

Advancing SDG 4 through Kosifacay Media-Assisted Problem-Based Learning: Effects on Elementary Students' Learning Interest and Conceptual Understanding

Yuan Alfa Yoga Winarta^{1*}, Joko Sulianto¹, Iin Purnamasari¹

¹ Master of Elementary Education, Graduate School, Universitas PGRI Semarang (UPGRIS), Semarang, Indonesia.

Received: June 07, 2026

Revised: August 15, 2026

Accepted: August 24, 2026

Published: August 31, 2026

Corresponding Author:

Yuan Alfa Yoga Winarta

you.one91@gmail.com

DOI: [10.29303/jppipa.v12i8.15950](https://doi.org/10.29303/jppipa.v12i8.15950)

 Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)



Abstract: Advancing Sustainable Development Goal (SDG) 4 requires student-centered instructional approaches that improve both cognitive and affective learning outcomes. This study examined the effectiveness of Kosifacay media-assisted Problem-Based Learning (PBL) in enhancing Grade V elementary students' learning interest and conceptual understanding of the properties of light. A quasi-experimental study employing a Matching Only Pretest-Posttest Control Group Design was conducted using intact classroom groups comprising 43 students (15 experimental and 28 control) from two public elementary schools in Blora Regency, Indonesia. The unequal group sizes reflected naturally existing classrooms where random assignment was not feasible. Data were collected using a 20-item learning interest questionnaire and a 30-item conceptual understanding test and analyzed using descriptive statistics, multivariate analysis of variance (MANOVA), and Cohen's d. MANOVA revealed a significant multivariate effect of Kosifacay media-assisted PBL on learning interest and conceptual understanding (Pillai's Trace = 0.73, $p < .001$), with moderate effect sizes for learning interest ($d = 0.42$) and conceptual understanding ($d = 0.50$). These findings suggest that integrating Kosifacay media with PBL effectively enhances elementary students' learning outcomes while supporting the implementation of SDG 4: Quality Education.

Keywords: Conceptual understanding; Kosifacay media; Learning interest; Problem-based learning; Quality education; SDG 4

Introduction

Improving the quality of science education has become a global priority in achieving Sustainable Development Goal (SDG) 4, which seeks to ensure inclusive, equitable, and quality education while promoting lifelong learning opportunities for all. Within this global agenda, elementary science education plays a fundamental role in equipping students with scientific literacy, critical thinking, and problem-solving skills that enable them to understand natural phenomena and apply scientific knowledge in everyday life. Achieving these outcomes requires instructional approaches that move beyond knowledge transmission toward student-centered learning, where learners actively construct conceptual understanding through meaningful inquiry,

collaboration, and authentic learning experiences. Such approaches not only strengthen students' cognitive achievement but also foster learning interest, engagement, and long-term motivation, all of which are essential for improving the quality and sustainability of science education. Consequently, integrating innovative, student-centered pedagogies has become increasingly important for supporting high-quality elementary science learning and advancing the successful implementation of SDG 4: Quality Education (Chen & Xiao, 2024; David & Weinstein, 2024; Howard et al., 2021; Suhelayanti et al., 2023; Smith et al., 2022; Yu & Zin, 2023; Asfiya & Widiyono, 2025).

Despite the global emphasis on improving science education, many elementary students continue to

How to Cite:

Winarta, Y. A. Y., Sulianto, J., & Purnamasari, I. (2026). Article Advancing SDG 4 through Kosifacay Media-Assisted Problem-Based Learning: Effects on Elementary Students' Learning Interest and Conceptual Understanding. *Jurnal Penelitian Pendidikan IPA*, 12(8), 19-32. <https://doi.org/10.29303/jppipa.v12i8.15950>

experience difficulties in developing scientific literacy and conceptual understanding, particularly when learning abstract scientific concepts that require inquiry, reasoning, and evidence-based explanations (OECD, 2023). These challenges are also evident in Indonesia. The Programme for International Student Assessment (PISA) 2022 reported that Indonesian students achieved an average science score of 383, substantially below the OECD average, indicating persistent weaknesses in scientific reasoning, conceptual understanding, and the application of scientific knowledge to real-world contexts (OECD, 2023). At the elementary level, science instruction remains predominantly teacher-centered, limiting students' opportunities to actively construct knowledge through inquiry, collaboration, and problem-solving activities. As a result, students often rely on memorization rather than developing meaningful conceptual understanding, leading to low learning interest and inadequate mastery of science concepts (Julianto et al., 2023). Similar conditions were identified in this study at SDN 1 Jepangrejo and SDN Kauman, Blora Regency. Preliminary classroom observations and interviews with Grade V teachers revealed that science lessons were primarily delivered through lectures and written assignments, with limited implementation of student-centered learning models or concrete instructional media. Consequently, students demonstrated low classroom participation and experienced difficulties in understanding the properties of light. Furthermore, school assessment records showed that only 18 of 43 Grade V students (41.86%) achieved the Minimum Learning Competency Criteria (KKTP) prior to the instructional intervention, highlighting the urgent need for innovative, student-centered instructional approaches that can improve both learning interest and conceptual understanding.

Addressing these challenges is particularly important in the Indonesian educational context, where improving science learning has become a national priority following the implementation of the Merdeka Curriculum. The curriculum emphasizes student-centered learning, inquiry-based activities, collaboration, and meaningful learning experiences to develop higher-order thinking skills and scientific literacy. Within elementary Natural and Social Sciences (IPAS), students are expected to investigate natural phenomena, solve authentic problems, and construct scientific knowledge through direct experience rather than passive memorization. These expectations are especially relevant to the topic of light properties, which is inherently abstract and often difficult for elementary students to understand without concrete learning experiences and active exploration. However, classroom instruction continues to be dominated by teacher-centered practices, limiting opportunities for students to

investigate scientific phenomena, interact with learning materials, and develop meaningful conceptual understanding. Consequently, innovative instructional approaches that integrate student-centered pedagogy with appropriate instructional media are urgently needed to support the effective implementation of the Merdeka Curriculum, improve students' learning interest and conceptual understanding, and ultimately contribute to achieving Sustainable Development Goal 4 (Quality Education) (Asnawi et al., 2023; Halim et al., 2024).

Among the instructional approaches recommended for improving elementary science learning, Problem-Based Learning (PBL) has consistently been recognized as an effective student-centered pedagogy. Grounded in constructivist learning theory, PBL encourages students to actively construct knowledge through authentic problem solving, collaborative inquiry, reflection, and evidence-based reasoning rather than passively receiving information from teachers (Anggraeni et al., 2023). By engaging students in meaningful scientific investigations, PBL promotes conceptual understanding, critical thinking, and sustained learning motivation. Previous studies have consistently reported that PBL improves students' conceptual understanding, learning interest, motivation, and overall science achievement by increasing active participation and meaningful engagement throughout the learning process (Neroni et al., 2024; Hidayati & Purwaningsih, 2023; Rizki & Suprpto, 2024).

