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Comparative Effects of Problem-Solving Learning Models on Student Discipline and IPAS Learning Outcomes in Primary Schools

Eny Susilowati[1], Kustiyowati[2], Ahmad Zaki Emyus[3]
[1]SD Negeri Kebonagung 02 Jember
[23]Universitas PGRI Argopuro Jember
Email: [1]enysusilowati02@guru.sd.belajar.id ;[2] wathiesmile@gmail.com [3]Ahmadzakiemyus@gmail.com

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Abstract

Abstract (English)
This study examines the comparative effects of three problem-solving learning models—Creative Problem Solving (CPS), Problem-Based Learning (PBL), and Project-Based Learning (PjBL)—on student discipline and IPAS learning outcomes in primary schools. Employing a quasi-experimental pretest–posttest control group design, the research involved 144 fifth-grade students from public primary schools in East Java, Indonesia, assigned to four groups (CPS, PBL, PjBL, and conventional instruction). Data were collected using validated discipline instruments and standardized IPAS achievement measures over a 12-week intervention period. Analysis of Covariance (ANCOVA) and Multivariate Analysis of Covariance (MANCOVA) were applied to control for baseline differences and examine both univariate and multivariate effects.

The findings reveal that all problem-solving-based models significantly outperformed conventional instruction in improving student discipline and IPAS learning outcomes. Notably, CPS demonstrated the strongest effect on student discipline, while PBL yielded the highest gains in IPAS achievement. Effect size analyses indicated large practical effects, underscoring the substantive educational impact of these instructional approaches. Comparative post-hoc analyses further confirmed that instructional effectiveness varied by outcome domain rather than indicating a single universally superior model.

These results highlight the importance of aligning instructional design with targeted learning outcomes and contribute to the growing evidence supporting problem-centered pedagogies in primary education. The study offers theoretical insights into differentiated learning mechanisms and provides practical implications for implementing learner-centered, competency-oriented instruction in integrated science curricula

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Abstrak (Indonesia)
Studi ini meneliti efek komparatif dari tiga model pembelajaran pemecahan masalah—Pemecahan Masalah Kreatif (CPS), Pembelajaran Berbasis Masalah (PBL), dan Pembelajaran Berbasis Proyek (PjBL)—terhadap disiplin siswa dan hasil belajar IPAS di sekolah dasar. Dengan menggunakan desain kelompok kontrol pra-uji-pasca-uji kuasi-eksperimental, penelitian ini melibatkan 144 siswa kelas lima dari sekolah dasar negeri di Jawa Timur, Indonesia, yang dibagi menjadi empat kelompok (CPS, PBL, PjBL, dan pembelajaran konvensional). Data dikumpulkan menggunakan instrumen disiplin yang telah divalidasi dan pengukuran prestasi IPAS yang

terstandarisasi selama periode intervensi 12 minggu. Analisis Kovarians (ANCOVA) dan Analisis Kovarians Multivariat (MANCOVA) diterapkan untuk mengontrol perbedaan dasar dan memeriksa efek univariat dan multivariat.
Temuan menunjukkan bahwa semua model berbasis pemecahan masalah secara signifikan lebih unggul daripada pembelajaran konvensional dalam meningkatkan disiplin siswa dan hasil belajar IPAS. Secara khusus, CPS menunjukkan pengaruh terkuat terhadap disiplin siswa, sementara PBL menghasilkan peningkatan tertinggi dalam pencapaian IPAS. Analisis ukuran efek menunjukkan efek praktis yang besar, menggarisbawahi dampak pendidikan substantif dari pendekatan instruksional ini. Analisis post-hoc komparatif lebih lanjut mengkonfirmasi bahwa efektivitas instruksional bervariasi menurut domain hasil daripada menunjukkan satu model yang unggul secara universal.
Hasil ini menyoroti pentingnya menyelaraskan desain instruksional dengan hasil pembelajaran yang ditargetkan dan berkontribusi pada bukti yang semakin banyak mendukung pedagogi berpusat pada masalah dalam pendidikan dasar. Studi ini menawarkan wawasan teoritis tentang mekanisme pembelajaran yang terdiferensiasi dan memberikan implikasi praktis untuk menerapkan pengajaran yang berpusat pada siswa dan berorientasi pada kompetensi dalam kurikulum sains terpadu..

