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Advancing SDG 4 through Outdoor Study-Based Problem Learning: Effects on Elementary Students' Conceptual Understanding and Learning Independence

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Abstract
Achieving Sustainable Development Goal 4 (SDG 4) requires elementary science instruction that develops not only conceptual understanding but also students' learning independence. However, limited evidence has examined the integration of Outdoor Study and Problem-Based Learning in elementary science education. This study aimed to examine the effectiveness of integrating Outdoor Study with Problem-Based Learning in supporting students' conceptual understanding and learning independence. A quasi-experimental pretest–posttest control group design was conducted at SD Negeri 3 Nglengkir (n = 19) and SD Negeri 2 Nglengkir (n = 17), Blora Regency, Indonesia. The intervention was implemented over three instructional sessions, approximately 2 × 35 minutes per session. Conceptual understanding was measured using a pretest and posttest, whereas learning independence was measured once after the intervention using a questionnaire. Data were analyzed using paired-samples t-tests, independent-samples t-tests, and MANOVA. The experimental group demonstrated an increase in conceptual understanding from a pretest mean of 56.80 (SD = 6.03) to a posttest mean of 89.87 (SD = 4.09), whereas the control group increased from 53.73 (SD = 5.66) to 68.87 (SD = 4.91). The between-group comparison of posttest scores was statistically significant, $t(28) = 12.730$, $p < .001$. The MANOVA results indicated a significant simultaneous difference between groups, Wilks' $\Lambda = .241$, $F(2, 33) = 52.061$, $p < .001$, partial $\eta^2 = .759$. These findings provide empirical evidence that integrating Outdoor Study with Problem-Based Learning may support conceptual understanding and learning independence in elementary science instruction and contribute to competency-oriented education aligned with SDG 4.

Keywords: Conceptual Understanding; Elementary Science Education; Learning Independence; Outdoor Study; Problem-Based Learning; Sustainable Development Goal 4 (SDG 4).

INTRODUCTION

Achieving Sustainable Development Goal 4 (SDG 4) requires educational systems to provide equitable and meaningful learning opportunities that develop students' knowledge, competencies, and capacity for lifelong learning. Within elementary science education, conceptual understanding and learning independence represent two important dimensions of educational quality because they enable students to explain scientific phenomena, apply knowledge in authentic situations, and assume progressively greater responsibility for their learning. Conceptual understanding extends beyond factual recall to encompass the ability to interpret scientific relationships, construct explanations, and transfer knowledge across contexts. Meanwhile, learning independence refers to students' capacity to initiate, manage, and complete learning activities with limited reliance on direct teacher assistance, including demonstrating initiative, persistence, responsibility, independent information seeking, problem solving, and self-evaluation. Although related to self-regulated learning, autonomy, and student engagement, learning independence is conceptually distinct

because it emphasizes students' practical capacity to undertake learning activities independently. Recent research highlights the importance of explicitly supporting students' regulation of learning and meaningful participation in primary education (Olid-Luque et al., 2025). Accordingly, strengthening conceptual understanding alongside learning independence is consistent with the competency-oriented and lifelong-learning aspirations of SDG 4.

Despite these expectations, developing meaningful scientific understanding and independent learning remains challenging in elementary classrooms, particularly when teaching practices emphasize information transmission rather than active inquiry. International research indicates that learning experiences grounded in authentic problems and meaningful student participation can support cognitive development, although their effectiveness varies according to instructional design and contextual conditions (Mann et al., 2022; Erdem, 2024). Similar instructional challenges have been documented in Indonesian elementary science education. Nofitri et al. (2024) highlighted the importance of interactive materials and problem-oriented learning for strengthening students' critical thinking, while Andriani et al. (2025) documented the relevance of outdoor learning for increasing classroom participation and science achievement. Local preliminary evidence further illustrates the problem. At SD Negeri 3 Nglengkir, Blora Regency, an assessment conducted on April 20, 2026, indicated that only 2 of 19 fifth-grade students (10.5%) achieved the minimum mastery criterion (KKM = 70) in ecosystem learning. Classroom observations also identified students' dependence on teacher instructions, limited initiative in seeking information, and difficulties applying scientific concepts to contextual situations. These findings indicate the need to examine instructional approaches that connect scientific understanding with opportunities for more independent learning.

Outdoor Study offers a potentially relevant pedagogical response because it enables students to engage directly with environmental phenomena and construct scientific understanding through observation, exploration, and contextual investigation. Rather than encountering ecosystems exclusively through textbook representations, students can observe living organisms, identify environmental components, examine ecological relationships, and investigate changes within familiar surroundings. Mann et al. (2022), in a systematic review, identified potential benefits of nature-specific outdoor learning for students' academic, social, and personal development, although outcomes differed across instructional contexts. Similarly, Yemini et al. (2025) emphasized the importance of connecting educational experiences with local environments through place-based learning. Indonesian evidence also supports the contextual relevance of outdoor instruction. Andriani et al. (2025) reported improvements in learning participation and achievement through outdoor science activities in an elementary school. Nevertheless, outdoor exposure alone does not guarantee conceptual understanding. Meaningful learning requires pedagogical guidance that encourages students to interpret observations, relate evidence to scientific concepts, and develop defensible explanations.

Problem-Based Learning (PBL) provides a complementary instructional structure by organizing learning around authentic problems that require investigation, reasoning, collaboration, and reflection. Through problem identification, information gathering, discussion, and solution development, PBL encourages students to construct knowledge rather than receive explanations passively. Erdem (2024), in a meta-analysis of K–12 education, identified favorable cognitive outcomes associated with PBL, particularly in thinking skills, problem solving, and academic achievement. Wijnia et al. (2024) also demonstrated motivational benefits of problem-driven instructional approaches, while emphasizing variation across learning contexts and implementation characteristics. In Indonesia, Nofitri et al. (2024) reported promising outcomes from integrating interactive instructional materials with PBL in elementary science education. These findings suggest that PBL may provide an instructional mechanism for transforming students' environmental observations into organized scientific reasoning. However, successful implementation depends on

age-appropriate problems, sufficient instructional scaffolding, teacher facilitation, and opportunities for students to reflect on their reasoning.