In addition to pedagogical approaches, the availability of appropriate instructional media plays an important role in facilitating elementary students' understanding of abstract science concepts. Kosifacay media has been developed as a concrete learning medium that enables students to observe scientific phenomena directly and construct concepts through hands-on experimentation. Such concrete learning experiences are particularly beneficial for learning abstract topics, including the properties of light, because they bridge the gap between theoretical explanations and observable scientific phenomena. Previous studies have demonstrated that Kosifacay media enhances students' science achievement, classroom engagement, and conceptual understanding in elementary science learning (Smith et al., 2022; Yu & Zin, 2023; Asfiya & Widiyono, 2025). These findings indicate that both Problem-Based Learning and Kosifacay media have considerable potential to improve the quality of elementary science instruction by promoting active participation and meaningful learning experiences.

Previous studies have demonstrated the effectiveness of Problem-Based Learning (PBL) in fostering students' higher-order thinking skills, conceptual understanding, and learning motivation,

while separate investigations have shown that Kosifacay media enhances science achievement, classroom engagement, and conceptual understanding through concrete learning experiences (Smith et al., 2022; Yu & Zin, 2023; Asfiya & Widiyono, 2025; Liu & Pásztor, 2022; Lonergan et al., 2022; Rafie-Papkiadeh et al., 2024). However, these studies have generally examined PBL and concrete instructional media as independent interventions rather than as an integrated instructional approach. Moreover, existing research has predominantly focused on single learning outcomes, such as science achievement, classroom participation, or conceptual understanding, with limited attention to the simultaneous development of students' learning interest and conceptual understanding, which are complementary dimensions of meaningful science learning. Therefore, empirical evidence regarding the effectiveness of integrating Kosifacay media-assisted Problem-Based Learning remains limited, particularly in elementary science learning involving abstract topics such as the properties of light. This study proposes an integrated instructional framework that combines Problem-Based Learning with Kosifacay media to simultaneously enhance elementary students' learning interest and conceptual understanding. By examining both cognitive and affective learning outcomes within a single quasi-experimental study, this research extends previous work and provides new empirical evidence supporting the implementation of SDG 4 (Quality Education) through innovative, student-centered elementary science instruction.

Based on the identified research gap, this study aims to examine the effectiveness of Kosifacay media-assisted Problem-Based Learning (PBL) in enhancing elementary students' learning interest and conceptual understanding of the properties of light. Specifically, the study investigates the effects of the proposed instructional approach on students' learning interest, conceptual understanding, and the simultaneous improvement of both learning outcomes compared with conventional instruction. By providing empirical evidence on the integration of student-centered pedagogy and concrete instructional media, this study is expected to contribute to the growing body of knowledge on elementary science education and offer practical implications for implementing SDG 4 (Quality Education) through innovative and meaningful science learning.

Method

Research Design

This study adopted a quasi-experimental research design employing a Matching Only Pretest-Posttest Control Group Design to evaluate the effectiveness of

Problem-Based Learning (PBL) assisted by Kosifacay media in improving elementary students' learning interest and conceptual understanding of the properties of light. A quasi-experimental design was considered appropriate because the participating schools had already established Grade V classroom structures, making the random assignment of students to experimental and control groups neither administratively feasible nor ethically appropriate. Therefore, the study was conducted using intact classroom groups, a methodological approach commonly applied in educational research conducted under authentic school conditions (Fraenkel et al., 2024; Creswell & Creswell, 2023).

To enhance baseline comparability and minimize potential selection bias, the experimental and control groups were matched based on students' previous science achievement prior to the implementation of the intervention. The experimental group participated in Problem-Based Learning integrated with Kosifacay media, whereas the control group received conventional teacher-centered instruction covering the same curriculum content and learning objectives. In this study, the independent variable was the implementation of Kosifacay media-assisted Problem-Based Learning, while the dependent variables were students' learning interest and conceptual understanding of the properties of light.

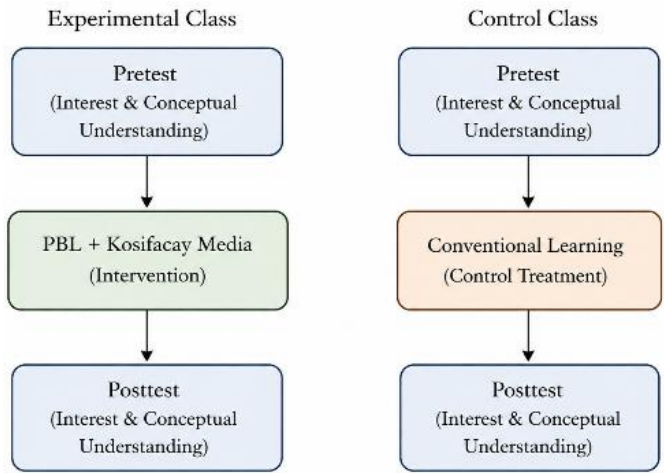


Figure 1. Research design

The overall research framework is presented in Figure 1, illustrating the participant selection process, matching procedure, assignment of intact classroom groups, implementation of the instructional intervention, and the subsequent stages of data collection and statistical analysis.

Participants

The study was conducted during the second semester of the 2025/2026 academic year at two public elementary schools in Blora Regency, Central Java, Indonesia, namely SDN 1 Jepangrejo and SDN Kauman, where the Merdeka Curriculum had been implemented in Grade V Natural and Social Sciences (IPAS). The study population comprised all Grade V students enrolled in both schools who had completed the same science curriculum prior to the intervention.

A purposive sampling technique was employed because the classroom organization in the participating schools could not be modified during the research period. Consequently, random assignment of students to experimental and control groups was not feasible. Consistent with the Matching Only Pretest-Posttest Control Group Design, the study utilized intact classroom groups, and the experimental and control classes were selected based on comparable previous science achievement to establish baseline equivalence

and reduce potential selection bias before the intervention (Cohen et al., 2024; Nofitri et al., 2024).

A total of 43 Grade V students participated in the study, consisting of 15 students from SDN 1 Jepangrejo assigned to the experimental group and 28 students from SDN Kauman assigned to the control group. The unequal group sizes reflected the actual enrollment of Grade V students in each participating school because the study was conducted using naturally existing classrooms rather than researcher-assigned groups. Although the sample sizes differed between groups, baseline comparability was established through matching based on previous science achievement prior to the intervention. During the study, the experimental group received Problem-Based Learning assisted by Kosifacay media, whereas the control group received conventional teacher-centered instruction covering the same curriculum content and learning objectives. The demographic characteristics of the participants are presented in Table 1.

Table 1. Characteristics of research participants

Group	School	Grade	n	Learning Treatment
Experimental	SDN 1 Jepangrejo	V	15	Problem-Based Learning assisted by Kosifacay media
Control	SDN Kauman	V	28	Conventional teacher-centered learning
Total			43	

Research Procedures

The research was implemented through four sequential stages: preparation, pretest, treatment, and posttest, to ensure the systematic execution of the instructional intervention.

The preparation stage involved obtaining research permission from the participating schools, developing

and validating the learning and research instruments, and selecting the experimental and control classes based on comparable previous science achievement. Lesson plans and instructional materials were also prepared to ensure that both groups received identical curriculum content and learning objectives throughout the study.