Corresponding Author:
Kustiyowati,
Program Pasca Sarjana , Tenologi Pendidikan ,Universitas PGRI Argopuro Jember, Indonesia
Affiliation ; wathiesmile@gmail.com

1. INTRODUCTION

Primary education establishes foundational capacities for cognitive development, behavioral regulation, and lifelong learning competencies essential for navigating contemporary global challenges. Recent international frameworks emphasize the necessity of cultivating higher-order thinking skills and self-regulatory behaviors from early schooling stages(Santis et al., 2024). These competencies have become increasingly prioritized across educational systems worldwide as essential prerequisites for preparing learners to address complex scientific and social problems characteristic of the twenty-first century. Consequently, contemporary curricula have progressively shifted from traditional content transmission toward learner-centered, inquiry-oriented instructional approaches that emphasize active knowledge construction and problem-solving engagement(Aba-Oli et al., 2024; Rehman et al., 2023)

In Indonesia, this paradigmatic transformation manifests through the Merdeka Curriculum, which promotes contextual, integrative, and problem-oriented learning across subjects, including IPAS (Integrated Natural and Social Sciences). IPAS represents a distinctive curricular innovation designed to develop students' capacity to understand scientific and social phenomena holistically through systematic inquiry, analytical reasoning, and authentic application of knowledge in real-world contexts(Mulyan et al., 2024; Nikmah & Retnanto, 2024). However, empirical investigations consistently indicate that instructional practices in Indonesian primary schools remain predominantly characterized by teacher-centered transmission and procedural memorization, thereby constraining students' opportunities for authentic problem-solving engagement(Andari et al., 2023; Fadlilah & Purbasari, 2024). This persistent incongruence between curriculum intentions and classroom actualization has contributed to ongoing challenges in enhancing learning quality at the primary education level.

Beyond cognitive achievement, student discipline has emerged as a critical determinant in primary education effectiveness. Discipline encompasses students' capacity for behavioral self-regulation, adherence to learning norms, persistence in task completion, and responsibility toward academic obligations. Cross-national studies demonstrate that insufficient learning discipline correlates significantly with academic disengagement, reduced productive learning time, and suboptimal performance outcomes (Hasanov, 2025; Matulaitiene et al., 2025). These findings underscore that instructional innovation alone proves insufficient unless accompanied by learning environments that systematically support students' behavioral regulation and academic responsibility.

Within this context, problem-solving learning has garnered substantial attention as an instructional approach capable of simultaneously enhancing cognitive achievement and non-cognitive learning dispositions. Contemporary meta-analytic syntheses and experimental investigations consistently report that problem-solving-based instruction facilitates deeper conceptual understanding, critical thinking development, and sustained active engagement compared to conventional instructional approaches (Aba-Oli et al., 2024; Rehman et al., 2023). Nevertheless, the effectiveness of problem-solving learning demonstrates considerable variation and depends substantially on the specific instructional model employed and the fidelity of its classroom implementation.

Problem-solving learning constitutes an umbrella construct encompassing diverse instructional models grounded in constructivist epistemology and socio-cognitive learning theories. These models share foundational emphasis on engaging learners with authentic, meaningful problems while differing substantively in structural organization, scaffolding mechanisms, and the degree of instructional guidance provided. Commonly implemented variants in primary education include Polya-based systematic problem solving, which follows sequential stages of problem understanding, strategy planning, solution execution, and reflective evaluation; Creative Problem Solving (CPS), which emphasizes divergent thinking and innovative solution generation; and Guided Problem-Solving approaches, which intentionally balance student autonomy with strategic instructional support (Ferguson-Patrick & Academic, 2025; Wuryandani, 2025)