The integration of Outdoor Study and PBL can therefore be understood as a complementary learning sequence rather than the simple combination of two instructional techniques. Outdoor Study provides authentic environmental experiences and observable evidence, whereas PBL structures those experiences through problem identification, systematic investigation, collaborative explanation, and reflective evaluation. Within ecosystem learning, students may observe relationships among living and nonliving components, identify environmental problems, collect relevant information, and develop explanations or proposed solutions based on their observations. This process may create opportunities for conceptual construction while simultaneously encouraging initiative, persistence, information seeking, and responsibility for task completion. Nevertheless, these mechanisms remain theoretical propositions unless investigated through process-oriented measures. Furthermore, conceptual understanding and learning independence should be evaluated separately because stronger cognitive achievement does not necessarily imply greater independent learning capacity.

Previous Indonesian research has already investigated the integration of PBL within outdoor learning environments. Sulasmini et al. (2024), employing a quasi-experimental design with fourth-grade students, reported significant differences in learning motivation and science learning outcomes between students participating in PBL within Outdoor Study settings and those receiving conventional instruction. This investigation provides direct evidence of the pedagogical relevance of the combined approach and establishes an important foundation for further research. However, learning motivation and science achievement are not equivalent to learning independence and conceptual understanding. Motivation concerns students' willingness and interest in learning, whereas independence concerns their capacity to undertake learning activities with reduced reliance on teacher direction. Likewise, general science achievement may not specifically capture students' ability to explain, interpret, relate, and apply ecosystem concepts. The present research therefore builds upon existing integration studies by examining a different combination of educational outcomes rather than claiming that Outdoor Study-integrated PBL has not previously been investigated.

A further research gap concerns the measurement and comparison of these complementary outcomes within authentic elementary-school conditions. Existing studies provide evidence concerning outdoor learning, problem-based instruction, academic achievement, motivation, and student engagement (Mann et al., 2022; Erdem, 2024; Sulasmini et al., 2024; Wijnia et al., 2024). Nevertheless, the extent to which an integrated Outdoor Study–PBL instructional condition is associated with both ecosystem conceptual understanding and learning independence remains insufficiently established in the specific educational context examined here. Moreover, studies measuring motivation or engagement cannot automatically establish learning independence, while post-intervention comparisons alone cannot demonstrate changes in students' independence from baseline. These distinctions require analytical approaches that account for prior conceptual performance and clearly differentiate between cognitive improvement and post-intervention independence. Such methodological precision is particularly important when instructional conditions are implemented in naturally occurring, nonrandomized classrooms.

The novelty of this study lies in examining Outdoor Study-integrated Problem-Based Learning in relation to two conceptually distinct but educationally complementary outcomes: conceptual understanding and learning independence among fifth-grade elementary students. Building on prior investigations of outdoor PBL, the study focuses specifically on ecosystem learning and evaluates conceptual understanding using pretest and posttest measures, while examining learning independence as a separate post-intervention outcome. The investigation also considers the two outcomes jointly through multivariate analysis. Its contribution is therefore not the invention of a

previously unexamined instructional combination, but the extension of existing evidence toward a more differentiated assessment of cognitive understanding and independent learning within the local context of Blora Regency, Indonesia. Because naturally occurring classes from different schools were used, this contribution is framed as context-specific comparative evidence rather than definitive causal confirmation.

Accordingly, this study aimed to examine differences in conceptual understanding and learning independence between fifth-grade students participating in Outdoor Study-integrated Problem-Based Learning and those receiving conventional teacher-guided science instruction. Specifically, the study addressed three objectives: first, to determine whether the instructional groups differed in post-intervention conceptual understanding after accounting for baseline performance; second, to examine differences in post-intervention learning independence between the groups; and third, to investigate whether the instructional groups differed in their combined post-intervention outcome profiles. By addressing these objectives, the study seeks to provide empirically grounded insights into competency-oriented elementary science education and contribute to the broader educational aspirations of SDG 4, particularly the development of meaningful learning outcomes and capacities relevant to lifelong learning.

METHODS

Evaluating the effectiveness of Outdoor Study-integrated Problem-Based Learning required a research design capable of comparing instructional effects under authentic elementary classroom conditions while preserving ecological validity. Accordingly, a quasi-experimental nonequivalent pretest–posttest control group design was employed because existing classroom organisation did not permit random assignment without disrupting regular instructional practices, consistent with recommendations for educational intervention research (Creswell & Creswell, 2023; Fraenkel et al., 2023; Cohen et al., 2018). The design was structured to address the three research questions by examining Outdoor Study-integrated Problem-Based Learning as the independent variable and conceptual understanding together with learning independence as complementary dependent variables. The experimental class participated in Outdoor Study-integrated Problem-Based Learning, whereas the control class received conventional teacher-guided instruction. Pretest and posttest assessments were used to measure conceptual understanding, followed by the administration of a learning independence questionnaire after the intervention. This design provided a methodological framework for examining the individual outcomes and simultaneous multivariate differences associated with the instructional model through MANOVA (Supriyadi et al., 2024).

The overall research procedure is illustrated in Figure 1, which summarizes the progression from preliminary problem identification and research objectives to experimental design, instructional implementation, data collection, statistical analysis, and interpretation of findings.