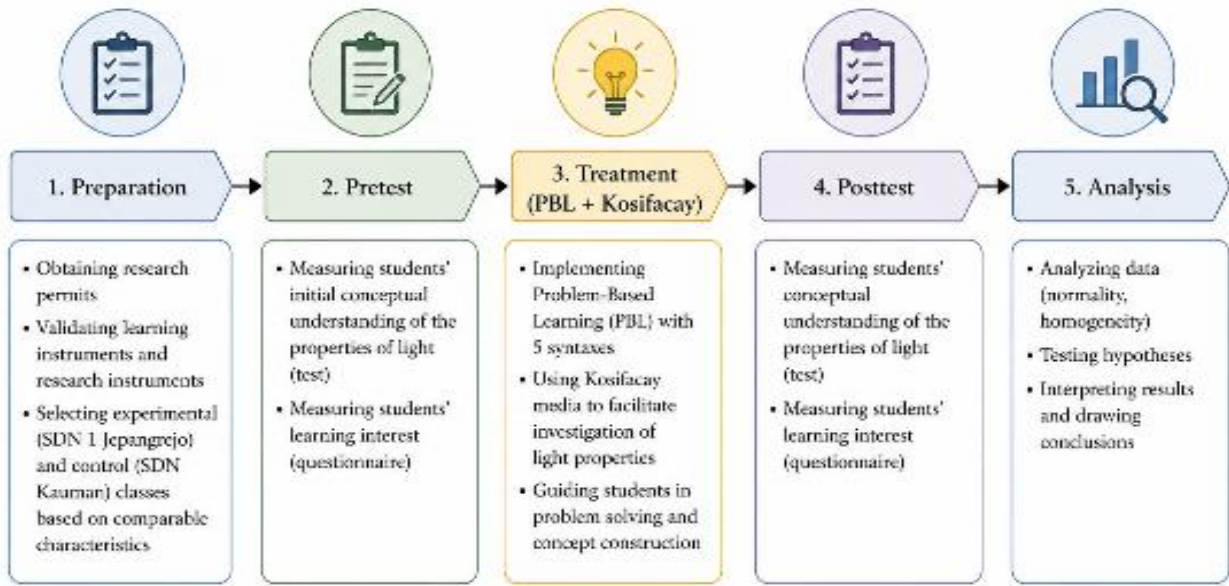


Figure 2. Research procedure

Table 2. Research instruments

Instrument	Variable	Indicators	Scale	Items
Learning Interest Questionnaire	Learning Interest	Feeling of enjoyment, interest, attention, involvement	4-point Likert	20
Conceptual Understanding Test	Conceptual Understanding	Reflection, refraction, light transmission, straight-line propagation, light dispersion, integrated concepts (C4–C6)	Objective test	30

Before the instructional intervention, students in both the experimental and control groups completed a conceptual understanding pretest, while their initial learning interest was measured using a standardized questionnaire. The collected data served as baseline information for evaluating the effectiveness of the intervention.

Implementation of the treatment consisted of applying Problem-Based Learning (PBL) assisted by Kosifacay media in the experimental group through five instructional phases: problem orientation, problem organization, guided investigation, development and presentation of solutions, and evaluation and reflection. Integration of Kosifacay media enabled students to observe scientific phenomena directly, conduct hands-on investigations, and construct conceptual understanding through authentic learning experiences. In contrast, the control group participated in conventional teacher-centered instruction covering the same curriculum content and learning objectives.

Completion of the intervention was followed by administering the conceptual understanding posttest and the learning interest questionnaire to both groups using the same instruments employed during the pretest. The resulting data were analyzed to determine the effectiveness of Kosifacay media-assisted Problem-Based Learning on students' learning interest and conceptual understanding. Figure 2 summarizes the overall research procedure.

A summary of the research instruments is presented in Table 2, while the results of the validity and reliability analyses are described in the subsequent subsection.

Instrument Validation and Reliability

Prior to data collection, all research instruments underwent content validation to ensure their appropriateness for measuring the intended constructs. The learning interest questionnaire and conceptual understanding test were reviewed by experts in elementary science education and educational assessment, who evaluated each instrument in terms of content relevance, construction, language clarity, and presentation quality. Revisions were made based on the experts' recommendations before the instruments were administered in the pilot study.

Following expert validation, a pilot study involving 30 Grade V students was conducted to examine the

psychometric properties of the instruments before their implementation in the main study. Item validity was assessed using the Pearson Product–Moment correlation coefficient at a significance level of 5% ($r_{table} = 0.361$, $n = 30$). The results indicated that all 20 items of the Learning Interest Questionnaire ($r_{count} = 0.669$ – 0.886) and all 30 items of the Conceptual Understanding Test ($r_{count} = 0.380$ – 0.890) exceeded the minimum validity criterion, indicating that all items were statistically valid.

Instrument reliability was subsequently evaluated using Cronbach's alpha coefficient to determine internal consistency. The Learning Interest Questionnaire achieved a Cronbach's alpha value of 0.966, while the Conceptual Understanding Test obtained a value of 0.958. Both coefficients exceeded the recommended threshold for educational research, indicating excellent internal consistency and confirming that the instruments were reliable for measuring students' learning interest and conceptual understanding in the main study.

Data Collection

Data were collected systematically at four stages of the study, namely pre-intervention, during the intervention, post-intervention, and documentation. Prior to the instructional intervention, students in both the experimental and control groups completed the Conceptual Understanding Test to establish baseline cognitive achievement. Baseline data on students' learning interest were simultaneously obtained using the Learning Interest Questionnaire.

Throughout the intervention, classroom implementation was monitored to ensure that the instructional procedures were conducted according to the research design. The experimental group participated in Problem-Based Learning (PBL) assisted by Kosifacay media, whereas the control group received conventional teacher-centered instruction covering the same curriculum content and learning objectives.

Following completion of the intervention, both groups completed the Conceptual Understanding Test and the Learning Interest Questionnaire using the same instruments administered during the pre-intervention stage. Additional supporting data were collected through documentation, including lesson plans, instructional materials, classroom implementation records, and photographs of learning activities, to verify

the fidelity of the intervention and support the interpretation of the research findings.

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics version 27 and consisted of descriptive and inferential statistical analyses. Descriptive statistics were first calculated to summarize students' learning interest and conceptual understanding scores, including the mean, standard deviation, minimum, and maximum values for both the experimental and control groups.

Prior to hypothesis testing, the assumptions underlying parametric analyses were evaluated. Data normality was examined using the Shapiro-Wilk test, while the homogeneity of variances was assessed using Levene's test, both at a significance level of 0.05. These preliminary analyses ensured that the data met the assumptions required for subsequent parametric testing.

Changes in students' learning interest and conceptual understanding within each group were examined using the Paired Samples t-test, which compared pretest and posttest scores to determine the

effectiveness of the instructional intervention over time. To evaluate the overall effectiveness of the intervention between the experimental and control groups, Multivariate Analysis of Variance (MANOVA) was employed because the study simultaneously investigated two correlated dependent variables, namely learning interest and conceptual understanding. Considering the unequal sample sizes between the two groups, Pillai's Trace was selected as the primary multivariate test statistic because it is widely regarded as the most robust criterion under conditions of unequal group sizes and potential violations of multivariate assumptions (Tabachnick & Fidell, 2019).

