Guo et al., 2020; Krajcik, 2015). The potential of PjBL to provide meaningful learning in science lessons in schools is still a challenge for students and its implementation is still being developed (Severance et al., 2025).

The results of the study also show that the diversity of student learning styles has a significant effect on the learning outcomes of Energy Saving Material Science. Students who demonstrate active engagement and hands-on learning experience have higher learning outcomes, especially in PBL learning environments. These findings show the importance of adaptive and student-centered learning strategies in supporting learning success in elementary schools (Tomlinson, 2017; UNESCO, 2021).

These findings also support contemporary educational technology perspectives that advocate adaptive and learner-centered learning environments. The significant interaction between instructional models and learning style indicates that effective science instruction should not rely on a single instructional approach but should accommodate learner diversity through adaptive inquiry-based learning strategies. Such environments are increasingly recognized as essential components of educational innovation in elementary science education (Lee & Hannafin, 2016; Sayadi & Pangandaman, 2025).

The significant interaction between instructional models and learner characteristics suggests that inquiry-based learning effectiveness is influenced by learning style. Students with stronger experiential inquiry preferences appear to benefit more from learning environments that emphasize active investigation and collaborative problem-solving. This finding reinforces the importance of differentiated instructional strategies that align learning experiences with students' engagement preferences and learning needs (Tomlinson, 2017).

From a theoretical perspective, the findings extend current inquiry-learning literature by demonstrating that the effectiveness of inquiry-based instructional models is not solely determined by the instructional strategy itself but also by learner characteristics. This finding supports contemporary perspectives on adaptive learning and differentiated instruction, which emphasize the alignment between learning environments and learner diversity to optimize educational outcomes (Lee & Hannafin, 2016; Tomlinson, 2017).

Limitations and Future Research

The research findings confirm the importance of the application of innovative and student-centered learning in supporting the development of inquiry and problem-solving skills in elementary school science learning. Further research is suggested to develop technology-based inquiry learning with a wider sample and a longer duration of implementation (Almulla, 2020; Miller & Krajcik, 2019; Saavedra & Rapaport, 2024).

5. CONCLUSION

This study concludes that problem-based learning (PBL) is more effective than project-based learning (PjBL) in improving the learning outcomes of science and energy saving for elementary school students on energy-saving materials. Inquiry-based problem-solving activities in PBL provide stronger support for conceptual understanding, active engagement, and student collaboration. The learning styles also has a significant effect on the learning outcomes of energy-saving materials. The significant interaction between learning models and student learning style suggests that effective learning needs to accommodate the diversity of student learning engagement. These findings contribute to the growing discourse on innovative science pedagogy by emphasizing the importance of inquiry-based learning, learner-centered instruction, and adaptive educational practices in elementary science education. The study also supports the implementation of active learning environments aligned with 21st-century educational goals, particularly in developing students' scientific reasoning and problem-solving competencies (OECD, 2019; UNESCO, 2021).

The most important practical aspect of the study's findings is expected to enable educators to respond to individual differences and needs, such that schools can enable all children to discover positive pathways to adulthood (Darling-Hammonda et al., 2020) and to fulfil students wellbeing(OECD, 2025) .

Author Contributions:

Conceptualization, [RAM, INSD, NCS]; **Methodology**, [INSD, RAM]; **Software,** [RAM)]; **Validation**, [RAM, NCS]; **Formal Analysis**, [RAM]; **Investigation**, [RAM]; **Resources**, [RAM]; **Data Curation**, [RAM]; **Writing—Original Draft Preparation**, [RAM, NCS]; **Writing—Review & Editing**, [NCS]; **Visualization**, [NCS]; **Supervision**, [INSD, NCS]; All authors have read and agreed to the published version of the manuscript.

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