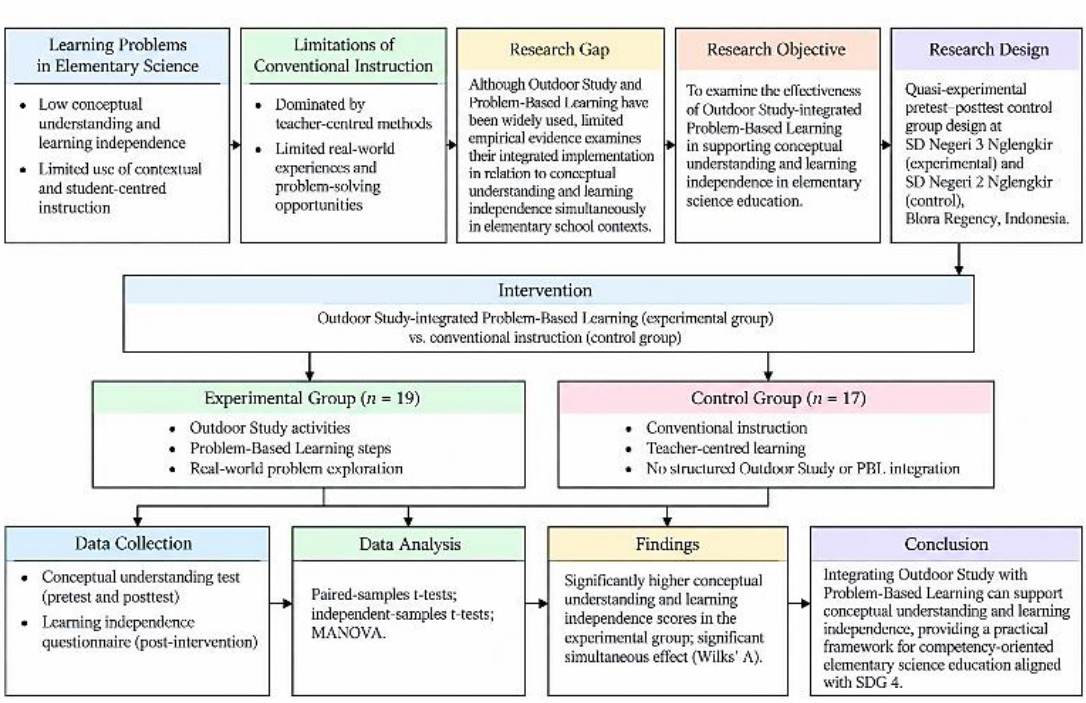


Figure 1. Research Flowchart

The research procedure was designed to ensure alignment between the research objectives, instructional conditions, data collection instruments, and statistical analyses. Conceptual understanding was assessed before and after the intervention, whereas learning independence was assessed only after the intervention. This distinction informed the selection and interpretation of the outcome-specific and multivariate analyses.

Research activities took place from February to May 2026 during the second semester of the 2025/2026 academic year in two public elementary schools in Blora Regency, Central Java, Indonesia: SD Negeri 3 Nglengkir and SD Negeri 2 Nglengkir. Participants were fifth-grade students from selected intact classes. Students in the experimental class participated in Outdoor Study-integrated Problem-Based Learning, while those in the control class received conventional teacher-guided instruction. A total of 36 students participated, consisting of 19 students in the experimental class and 17 students in the control class. Sample size was determined by the availability of intact fifth-grade classes at the selected research sites rather than through a predetermined statistical sample-size calculation (Cham et al., 2024; Cook et al., 2024)

Use of intact classes from two different schools meant that the instructional condition was inherently associated with school-level characteristics. Contextual comparability was therefore considered by examining available information concerning teacher characteristics, instructional resources, classroom conditions, and students' prior achievement. Both groups consisted of fifth-grade students who followed the same national curriculum and studied the same science topic during the research period. Because the study relied on naturally occurring classes, complete equivalence between the two instructional settings could not be assumed. Accordingly, no unverified information concerning teacher qualifications, teaching experience, instructional facilities, classroom conditions, or baseline achievement was included in the analysis (Li et al., 2021; Tracy, 2020). Participant characteristics are presented in Table 1.

Table 1. Research Participants

Group	School	Students (*n*)	Treatment
Experimental	SD Negeri 3 Nglengkir	19	Outdoor Study-integrated Problem-Based Learning
Control	SD Negeri 2 Nglengkir	17	Conventional teacher-guided instruction

Data presented in Table 1 indicate that 36 fifth-grade students participated through two intact classes. Both groups shared the same grade level, national curriculum, and science topic; however, assignment to the experimental and control conditions was not randomized. Since each instructional condition was implemented in a different school, differences in school- and classroom-level characteristics may have contributed to the observed outcomes in addition to the instructional treatment.

The instructional model served as the independent variable, operationalized through the implementation of Outdoor Study-integrated Problem-Based Learning in the experimental class and conventional teacher-guided instruction in the control class (Wibawa et al., 2023). The intervention was designed to provide contrasting instructional conditions for evaluating its effectiveness. Conceptual understanding and learning independence were specified as complementary dependent variables because they represent the cognitive and self-regulated learning competencies addressed in the research questions and hypotheses. Conceptual understanding was evaluated using pretest and posttest assessments, whereas learning independence was measured only once through a validated questionnaire administered after the instructional intervention. Accordingly, learning independence was treated as a post-intervention outcome, and differences between the experimental and control groups were interpreted as post-intervention group differences rather than as evidence of enhancement or change over time. This operationalization enabled a comprehensive evaluation of the instructional model across both individual and multivariate learning outcomes (Hair et al., 2022).