The practical significance of the intervention was further examined using Cohen's d effect size, with values of 0.20, 0.50, and 0.80 interpreted as small, medium, and large effects, respectively Cohen et al. (2024). In addition, the proportion of variance explained by the instructional intervention was interpreted using the coefficient of determination (R^2) where appropriate. A summary of the statistical analyses performed in this study is presented in Table 3.

Table 3. Summary of data analysis

Analysis		Purpose
Descriptive Statistics	Summarize the distribution of learning interest and conceptual understanding scores.	
Shapiro-Wilk Test		Examine the assumption of normality.
Levene's Test		Examine the assumption of homogeneity of variance.
Paired Sample t-Test	Determine the effect of the instructional treatment by comparing pretest and posttest scores within the experimental group.	
MANOVA (Pillai's Trace)	Examine the simultaneous effect of the instructional treatment on learning interest and conceptual understanding between groups.	
Cohen's d and R^2	Determine the magnitude and practical significance of the treatment effect.	

Result and Discussion

This study investigated the effectiveness of Problem-Based Learning assisted by Kosifacay media in improving Grade V elementary students' learning interest and conceptual understanding of the properties of light. The analyzed data consisted of students' pretest and posttest scores on conceptual understanding as well as responses to the learning interest questionnaire collected from both the experimental and control groups. The study focused on two dependent variables, namely learning interest and conceptual understanding, measured using a 20-item learning interest questionnaire and a 30-item conceptual understanding test, respectively. The findings are presented according to the research objectives and hypotheses, beginning with the effect of the instructional intervention on learning interest, followed by conceptual understanding, and finally the simultaneous effect on both learning outcomes.

Effect of Problem-Based Learning Assisted by Kosifacay Media on Students' Learning Interest

This section presents the findings related to the first research objective, namely to examine the effect of Problem-Based Learning assisted by Kosifacay media on Grade V students' learning interest in learning the properties of light. The results are presented through descriptive statistics, changes in students' learning interest categories, and inferential statistical analysis to provide comprehensive evidence regarding the effectiveness of the instructional intervention.

Table 4. Descriptive statistics of students' learning interest scores

Group	n	Minimum	Maximum	Mean	SD
Experimental (Pretest)	15	36	52	44.20	4.52
Experimental (Posttest)	15	54	69	61.40	4.01
Control (Pretest)	28	45	57	50.68	3.26
Control (Posttest)	28	43	56	49.07	3.11

Table 4 shows that students in the experimental group demonstrated a substantial increase in learning interest after the implementation of Problem-Based Learning assisted by Kosifacay media. The mean score increased from 44.20 on the pretest to 61.40 on the posttest, indicating an improvement of 17.20 points. In

contrast, the control group showed a slight decrease in the mean score from 50.68 to 49.07 following conventional instruction. These findings suggest that students receiving the instructional intervention exhibited greater improvement in learning interest than those taught using conventional learning methods.

Table 5. Distribution of students' learning interest categories

Category	Experimental Pretest (n = 15)	Experimental Posttest (n = 15)	Control Pretest (n = 28)	Control Posttest (n = 28)
Very Good	0 (0.0%)	2 (13.3%)	0 (0.0%)	0 (0.0%)
Good	1 (6.7%)	13 (86.7%)	16 (57.1%)	12 (42.9%)
Moderate	14 (93.3%)	0 (0.0%)	12 (42.9%)	16 (57.1%)
Poor	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

As presented in Table 5, the distribution of learning interest categories in the experimental group changed markedly following the implementation of Problem-Based Learning assisted by Kosifacay media. Before the intervention, 93.3% of students were categorized as having moderate learning interest, while only 6.7% were classified in the good category. After the intervention, the distribution shifted substantially, with 86.7% of students reaching the good category and 13.3% achieving the very good category. No students remained in the moderate or poor categories after the instructional intervention.

In contrast, the control group did not demonstrate comparable improvement following conventional instruction. Before the intervention, 57.1% of students were already classified in the good category and 42.9% in the moderate category. However, after the learning process, the proportion of students in the good category decreased to 42.9%, whereas the percentage of students in the moderate category increased to 57.1%. These findings indicate that conventional learning was less effective in enhancing students' learning interest than Problem-Based Learning assisted by Kosifacay media.

Table 6. Results of the paired sample t-test and effect size for learning interest

Variable	Mean Difference	T	df	p	Cohen's d	Interpretation
Learning Interest	4.953	2.748	42	.009	0.419	Moderate

The results of the Paired Sample t-test revealed a statistically significant difference between the pretest and posttest learning interest scores ($t = 2.748$, $p = .009$). Because the probability value was lower than 0.05, the first hypothesis was accepted, indicating that Problem-Based Learning assisted by Kosifacay media significantly improved students' learning interest. Furthermore, the calculated Cohen's d value of 0.419 indicates a moderate effect size, suggesting that the instructional intervention produced a meaningful improvement in students' learning interest.

The findings confirm that Problem-Based Learning assisted by Kosifacay media significantly enhanced Grade V students' learning interest in learning the properties of light. Therefore, the first research objective and the first research hypothesis were successfully achieved.

Effect of Problem-Based Learning Assisted by Kosifacay Media on Students' Conceptual Understanding

This section presents the findings related to the second research objective, namely to examine the effect of Problem-Based Learning (PBL) assisted by Kosifacay media on Grade V students' conceptual understanding of the properties of light. The results are presented

sequentially through descriptive statistics, the distribution of conceptual understanding categories, hypothesis testing using the Paired Sample t-test, and effect size analysis to provide comprehensive evidence regarding the effectiveness of the instructional intervention.

Table 7. Descriptive statistics of students' conceptual understanding scores

Group	n	Minimum	Maximum	Mean	SD
Experimental (Pretest)	15	15	25	19.67	2.795
Experimental (Posttest)	15	25	35	29.60	2.849
Control (Pretest)	28	12	27	19.89	3.765
Control (Posttest)	28	12	28	20.25	4.317

Table 7 shows that students who learned through Problem-Based Learning assisted by Kosifacay media experienced a substantial improvement in conceptual understanding after the instructional intervention. The mean score of the experimental group increased from 19.67 (SD = 2.795) on the pretest to 29.60 (SD = 2.849) on the posttest, representing an average gain of 9.93 points.

In addition, the minimum score increased from 15 to 25, while the maximum score increased from 25 to 35, indicating that learning gains occurred across students with different initial achievement levels. Conversely, the control group demonstrated only a marginal improvement, with the mean score increasing from 19.89 (SD = 3.765) to 20.25 (SD = 4.317). The minimum score

remained unchanged at 12, whereas the maximum score increased only slightly from 27 to 28. Overall, these descriptive findings indicate that students receiving Problem-Based Learning assisted by Kosifacay media achieved considerably greater conceptual understanding than those who participated in conventional learning.

Table 8. Distribution of students' conceptual understanding categories

Category	Experimental Pretest (n = 15)	Experimental Posttest (n = 15)	Control Pretest (n = 28)	Control Posttest (n = 28)
Good	0 (0.0%)	15 (100.0%)	16 (57.1%)	12 (42.9%)
Moderate	13 (86.7%)	0 (0.0%)	12 (42.9%)	16 (57.1%)
Poor	2 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

As presented in Table 8, the distribution of conceptual understanding categories in the experimental group improved markedly following the implementation of Problem-Based Learning assisted by Kosifacay media. Prior to the intervention, 86.7% of students were categorized as having moderate conceptual understanding, while 13.3% were classified as poor, indicating that none of the students had achieved the good category. After the intervention, all students (100.0%) reached the good category, demonstrating a complete transition toward higher conceptual understanding.

In contrast, the control group did not demonstrate comparable improvement after conventional instruction. Before the intervention, 57.1% of students were already classified in the good category and 42.9% in the moderate category. However, after the learning process, the proportion of students in the good category decreased to 42.9%, whereas the percentage of students in the moderate category increased to 57.1%. These findings further indicate that conventional learning was less effective in improving students' conceptual understanding than Problem-Based Learning assisted by Kosifacay media.

Table 9. Results of the paired sample t-test and effect size for conceptual understanding

Variable	Mean Difference	t	p	Cohen's d	Interpretation
Conceptual Understanding	9.93	3.290	.002	0.502	Moderate to large

The Paired Sample t-test revealed a statistically significant difference between the pretest and posttest conceptual understanding scores of students in the experimental group ($t = 3.290$, $p = .002$). Since the significance value was lower than the predetermined significance level of 0.05, the second research hypothesis was accepted. These results indicate that Problem-Based Learning assisted by Kosifacay media significantly improved students' conceptual understanding of the properties of light. Furthermore, the calculated Cohen's

d value of 0.502 indicates a moderate-to-large effect size, demonstrating that the instructional intervention produced not only statistically significant but also educationally meaningful improvements in students' conceptual understanding.

The findings demonstrate that the implementation of Problem-Based Learning assisted by Kosifacay media significantly enhanced Grade V students' conceptual understanding of the properties of light. The substantial increase in descriptive statistics, the complete shift toward the good conceptual understanding category, and the significant results of the Paired Sample t-test with a moderate-to-large effect size collectively support the second research objective and confirm the acceptance of the second research hypothesis.

Simultaneous Effect of Problem-Based Learning Assisted by Kosifacay Media on Students' Learning Interest and Conceptual Understanding

This section presents the findings related to the third research objective, namely to examine the simultaneous effect of Problem-Based Learning (PBL) assisted by Kosifacay media on Grade V students' learning interest and conceptual understanding of the properties of light. The multivariate analysis was conducted using Multivariate Analysis of Variance (MANOVA) to determine whether the instructional intervention simultaneously influenced both dependent variables.

Table 10. Results of multivariate analysis of variance (MANOVA)

Multivariate Test	Value	F	Hypothesis df	Error df	p
Pillai's Trace	0.733	54.870	2	40	< .001
Wilks' Lambda	0.267	54.870	2	40	< .001
Hotelling's Trace	2.743	54.870	2	40	< .001
Roy's Largest Root	2.743	54.870	2	40	< .001

Table 10 presents the results of the multivariate analysis examining the simultaneous effect of Problem-Based Learning assisted by Kosifacay media on students' learning interest and conceptual understanding.

Considering the unequal sample sizes between the experimental and control groups, Pillai's Trace was used as the primary multivariate statistic because it provides a robust estimate under such conditions. The analysis yielded a Pillai's Trace value of 0.733, with $F(2, 40) = 54.870$ and $p < .001$, indicating a statistically significant multivariate effect of the instructional treatment on the combined dependent variables. These findings demonstrate that the instructional intervention simultaneously influenced students' learning interest and conceptual understanding.

To determine the practical significance of the multivariate effect, the coefficient of determination (R^2) was examined for each dependent variable. The results showed that the instructional treatment explained 53.4% of the variance in learning interest ($R^2 = 0.534$) and 58.1% of the variance in conceptual understanding ($R^2 = 0.581$). These coefficients indicate that more than half of the variation in both learning outcomes was attributable to the implementation of Problem-Based Learning assisted by Kosifacay media, suggesting a substantial educational impact of the intervention.

Discussion

Problem-Based Learning assisted by Kosifacay media produced a significant improvement in students' learning interest. Such improvement can be interpreted from the perspective of constructivist learning theory, which conceptualizes learning as an active process in which learners construct knowledge through interaction, exploration, and reflection rather than passively receiving information. From this perspective, student-centered learning environments characterized by active participation, collaborative inquiry, and authentic problem-solving activities are more likely to foster students' engagement, motivation, and interest in science learning (Safitri et al., 2023; Apriansyah et al., 2024). Within the PBL environment, students were encouraged to investigate authentic problems, collaborate with peers, and formulate solutions based on direct observations, creating meaningful learning experiences that increased students' engagement, curiosity, and active participation during science learning (Aripin et al., 2025).

Student-centered learning principles also suggest that learning motivation increases when students experience autonomy, competence, and collaborative interaction throughout instructional activities (Irwandi et al., 2024; Pangestu et al., 2024; Auliya et al., 2025). In the present study, students actively investigated the properties of light using Kosifacay media, discussed experimental findings within their groups, and presented solutions to contextual problems. Such activities provided opportunities for autonomous learning, collaborative interaction, and successful

problem solving, thereby strengthening students' intrinsic interest in learning science (Gunawan & Al, 2025).

A growing body of empirical evidence suggests that Problem-Based Learning improves students' learning motivation, classroom engagement, and learning interest because it actively involves learners in collaborative inquiry and authentic problem-solving experiences (Simanjuntak et al., 2024; Marhami et al., 2024). Likewise, previous studies have demonstrated that concrete instructional media enhance students' enthusiasm, participation, and conceptual understanding by transforming abstract scientific concepts into observable and meaningful learning experiences (Putri et al., 2025; Setianingsih et al., 2024; Anas et al., 2024). However, unlike previous studies that examined Problem-Based Learning and instructional media separately, this study integrated Problem-Based Learning with Kosifacay media into a single instructional framework, whereas previous studies generally focused either on developing PBL-based learning media or implementing PBL with different instructional media without specifically integrating a concrete learning medium designed for elementary science learning (Pratama et al., 2024). This integration represents the principal novelty of the study because students not only solved contextual problems but also verified their ideas through direct experimentation using concrete media. Consequently, learning became more meaningful, interactive, and motivating, demonstrating that combining student-centered pedagogy with concrete instructional media provides greater educational benefits than implementing either component independently (Nurhamidah et al., 2023).