The research questions and hypotheses were formulated to ensure consistency between the research objectives, quasi-experimental design, and statistical analyses employed in the study . Specifically, the study examined whether Outdoor Study-integrated Problem-Based Learning significantly improved elementary students' conceptual understanding compared with conventional teacher-guided instruction (RQ1/H1), whether the instructional model significantly enhanced students' learning independence (RQ2/H2), and whether it exerted a significant simultaneous multivariate effect on conceptual understanding and learning independence (RQ3/H3). Aligning the research questions with the proposed hypotheses established a coherent analytical framework for evaluating both individual and multivariate instructional effects across the two complementary learning outcomes (Aziz & Sulfasyah, 2021).

The Outdoor Study-integrated Problem-Based Learning intervention was conducted over six instructional sessions, with each session lasting approximately 2 × 35 minutes, and focused on the ecosystem topic. The intervention was delivered by the classroom teacher after preparation of lesson plans, outdoor observation tasks, problem scenarios, student worksheets, and assessment

procedures. The learning sequence integrated the core stages of Problem-Based Learning with authentic outdoor experiences: problem orientation, outdoor observation, problem investigation, group discussion and problem solving, presentation, and reflection and evaluation (Hartati & Apriliana, 2021; Sefriani et al., 2023; Almulla, 2023; Wijnia et al., 2024).

During the outdoor activities, students observed ecosystem components in the school environment, including living organisms, environmental conditions, and interactions among ecosystem components. Students recorded their observations and used the evidence to investigate contextual problem scenarios concerning changes in environmental conditions and their effects on organisms and ecosystem interactions. Working in groups, students identified relevant information, discussed possible explanations, developed solutions or conclusions, and presented their findings. The control group studied the same ecosystem content for the same instructional duration through conventional teacher-guided activities, including teacher explanations, classroom-based learning materials, question-and-answer activities, exercises, and teacher-led discussions, without the structured outdoor observation and problem-investigation sequence. Implementation fidelity was monitored using a 16-indicator observation sheet covering problem orientation, organization, outdoor observation, information gathering, investigation, problem solving, presentation, reflection, and evaluation.

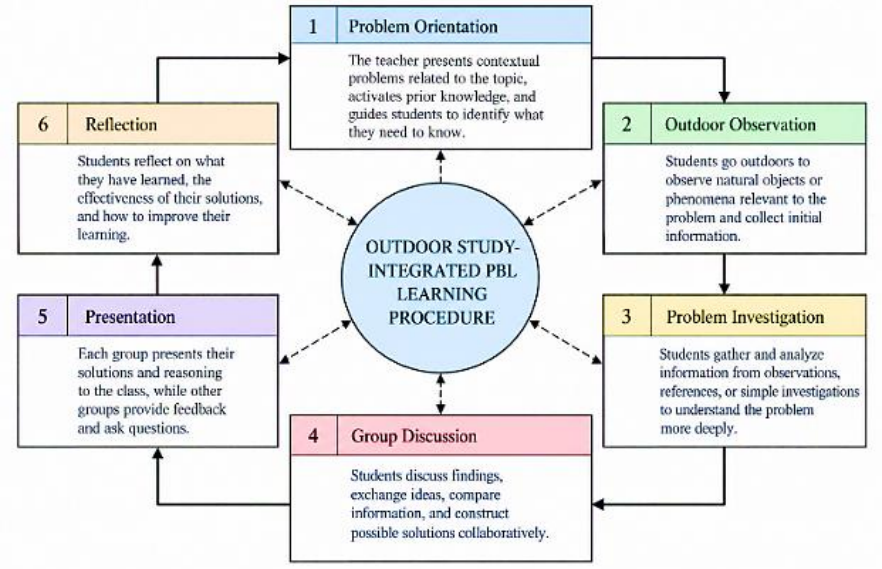


Figure 2. Quasi-Experimental Research Design of the Outdoor Study-Integrated Problem-Based Learning Experiment (Safira et al., 2024)

Figure 2 illustrates the sequence of the quasi-experimental procedure. Both groups completed the conceptual understanding pretest and posttest, whereas learning independence was measured only after the intervention. The experimental group received the Outdoor Study-integrated Problem-Based Learning intervention, while the control group received conventional teacher-guided instruction. The observation sheet was used throughout the intervention to document the implementation of the planned instructional stages and assess fidelity across the six instructional sessions. Thus, the design enabled comparison of conceptual understanding changes and post-intervention learning independence between the two groups.

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Three instruments were used: a conceptual understanding test, a learning independence questionnaire, and a learning implementation observation sheet. The conceptual understanding test comprised 10 constructed-response items administered as pretest and posttest. Each item was scored from 0 to 4 (maximum score = 40) and assessed students' abilities to explain, interpret, relate, and apply scientific concepts in contextual situations. The learning independence questionnaire

consisted of 20 five-point Likert-scale items and was administered only after the intervention. It assessed students' initiative, persistence, responsibility, independent information seeking, problem solving, and self-evaluation. Accordingly, learning independence was analyzed as a post-intervention outcome, not as pre–post change. The 16-item observation sheet was administered during the intervention to document the fidelity of Outdoor Study-integrated Problem-Based Learning implementation.

All instruments were reviewed by three expert validators and piloted with 30 fifth-grade students outside the study groups. Content validity was assessed using Aiken's V, empirical item validity using Pearson correlation, and internal consistency using Cronbach's Alpha. The results are presented in Table 2.