Students' conceptual understanding improved substantially following the implementation of Problem-Based Learning assisted by Kosifacay media. This outcome is closely related to the cognitive characteristics of elementary school students, who are generally at Piaget's concrete operational stage and therefore learn scientific concepts more effectively through direct experiences than through abstract verbal explanations. Throughout the learning process, Kosifacay media provided opportunities for students to directly observe light reflection, refraction, transmission, and shadow formation, allowing them to connect scientific concepts with authentic observations and hands-on experimentation. Such learning experiences are consistent with the Cognitive Theory of Multimedia Learning, which suggests that conceptual understanding becomes deeper when verbal explanations are integrated with meaningful visual representations and practical activities, thereby reducing cognitive load and facilitating more effective knowledge construction (Mayer, 2021). Similar findings

have been reported in recent studies demonstrating that the integration of interactive learning media and problem-based learning facilitates deeper conceptual understanding by promoting active exploration, visualization, and meaningful learning experiences (Fajria & Utoyo, 2025; Darmawati et al., 2024; Dewanti et al., 2025).

Results of the present study are consistent with previous research demonstrating that Problem-Based Learning (PBL) improves students' conceptual understanding by engaging them in inquiry, evidence-based reasoning, collaborative problem solving, and active knowledge construction throughout the learning process (Ilahi et al., 2024). Likewise, recent studies have emphasized that the effectiveness of PBL is strengthened when instructional activities integrate inquiry-oriented learning with appropriate instructional media, enabling students to explore scientific phenomena more meaningfully and develop deeper conceptual understanding (Doyan et al., 2024). Similar evidence has also shown that Problem-Based Learning consistently improves students' learning outcomes and conceptual understanding across various educational contexts, particularly when learning activities emphasize active investigation and higher-order thinking (Asmiyunda & Hardeli, 2023). Nevertheless, previous investigations generally examined either instructional media or learning models independently. Recent studies have demonstrated that interactive learning media can improve elementary students' conceptual understanding, although the instructional emphasis remains primarily on media development rather than its integration with inquiry-oriented learning processes (Tirtawati et al., 2025). Likewise, the integration of Problem-Based Learning with digital instructional media has been shown to improve students' understanding of science concepts; however, these studies mainly employed digital game-based media and did not incorporate concrete manipulatives that facilitate direct scientific investigation (Ariyanti et al., 2025). The present study extends this literature by demonstrating that integrating Problem-Based Learning with Kosifacay media creates complementary learning experiences in which contextual problem solving is reinforced through direct scientific investigation. This instructional integration constitutes the principal novelty of the study and provides empirical evidence that combining inquiry-oriented pedagogy with concrete learning media effectively supports higher levels of conceptual understanding in elementary science education.

The significant simultaneous improvement in students' learning interest and conceptual understanding indicates that Problem-Based Learning assisted by Kosifacay media contributes to multiple

dimensions of learning quality rather than improving a single educational outcome. This finding aligns closely with the objectives of Sustainable Development Goal 4 (Quality Education), which emphasizes inclusive, equitable, and high-quality learning experiences that foster meaningful knowledge construction, critical thinking, and lifelong learning competencies. By engaging students in collaborative inquiry, authentic problem solving, and direct experimentation, the instructional intervention created meaningful learning experiences that simultaneously strengthened cognitive achievement and learning motivation. Such characteristics are also consistent with the principles of the Merdeka Curriculum, which encourages student-centered learning, contextual investigation, collaboration, and the development of higher-order thinking skills through authentic learning experiences (Azkia et al., 2025; Maharani et al., 2024).

Compared with previous studies that primarily focused on either learning motivation or conceptual understanding as separate outcomes, the present study provides a more comprehensive evaluation by demonstrating that both variables can be improved simultaneously within a unified instructional framework. The multivariate findings further indicate that the instructional treatment explained a substantial proportion of the variance in both learning interest and conceptual understanding, highlighting the practical significance of integrating innovative pedagogy with concrete instructional media. Accordingly, the study contributes new empirical evidence supporting the implementation of Problem-Based Learning assisted by Kosifacay media as an effective instructional strategy for elementary science education. The findings also provide practical implications for teachers by demonstrating that the integration of contextual problem solving with concrete learning media can facilitate meaningful learning, improve students' engagement and conceptual understanding, and support the successful implementation of the Merdeka Curriculum while advancing the achievement of SDG 4: Quality Education.

Conclusion

This study demonstrated that Problem-Based Learning assisted by Kosifacay media effectively improved Grade V elementary students' learning interest and conceptual understanding of the properties of light. The instructional intervention not only produced significant improvements in each learning outcome individually but also generated a significant simultaneous effect on both variables. These findings indicate that integrating problem-based inquiry with concrete learning media creates meaningful learning

experiences that actively engage students in investigating scientific phenomena, constructing conceptual understanding, and increasing their interest in science learning. Therefore, the study confirms that combining student-centered pedagogy with hands-on instructional media represents an effective strategy for improving the quality of elementary science learning and supports the implementation of Sustainable Development Goal (SDG) 4: Quality Education. The principal contribution of this study lies in the integration of Problem-Based Learning and Kosifacay media within a single instructional framework, enabling simultaneous improvement in students' cognitive and affective learning outcomes. This finding extends previous research that predominantly examined learning models and instructional media separately by providing empirical evidence that their integration produces more comprehensive educational benefits. Practically, the study offers an alternative instructional approach for elementary teachers implementing the Merdeka Curriculum, particularly when teaching abstract science concepts that require concrete learning experiences. Nevertheless, this study was conducted in two elementary schools with a relatively limited sample size and focused on a single science topic. Future studies are therefore recommended to investigate the long-term effectiveness of this instructional approach across different science topics, educational levels, and broader learning contexts while incorporating additional variables such as scientific literacy, critical thinking, or problem-solving skills.

Acknowledgements

The authors would like to express their sincere gratitude to SDN 1 Jepangrejo and SDN Kauman, Blora Regency, for their support and cooperation throughout the implementation of this study. The authors also extend their appreciation to the school principals, Grade V teachers, and all students who participated in the research. Special thanks are addressed to the expert validators for their valuable suggestions in improving the research instruments and to all individuals whose contributions facilitated the successful completion of this study.

Author Contributions

Conceptualization, methodology, formal analysis, Y.A.Y.W. and J.S.; investigation, data curation, resources, visualization, writing—original draft, Y.A.Y.W.; writing—review and editing, supervision, J.S. and I.P. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding and was conducted without financial support from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors declare no conflict of interest. The authors have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Anas, N., Hartono, H., & A, A. (2024). Science Learning Media for Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, 10(1), 9020–9026. <https://doi.org/10.29303/jppipa.v10i11.9227>
- Anggraeni, D. M., Prahani, B. K., Suprpto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic Review of Problem Based Learning Research in Fostering Critical Thinking Skills. *Thinking Skills and Creativity*, 49, 101334. <https://doi.org/10.1016/j.tsc.2023.101334>
- Apriansyah, A. H., Sari, N., Nizaar, M., & Alaa, S. (2024). Project Based Learning Model on Elementary School Students' Science Process Skills and Creative Thinking Skills. *Jurnal Ilmiah Sekolah Dasar*, 8(1), 120–128. <https://doi.org/10.23887/jisd.v8i1.64273>
- Aripin, N., Festiyed, F., Yerimadesi, Y., Alberida, H., Ahda, Y., & Mufit, F. (2025). The Impact of Problem-Based Learning on Science Learning to Improve Students' Critical Thinking and Problem-Solving Skills: A Meta-Analysis. *Jurnal Penelitian Pendidikan IPA*, 11(6), 45–57. <https://doi.org/10.29303/jppipa.v11i6.10051>
- Ariyanti, D., M, R., Sulianto, J., & Buchori, A. (2025). Development of EDUMEDIG Media with the Problem-Based Learning Model to Improve Science Understanding. *Indonesian Journal of Educational Development*, 6(3), 055–1070. <https://doi.org/10.59672/ijed.v6i3.5614>
- Asfiya, M., & Widiyono, A. (2025). Pengaruh Model Ekspositori Berbasis Media Kotak Sifat Cahaya Terhadap Keterampilan Berpikir Kritis pada Siswa Kelas V SD Negeri 2 Terkesi. *Journal of Classroom Action Research*, 7(2), 854–862. <https://doi.org/10.29303/jcar.v7i2.11158>
- Asmiyunda, A., & Hardeli, H. (2023). The Effect of Problem-Based Learning (PBL) on Learning Outcomes: Meta-Analysis. *Pedagogia: Jurnal Ilmu Pendidikan*, 21(2), 161–172. <https://doi.org/10.17509/pdgia.v21i2.65061>
- Asnawi, A., Sahudra, T. M., Ramadhani, D., Kenedi, A. K., Aosi, G., Wardhana, M. R., & Khalil, N. A. (2023). Development of Digital Diagnostic Test Instruments for Differentiated Learning Process in Elementary Schools. *Jurnal Penelitian Pendidikan IPA*, 9(SpecialIssue), 460–466. <https://doi.org/10.29303/jppipa.v9iSpecialIssue.6125>

- Auliya, R. H., Adi, S., B., Rakhmawati, S., Suryani, L., Haliem, D. T., & Pangastuti, P. (2025). Enhancing Third Graders' Understanding of the Water Cycle Through Problem-Based Learning and Wordwall Integration. *Jurnal Prima Edukasia*, 13(2), 324–338. <https://doi.org/10.21831/jpe.v13i2.80657>
- Azkie, S. A., Maksum, A., & Usman, H. (2025). Improving Critical Thinking Abilities in Social Studies Learning Using the Problem Based Learning Model Assisted by Audio-Visual Media in Elementary School Students. *Urnal Cakrawala Pendas*, 11(1), 18–32. <https://doi.org/10.31949/jcp.v11i1.11809>
- Chen, X., & Xiao, Y. (2024). Pathways to Digital Reading Literacy Among Secondary School Students: A Multilevel Analysis Using Data from 31 Economies. *Computers & Education*, 218, Article 105090. <https://doi.org/10.1016/j.compedu.2024.105090>
- Cohen, L., Manion, L., & Morrison, K. (2024). *Research Methods in Education* (9th ed.). Routledge. <https://doi.org/10.4324/9781315456539>
- Creswell, J. W., & Creswell, J. D. (2023). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* ((6th ed.)). SAGE Publications.
- Darmawati, B., D, R., Santiago, S., & S, P. V. D. (2024). Contemporary Mathematics Learning: Instagram-Based Math Learning Medium Increased Elementary School Students' Math Literacy. *Journal of Teaching and Learning Mathematics*, 12(2), 142–150. <https://doi.org/10.22219/jtlm.v1i2.31310>
- David, L., & Weinstein, N. (2024). Using Technology to Make Learning Fun: Technology Use is Best Made Fun and Challenging to Optimize Intrinsic Motivation and Engagement. *European Journal of Psychology of Education*, 39, 1441–1463. <https://doi.org/10.1007/s10212-023-00734-0>
- Dewanti, S. S., Rahmawati, S., & Sumardi, S. (2025). Problem-Based Learning with Manipulative Media: Enhancing Elementary Students' Conceptual Understanding in Area and Volume. *Jurnal Ilmiah Sekolah Dasar*, 8(3), 487–499. <https://doi.org/10.23887/jisd.v8i3.80221>
- Doyan, A., Rahayu, S., Lugi, F., & Annam, S. (2024). Trends Research Problem-Based Learning (PBL) Model to Improve Generic Science Skills in Students' Science Learning (2015–2024): A Systematic Review. *Jurnal Penelitian Pendidikan IPA*, 10(9), 621–630. <https://doi.org/10.29303/jppipa.v10i9.8370>
- Fajria, L., & Utoyo, S. (2025). Lift the Flap Book Media and Learning Motivation Improve Reading Literacy Skills in Early Elementary School Grades. *Jurnal Pendidikan Indonesia (JPI)*, 14(3), 556–564. <https://doi.org/10.23887/jpi-undiksha.v14i3.91756>
- Fraenkel, J. R., Wallen, N. E., & Hyun, H. (2024). *How to Design and Evaluate Research in Education* (11th ed.). McGraw-Hill.
- Gunawan, W., & Al, E. (2025). Enhancing Students' Problem-Solving Abilities: The Role of Project-Based Learning, Problem-Based Learning, and Learning Motivation. *Urnal Pendidikan Progresif*, 15(1), 315–330. <https://doi.org/10.23960/jpp.v15i1.pp315-330>
- Halim, A., Iskandar, I., Ansari, A., & Halim, N. M. (2024). A Study on How the Merdeka Curriculum Promotes Multilingualism in Indonesian ELT Classrooms. *XLinguae*, 17(2), 107–121. <https://doi.org/10.18355/XL.2024.17.02.07>
- Hidayati, T., & Purwaningsih, D. (2023). The Effect of Applying Problem-Based Learning Model on Students' Critical Thinking Ability in Science Subjects. *Jurnal Pendidikan Indonesia*, 12(3), 576–585. <https://doi.org/10.23887/tscj.v6i2.61354>
- Howard, J. L., Bureau, J., Guay, F., Chong, J. X. Y., & Ryan, R. M. (2021). Student Motivation and Associated Outcomes: A Meta-Analysis from Self-Determination Theory. *Perspectives on Psychological Science*, 16(6), 1300–1323. <https://doi.org/10.1177/1745691620966789>
- Ilahi, D. P., Festiyed, F., Yerimadesi, Y., Yulkifli, Y., Utami, L., & Ratih, A. (2024). Evaluating the Impact of Problem-Based Learning on Students' Metacognition in Science Learning: A Meta-Analysis Review. *Jurnal Penelitian Pendidikan IPA*, 10(8), 526–525. <https://doi.org/10.29303/jppipa.v10i8.7892>
- Irwandi, I., Hartati, Y., Hidayat, T., & Fitriani, A. (2024). Impact of Problem Based Learning-Blended Learning on Students' Creativity and Learning Interest. *Jurnal Penelitian Pendidikan IPA*, 10(1), 37–46. <https://doi.org/10.29303/jppipa.v10i1.5366>
- Julianto, F., Hidayati, F., Rahmawati, J. F., Cahyaningsih, R., & Surrahman, I. (2023). Training Students' Critical Thinking Skills Through Inquiry Models to Minimize Science Misconceptions. *Jurnal Penelitian Pendidikan IPA*, 9(11), 1011–1015. <https://doi.org/10.29303/jppipa.v9i11.3757>
- Liu, Y., & Pásztor, A. (2022). Effects of Problem-Based Learning Instructional Intervention on Critical Thinking in Higher Education: A Meta-Analysis. *Thinking Skills and Creativity*, 45, 101069. <https://doi.org/10.1016/j.tsc.2022.101069>
- Lonergan, R., Cumming, T. M., & O'Neill, S. C. (2022). Exploring the Efficacy of Problem-Based Learning in Diverse Secondary School Classrooms: Characteristics and Goals of Problem-Based Learning. *International Journal of Educational Research*, 112, 101945. <https://doi.org/10.1016/j.ijer.2022.101945>