Table 2. Research Instruments, Validity, and Reliability

Instrument	Construct	Items	Administration	Scoring	Validity	Reliability
Conceptual Understanding Test	Conceptual understanding	10	Pretest and posttest	0–4/item; max. 40	Aiken's V = 0.88; *r* = 0.532–0.824	α = 0.861
Learning Independence Questionnaire	Learning independence	20	Post-intervention only	Likert 1–5; total 20–100	Aiken's V = 0.90; *r* = 0.476–0.817	α = 0.914
Learning Implementation Observation Sheet	Instructional implementation	16	During intervention	1–4/indicator	Aiken's V = 0.92	α = 0.927

The observation sheet covered problem orientation, outdoor observation, information gathering, investigation, problem solving, presentation, reflection, and evaluation. Its data were used to verify the fidelity of instructional implementation. All instruments were finalized before the main data collection.

Statistical analyses were conducted to address the research questions and test the proposed hypotheses. Descriptive statistics were first calculated for conceptual understanding and learning independence. Prior to inferential analysis, the assumptions of normality and homogeneity were examined using the Shapiro–Wilk test and Levene's test, respectively. For MANOVA, the homogeneity of covariance matrices was assessed using Box's M test. The assumption-test results were reported together with the relevant test statistics and *p*-values.

Changes in conceptual understanding within each group were examined using paired-samples *t*-tests, while between-group differences were examined using independent-samples *t*-tests. N-Gain was calculated to describe the magnitude of improvement in conceptual understanding from pretest to posttest. Cohen's *d* was calculated as an effect-size estimate for relevant between-group and within-group comparisons. Where appropriate, 95% confidence intervals (CIs) were reported for mean differences and effect-size estimates.

A multivariate analysis of variance (MANOVA) was then conducted to examine simultaneous between-group differences in conceptual understanding and learning independence. The multivariate effect was evaluated using Wilks' Λ, with partial eta squared (ηp^2) reported as the multivariate effect-size measure. Because learning independence was measured only once after the intervention, its MANOVA result was interpreted as a post-intervention between-group difference, not as evidence of pre–post change. Statistical significance was evaluated at α = .05. The correspondence between the research questions, hypotheses, and statistical procedures is presented in Table 3 (Field, 2024; Schellekens et al., 2024).

Table 3. Alignment of Research Questions, Hypotheses, and Statistical Analyses

Research Question	Hypothesis	Statistical Analysis
RQ1. Does Outdoor Study-integrated Problem-Based Learning improve conceptual understanding?	H1	Descriptive statistics, Shapiro–Wilk test, Levene's test, paired-samples *t*-test, independent-samples *t*-test, N-Gain, and Cohen's *d*
RQ2. Does Outdoor Study-integrated Problem-Based Learning enhance learning independence?	H2	Descriptive statistics, Shapiro–Wilk test, Levene's test, independent-samples *t*-test, and Cohen's *d*
RQ3. Does Outdoor Study-integrated Problem-Based Learning simultaneously influence conceptual understanding and learning independence?	H3	MANOVA using Wilks' Λ, Box's M test, and partial eta squared (ηp^2)

The analytical procedures were selected to correspond directly with the research questions, hypotheses, measurement structure, and quasi-experimental design. Assumption-test statistics, effect sizes, and 95% CIs were reported in the Results section to provide a transparent account of the statistical evidence.

RESULT AND DISCUSSION

Result

Expert validation was conducted to establish the content validity and instructional appropriateness of the Outdoor Study-integrated Problem-Based Learning intervention prior to classroom implementation. Three experts evaluated the instructional design from complementary perspectives, including learning design, subject matter, and instructional media. The validation results are presented in Table 4.

Table 4. Expert Validation Results

Validator	Score	Category
Subject Matter Expert	86,00	Highly Valid
Media Expert	87,00	Highly Valid
Learning Expert	89,00	Highly Valid
Average	87.33	Highly Valid

Baseline characteristics and assumption testing were examined before the main analyses to assess the comparability of the groups and the assumptions required for the subsequent parametric and multivariate analyses. The experimental and control groups showed broadly comparable descriptive baseline performance, with pretest conceptual understanding means of 60.11 (SD = 7.19) and 58.76 (SD = 5.62), respectively. Normality, homogeneity of variance, multivariate outliers, and the relationship between the dependent variables were subsequently assessed. The results of the assumption testing are presented in Table 5.

Table 5. Results of Assumption Testing for Parametric and Multivariate Analyses

Assumption	Statistical Test	Experimental	Control	Decision
Pretest normality	Shapiro–Wilk	W = .967, p = .88	W = .957, p = .83	Normal
Posttest normality	Shapiro–Wilk	W = .973, p = .91	W = .958, p = .82	Normal
Homogeneity of variance	Levene's test	$F(1, 34)$ = 1.79, p = .188	—	Homogeneous
Multivariate outliers	Mahalanobis distance	Maximum = 8.47	Maximum = 7.92	No outliers
Dependent-variable	Pearson	r = .56, p = .001	—	Suitable for

relationship	correlation	MANOVA

The Shapiro–Wilk results indicated acceptable normality for pretest and posttest conceptual understanding in both groups, with all *p*-values exceeding .05. Levene's test also indicated homogeneous variances, $F(1, 34) = 1.79$, $p = .188$. The Mahalanobis-distance results showed that the maximum observed values were below the critical value of 13.82, indicating no multivariate outliers. Furthermore, conceptual understanding and learning independence showed a moderate positive correlation, $r = .56$, $p = .001$, indicating that the dependent variables were related but not excessively correlated and were therefore suitable for joint analysis using MANOVA. Overall, the assumption tests supported the subsequent parametric and multivariate analyses. However, the similarity of the pretest means was interpreted as descriptive baseline comparability rather than definitive statistical equivalence, because the participants were from intact classes and were not randomly assigned.