- Maharani, W., N, K. A., Riastini, P. N., & Asril, N. M. (2024). Model Pembelajaran Problem Based Learning (PBL) Berorientasi Gaya Belajar Siswa Terhadap Minat Belajar IPAS Kelas IV Sekolah Dasar. *Jurnal Penelitian dan Pengembangan Sains dan Humaniora*, 8(1), 77–84. Retrieved from https://journal.unpas.ac.id/index.php/pendas/article/view/52211?utm_source
- Marhami, M., J, D., & Dasari, D. (2024). Indonesian Students' Numeracy Skills Based on PISA Mathematical Problems in Secondary School: A Meta-Synthesis. *Jurnal Pendidikan MIPA*, 25(1), 14–26. <https://doi.org/10.23960/jpmipa/v25i1.pp14-26>
- Mayer, R. E. (2021). *Multimedia Learning (3rd ed.)* (Cambridge University Press (ed.)). Cambridge University Press.
- Neroni, J., V, S. G., Baars, M., & Wijnia, L. (2024). The Effectiveness of Student-Centered, Problem-Driven Learning Methods for Self-Regulated Learning: What Works and for Whom? *Paper Presented at the American Educational Research Association (AERA) Annual Meeting, Philadelphia*. Retrieved from <https://research.ou.nl/en/publications/the-effectiveness-of-student-centered-problem-driven-learning-met>
- Nofitri, F., Desyandri, D., Eriyanti, F., & Yerizon, Y. (2024). Improving Critical Thinking Skills of Elementary Students Through Science Learning with Interactive Teaching Materials and Problem-Based Learning. *Jurnal Penelitian Pendidikan IPA*, 10(10), 7624–7633. <https://doi.org/10.29303/jppipa.v10i10.7503>
- Nurhamidah, R., Safitri, N., & Akmala, M. I. (2023). Implementation of E-Flipbook Learning Media Through the Problem-Based Learning Model on Natural and Social Sciences' Learning Outcomes at Fourth-Grade Elementary Students. *Primary: Jurnal Pendidikan Guru Sekolah Dasar*, 12(3), 629–641. <https://doi.org/10.33578/jpkip.v12i3.9752>
- OECD. (2023). PISA 2022 Results. *Factsheets, I*, 2–6. <https://doi.org/10.1787/53f23881-en>
- Pangestu, K., Malagola, Y., Robbaniyah, I., & Rahajeng, D. (2024). The Influence of Project-Based Learning on Learning Outcomes, Creativity and Student Motivation in Science Learning at Elementary Schools. *Jurnal Prima Edukasia*, 12(2), 194–203. <https://doi.org/10.21831/jpe.v12i2.63208>
- Pratama, A., Nurhasanah, N., & Syahrial, S. (2024). Development of Prezi Media Based on the Problem-Based Learning Model in Natural and Social Sciences Learning. *Jurnal Penelitian Pendidikan IPA*, 10(11), 9718–9728. <https://doi.org/10.29303/jppipa.v10i11.9473>
- Putri, R. C., Wibawa, C., I, M., & Astawan, I. G. (2025). The Influence of Media-Assisted Problem Based Learning with Concrete Media on Elementary Students' Conceptual Understanding. *MIMBAR PGSD Undiksha*, 13(3), 433–441. <https://doi.org/10.23887/jpgsd.v13i3.103543>
- Rafie-Papkiadeh, S., Taheri-Ezbarami, Z., Mirzaie-Taklimi, M., Kazemnejad-Leili, E., & Razaghpoor, A. (2024). Comparing the Effects of Problem- and Task-Based Learning on Knowledge and Clinical Decision-Making of Nursing Students Concerning the Use of Transfusion Medicine in Pediatric Nursing: An Educational Quasi-Experimental Study in Iran. *Heliyon*, 10(14), e34521. <https://doi.org/10.1016/j.heliyon.2024.e34521>
- Rizki, I. A., & Suprpto, N. (2024). Project-Oriented Problem-Based Learning Through SR-STEM to Foster Students' Critical Thinking Skills in Renewable Energy Material. *Journal of Science Education and Technology*, 33(4), 526–541. <https://doi.org/10.1007/s10956-024-10102-2>
- Safitri, R., Hadi, S., & Widiasih, W. (2023). Effect of the Problem Based Learning Model on the Students' Motivation and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, 9(9), 7310–7316. <https://doi.org/10.29303/jppipa.v9i9.4772>
- Setianingsih, D., S, E., T, Y., & Yumiati, Y. (2024). Pengembangan Media Pembelajaran Berbasis Web (Google Sites) untuk Meningkatkan Keterampilan Berpikir Kritis dan Literasi Digital Siswa Kelas V Sekolah Dasar. *ELSE (Elementary School Education Journal)*, 8(2), 440–450. <https://doi.org/10.30651/else.v8i2.23179>
- Simanjuntak, W., Y, I., & Purwaningsih, D. (2024). STEM Integrated Problem-Based Learning: The Implementation and Roles in Science Learning. *Jurnal Pendidikan MIPA*, 25(2), 686–700. <https://doi.org/10.23960/jpmipa/v25i2.pp686-700>
- Smith, K., Maynard, N., Berry, A., Stephenson, T. S. T., Corrigan, D., & Al. E. (2022). Principles of Problem-Based Learning (PBL) in STEM Education: Using Expert Wisdom and Research to Frame Educational Practice. *Education Sciences*, 12(10), 728. <https://doi.org/10.3390/educsci12100728>
- Suleman, N. (2023). *Pembelajaran Ilmu Pengetahuan Alam dan Sosial (IPAS)*. Medan: Yayasan Kita Menulis.
- Tabachnick, B. G., & Fidell, L. S. (2019). *Using Multivariate Statistics* (7th ed.). Pearson.
- Tirtawati, A., I, G., Wibawa, C., I, M., Dharmayanti, D., & A, P. (2025). Development of Problem-Solving-Based Flipbook Learning Media to Improve Science Learning Outcomes of Fifth Grade Elementary School Students. *Journal of Education Technology*, 9(2), 353–363. <https://doi.org/10.23887/jet.v9i2.91622>
- Yu, L., & Zin, Z. M. (2023). The Critical Thinking-

Oriented Adaptations of Problem-Based Learning Models: A Systematic Review. *Frontiers in Education*, 8, Article 1139987. <https://doi.org/10.3389/feduc.2023.1139987>