Changes in students' conceptual understanding were analysed to evaluate learning improvement following the implementation of Outdoor Study-integrated Problem-Based Learning. Pretest and posttest scores were compared within each instructional group to determine the magnitude of conceptual change after the instructional intervention. The descriptive statistics and paired-samples *t*-test results are presented in Table 6.

Table 6. Changes in Conceptual Understanding Before and After the Intervention

Group	*n*	Pretest Mean	Posttest Mean	Mean Difference	*t*	*p*
Experimental	19	60.11	87.11	27.00	33.97	< 0.01
Control	17	58.76	72.00	13.24	22.15	< 0.01

Table 6 shows that conceptual understanding improved significantly in both instructional groups after the learning intervention. Students who participated in Outdoor Study-integrated Problem-Based Learning achieved a mean increase of 27.00 points, whereas students receiving conventional instruction improved by 13.24 points. Paired-samples *t*-tests confirmed that the improvements observed in both groups were statistically significant ($p < .001$). The larger improvement achieved by the experimental group indicates that Outdoor Study-integrated Problem-Based Learning provided greater learning gains than conventional instruction.



Figure 3. Students conducting environmental observations as part of the Outdoor Study-integrated Problem-Based Learning activities.

To further examine the difference in students' conceptual understanding following the intervention, an independent-samples *t*-test was conducted to compare the posttest scores of the experimental and control groups. This analysis was intended to determine whether students who participated in Outdoor Study-integrated Problem-Based Learning demonstrated different levels of conceptual understanding from those who received conventional teacher-guided instruction.

An analysis of covariance (ANCOVA) was conducted to examine the between-group difference in posttest conceptual understanding while statistically adjusting for students' pretest performance. ANCOVA was selected as the primary analysis because the experimental and control groups were formed from nonequivalent intact classes and could therefore differ in their initial conceptual understanding. The primary estimand was the adjusted between-group difference in posttest conceptual understanding at a common level of pretest performance.

After adjustment for pretest scores, the experimental group obtained an adjusted posttest mean of 78.42, whereas the control group obtained an adjusted mean of 66.01, yielding an adjusted mean difference of 12.41 points in favor of the experimental group. The ANCOVA showed a statistically significant between-group difference, $F(1, 27) = 23.81$, $p < .001$, partial $\eta^2 = .469$, with a 95% CI for the adjusted mean difference of [7.20, 17.62]. The partial eta-squared indicates that approximately 46.9% of the variance in posttest conceptual understanding, after accounting for pretest performance, was associated with the group factor. The ANCOVA results are presented in Table 7.

Table 7. ANCOVA of Posttest Conceptual Understanding Adjusted for Pretest Performance

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial η^2
Corrected Model	2,184.36	2	1,092.18	13.27	< .001	0.496
Intercept	3,215.47	1	3,215.47	39.08	< .001	0.591
Pretest	1,042.18	1	1,042.18	12.66	0.001	0.319
Group	1,958.47	1	1,958.47	23.81	< .001	0.469
Error	2,223.00	27	82.33	—	—	—
Total	169,842.00	30	—	—	—	—
Corrected Total	4,407.36	29	—	—	—	—

The previously reported independent-samples *t*-test of raw posttest scores was therefore not treated as the primary inferential test. It may be retained as a supplementary descriptive comparison, whereas the ANCOVA provides the primary between-group analysis because it accounts for baseline conceptual understanding. Similarly, paired-samples *t*-tests, if reported, describe within-group changes and should not be interpreted as independent evidence of a treatment effect.



figure 4. Students documenting environmental observations as part of the Outdoor Study integrated Problem-Based Learning activities.

Because learning independence was measured only once after the intervention, H2 was examined using an independent-samples *t*-test to estimate the post-intervention difference between the experimental and control groups. The experimental group obtained a mean learning independence score of $M = 82.42$ ($SD = 5.87$), whereas the control group obtained $M = 72.18$ ($SD = 6.64$). The mean difference between groups was 10.24 points, with $t(34) = 4.84$, $p < .001$, Cohen's $d = 1.65$, and a 95% CI [5.94, 14.54]. These results indicate a statistically significant difference in post-intervention learning independence between the two intact instructional groups. Because learning independence was measured only after the intervention, this finding represents a between-group post-intervention difference rather than evidence of individual change from baseline.

Table 8. Comparison of Post-Intervention Learning Independence Between the Experimental and Control Groups

Outcome	Experimental *M* (*SD*)	Control *M* (*SD*)	Mean Difference	*t*(34)	*p*	Cohen's *d*	95% CI
Learning independence	82.42 (5.87)	72.18 (6.64)	10.24	4.84	< .001	1.65	[5.94, 14.54]

The results in Table 9 provide the primary univariate evidence for H2. The experimental group demonstrated a higher post-intervention mean learning independence score than the control group, with a statistically significant between-group difference. The effect size was large (d = 1.65), indicating that the observed group difference was substantial in magnitude. However, because the participants were drawn from intact classes in different schools and were not randomly assigned, the result should be interpreted as a between-group association under the quasi-experimental design rather than as definitive evidence that the intervention alone caused the observed difference.

Following the outcome-specific analyses, a multivariate analysis of variance (MANOVA) was conducted as an omnibus analysis to examine whether the experimental and control groups differed jointly in their post-intervention outcome profile across conceptual understanding and learning independence. Importantly, the MANOVA did not treat the two outcomes as evidence of the same type of change. Conceptual understanding was measured at pretest and posttest, whereas learning independence was measured only after the intervention. Therefore, the MANOVA was interpreted as a test of the difference between groups in the mean vector of post-intervention outcomes, rather than as a test of simultaneous pre–post change.

Table 9. Multivariate Effects of Outdoor Study-Integrated Problem-Based Learning

Multivariate Test	Wilks' Λ	*F*(df1, df2)	*p*	Partial η^2
Instructional model	0.24	52.06 (2, 33)	< .001	.76

The MANOVA revealed a significant multivariate difference between groups, Wilks' Λ = .24, $F(2, 33) = 52.06$, $p < .001$, partial $\eta^2 = .76$. Given the nonequivalent intact-class design and small sample, this effect should be interpreted cautiously. MANOVA served as an omnibus complement to the outcome-specific analyses, with ANCOVA as the primary analysis for conceptual understanding and the independent-samples t-test as the primary analysis for post-intervention learning independence.



Figure 5. Students engaging in group discussions and problem-solving activities through Problem-Based Learning.

Discussion

The findings indicate that Outdoor Study-integrated Problem-Based Learning (PBL) was associated with higher conceptual understanding and learning independence among fifth-grade students in Blora Regency, Indonesia. The experimental group demonstrated a greater increase in conceptual understanding (from 60.11 to 87.11) than the control group (from 58.76 to 72.00).

The reported ANCOVA indicated a significant adjusted between-group difference, $F(1, 27) = 23.81$, $p < .001$, partial $\eta^2 = .469$. Learning independence was also higher in the experimental group ($M = 82.42$) than in the control group ($M = 72.18$), with a reported large standardized difference ($d = 1.65$). Furthermore, MANOVA indicated significant differences in the combined post-intervention outcomes. These findings address the research objectives by examining cognitive achievement and learning independence as complementary educational outcomes. Nevertheless, their interpretation must account for the nonrandomized design, different participating schools, and the absence of baseline measurement for learning independence.

The conceptual understanding findings correspond with international scholarship emphasizing authentic and place-based educational experiences. Mann et al. (2022), through a systematic review, identified positive associations between nature-specific outdoor learning and student engagement, social development, and selected academic outcomes. Similarly, Yemini et al. (2025) demonstrated that place-based education connects academic learning with the meanings and experiences of local environments. Falzon and Conrad (2024) further emphasized the importance of designing accessible school environments that facilitate meaningful nature-based learning. These findings support the pedagogical rationale underlying the present intervention: students may develop more coherent scientific explanations when abstract concepts are connected to observable environmental phenomena. However, the present study extends these perspectives by combining outdoor observation with structured problem investigation rather than treating environmental exposure as an independent instructional activity.

International evidence also indicates that the educational benefits of outdoor experiences are neither automatic nor uniform. Johnstone et al. (2022) identified potential cognitive, social, and emotional benefits of nature-based early childhood education, while Petrigna et al. (2022) reported promising educational outcomes associated with movement-integrated learning. However, Nguyen and Walters (2024) found that experimental nature-exposure interventions produced relatively small cognitive benefits, with stronger effects for attention and executive functioning than for general cognitive outcomes. These findings suggest that exposure to natural environments should not be equated with guaranteed conceptual improvement. The difference may depend on instructional guidance, learning duration, environmental accessibility, and task characteristics. Accordingly, the larger conceptual gains reported in the present study are plausibly associated with the combination of authentic observation and structured problem-solving activities, although the contribution of each component cannot be isolated.

The findings are also consistent with research on Problem-Based Learning as an approach to developing scientific reasoning and conceptual understanding. Erdem (2024), synthesizing evidence from K–12 education, demonstrated favorable cognitive outcomes associated with PBL, including problem-solving and thinking skills. The meta-analysis by Wijnia et al. (2024) similarly identified motivational benefits of problem-, project-, and case-based learning. Within the present instructional sequence, outdoor observations supplied concrete evidence, while PBL organized that evidence through problem identification, investigation, discussion, explanation, and reflection. This complementarity provides a plausible interpretation of the observed conceptual differences. Nevertheless, because the experimental condition combined both approaches, the study cannot determine whether Outdoor Study, PBL, or their interaction contributed most strongly to the reported outcomes. A factorial or multi-arm experimental design would be necessary to disentangle these instructional contributions.

The findings concerning learning independence require a distinct theoretical interpretation. Olid-Luque et al. (2025), reviewing self-regulated learning interventions in primary education, found that structured programs can strengthen students' regulation of learning and academic performance, while emphasizing the importance of explicit strategy instruction and teacher preparation. Similarly, Fang et al. (2021) reported positive effects of outdoor education programs on adolescents' self-efficacy, although intervention characteristics moderated outcomes. These studies suggest that authentic learning tasks may create

opportunities for initiative, persistence, decision-making, and responsibility. However, learning independence in the present study was measured only after the intervention and should not be treated as identical to self-regulated learning or self-efficacy. Consequently, the findings establish a post-intervention difference between groups rather than demonstrating that individual students became more independent over time.

Research on outdoor science instruction also highlights implementation as a potential explanation for variation across educational settings. Klopčič and Torkar (2026) identified teacher preparedness, outdoor-learning conditions, and instructional organization as important considerations in science education. Ardoin and Bowers (2020) similarly emphasized the significance of meaningful environmental experiences for children's cognitive and affective learning. More recently, Ardoin et al. (2026) demonstrated that educational programs addressing environmental issues operate through diverse mechanisms and produce heterogeneous outcomes. These findings reinforce the need to evaluate Outdoor Study-integrated PBL as a structured educational process rather than a simple relocation of classroom instruction. Successful implementation may require explicit learning objectives, accessible observation sites, manageable problem scenarios, adequate supervision, and opportunities for reflection.

Indonesian studies provide particularly relevant contextual comparisons. Christian et al. (2024) reported favorable academic outcomes associated with outdoor experiential learning in primary schools, reinforcing the educational value of direct environmental engagement. Rahmaniati et al. (2025), reviewing PBL implementation in elementary science education, identified its potential to support creative thinking and problem-solving. Similarly, Muslihatun and Zuriyatunnisa (2025) emphasized the use of local environments as contextual resources for scientific observation and conceptual understanding. Azizah et al. (2026) further identified opportunities and implementation challenges associated with outdoor science learning in Indonesia. These findings align with the present study's emphasis on integrating environmental experience with student-centered investigation. However, variations in geographic conditions, school resources, teacher preparedness, and students' familiarity with independent inquiry may influence the transferability of reported educational benefits.

The Indonesian context also highlights the importance of culturally and environmentally relevant learning. Suwarno et al. (2026) demonstrated how local environmental sites can support contextual learning and environmental awareness, while Sholeh et al. (2026) described the educational relevance of nature-based experiences for character development. Such findings indicate that local environments may function simultaneously as scientific learning resources and settings for developing responsibility toward nature. However, environmental awareness, character formation, and scientific achievement represent distinct outcomes that require appropriate measurement. The present findings specifically concern ecosystem conceptual understanding and post-intervention learning independence; they do not establish changes in environmental behavior or character development. The broader relevance to Sustainable Development Goal 4 should therefore be interpreted through the provision of meaningful, competency-oriented educational experiences rather than as direct evidence of SDG achievement.

Contemporary digital-learning research offers a complementary perspective on learner agency. Handoko et al. (2026) identified relationships among digital biology learning, contextual meaning-making, and self-directed learning trajectories. Sidik et al. (2025) highlighted the relevance of problem-oriented instructional strategies for developing analytical and problem-solving competencies, although their review concerned programming education. Hariandini et al. (2026) further emphasized that educational innovation depends on how learning resources are pedagogically integrated rather than their availability alone. These findings suggest that digital and outdoor learning should not be positioned as competing approaches. Digital resources may support preparation, documentation, information evaluation, and reflection during outdoor investigations. Nevertheless, the present study did not evaluate digital interventions; such

applications should therefore be understood as possible extensions rather than explanations of the observed outcomes.

Theoretically, the findings are consistent with experiential and constructivist perspectives in which learners develop understanding through meaningful engagement with authentic phenomena and structured problem solving. The proposed integration positions outdoor observation as a source of contextual evidence and PBL as a framework for organizing inquiry, explanation, and reflection. Pedagogically, teachers should design age-appropriate environmental problems, provide observation guidelines, facilitate collaborative investigation, and gradually encourage students to plan, monitor, and evaluate their learning. These practices may foster student engagement and support confidence, cooperation, and emotional well-being when appropriate safety and instructional safeguards are provided. Digital media literacy could also be incorporated through critical evaluation of environmental information and responsible documentation of outdoor activities. At the policy level, schools should strengthen access to safe outdoor learning environments, teacher professional development, inclusive learning resources, and authentic assessment. Febriani et al. (2026) likewise emphasized connections among sustainability education, institutional support, and environmental governance. However, the present study did not directly measure emotional well-being, online behavior, or mental health, and policy recommendations concerning these outcomes require independent empirical evaluation.

The study's contribution lies in examining Outdoor Study and Problem-Based Learning as an integrated instructional condition associated with two complementary dimensions of elementary science education: conceptual understanding and learning independence. Unlike investigations focusing primarily on outdoor experiences or problem-based instruction separately, this study connects authentic ecosystem observation with structured inquiry and problem solving in Indonesian elementary-school settings. Methodologically, the combination of conceptual understanding pretests and posttests, post-intervention learning independence assessment, and multivariate analysis provides a preliminary basis for examining differentiated cognitive and learner-related outcomes. Nevertheless, the study does not isolate the independent effects of Outdoor Study and PBL, and the nonrandomized school-level allocation limits causal interpretation. Its contribution should therefore be regarded as context-specific comparative evidence and a foundation for stronger integrated-intervention research rather than definitive proof of instructional superiority.

Several limitations constrain interpretation. First, the sample comprised only 36 students from two schools, limiting statistical precision and external validity. Second, the experimental and control conditions were implemented in different schools, making instructional treatment inseparable from potentially influential school-level characteristics. Third, learning independence was measured only after the intervention, preventing evaluation of individual changes from baseline. Fourth, the relatively short intervention period limits conclusions concerning the durability of conceptual understanding and learning independence. Self-reported independence may also be affected by social desirability and response bias. Furthermore, the combination of Outdoor Study and PBL prevents identification of their separate or interactive contributions. Future research should involve multiple schools, randomized or carefully matched instructional groups, baseline and follow-up measures for both outcomes, and direct observation of independent learning behaviors. Longitudinal and factorial designs should examine implementation fidelity, teacher facilitation, environmental accessibility, and student characteristics as potential moderators. Such extensions would provide stronger evidence concerning the effectiveness, sustainability, and transferability of the integrated instructional approach.

CONCLUSION

Within the context of 36 fifth-grade students from two elementary schools in Blora Regency, students in the Outdoor Study-integrated Problem-Based Learning group showed higher post-

intervention conceptual understanding and learning independence than those receiving conventional instruction. The ANCOVA indicated a significant between-group difference in conceptual understanding after adjustment for pretest performance, while learning independence showed a significant post-intervention between-group difference. The MANOVA further indicated a significant difference between groups when the two outcomes were considered jointly. Because the study used nonrandomized intact classes from different schools, these findings should be interpreted as group differences associated with the instructional conditions rather than definitive causal effects.

The findings are therefore limited to the participating schools and sample and should not be broadly generalized. In particular, learning independence was measured only after the intervention; thus, the study does not establish change from baseline or causal improvement in this outcome. Future research should involve larger samples across multiple schools and use pretest–posttest measures of learning independence to provide stronger evidence regarding changes over time and the generalizability of the instructional approach.

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