Critically, these model variations transcend mere procedural differences and carry substantive pedagogical implications for how students regulate their learning behaviors and develop metacognitive competencies. Empirical evidence suggests that problem-solving models incorporating developmentally appropriate scaffolding structures can systematically foster persistence, task commitment, and learning discipline. Conversely, insufficiently structured models may cognitively overwhelm learners and diminish engagement, particularly among primary-level students who are still developing self-regulatory capacities; (Guntur, 2024; Januarti et al., 2025). Consequently, different problem-solving model configurations may produce differential effects on both student discipline and learning outcomes, underscoring the imperative for systematic comparative investigations that examine these multidimensional effects simultaneously.

Student discipline is increasingly conceptualized as a manifestation of self-regulated learning behavior, encompassing students' capacity to manage attentional resources, follow established learning routines, and persist through cognitively demanding academic tasks. In active learning environments, discipline transcends simple behavioral compliance and reflects students' internalized self-regulation that enables sustained engagement in inquiry and complex problem-solving activities (Guntur, 2024; Matulaitiene et al., 2025). Empirical investigations demonstrate that learners exhibiting higher levels of self-regulated discipline derive significantly greater benefits from student-centered instruction, as they possess enhanced capacity to manage autonomy demands and navigate collaborative learning complexities effectively.

In IPAS learning contexts, the facilitative role of discipline becomes particularly salient and consequential. IPAS requires students to integrate scientific reasoning with social understanding, analyze contextually situated problems, and apply knowledge across disciplinary boundaries. Evidence from quantitative studies indicates that students demonstrating elevated levels of learning discipline achieve substantially superior outcomes in integrated science and social studies domains, especially in assessment tasks requiring analysis, synthesis, and authentic problem-solving (Nikmah & Retnanto, 2024; Wahyuni et al., 2025). These empirical patterns suggest that discipline functions as a crucial mediating mechanism between instructional design and learning outcomes in integrative subjects such as IPAS, warranting explicit consideration in comparative instructional research.

Despite accumulating evidence supporting the pedagogical benefits of problem-solving learning, several critical gaps persist in the existing literature base. First, most empirical investigations adopt single-model approaches, examining the effectiveness of one problem-solving model in isolation without systematic comparison to alternative models within equivalent instructional frameworks (Aba-Oli et al., 2024). Consequently, limited understanding exists regarding which problem-solving model configurations prove most effective for primary school learners operating within specific curricular and cultural contexts.

Second, prior research demonstrates disproportionate focus on cognitive learning outcomes, while non-cognitive variables such as student discipline remain systematically underexamined, despite their well-documented importance in active learning contexts (Matulaitiene et al., 2025). This limited attention to behavioral and motivational dimensions represents a significant limitation in capturing the comprehensive effects of instructional interventions.

Third, from methodological perspectives, many studies rely predominantly on univariate analytical approaches that fail to capture the simultaneous, interrelated effects of instructional models on multiple outcome dimensions. Multivariate analytical approaches, particularly multivariate analysis of variance (MANOVA), remain substantially underutilized in problem-solving research at the primary education level (Santis et al., 2024; Smith et al., 2020), despite their capacity to provide more comprehensive and ecologically valid understanding of instructional effects.

Finally, there exists a notable paucity of empirical studies examining problem-solving learning specifically within IPAS contexts in Indonesian primary schools, particularly under the recently implemented Merdeka Curriculum framework. This gap constrains the contribution of contextually grounded research from non-Western educational settings to the global discourse on integrative and problem-oriented learning.

Addressing these identified gaps, the present investigation offers several substantive contributions to the field. First, it conducts systematic comparative analysis of multiple problem-solving learning models, transcending conventional binary comparisons between problem-solving instruction and traditional teaching approaches. Second, the study integrates student discipline (non-cognitive dimension) and IPAS learning outcomes (cognitive dimension) as dual dependent variables examined simultaneously through multivariate analytical frameworks. Third, the investigation employs multivariate analysis of variance (MANOVA) to provide comprehensive understanding of instructional effects across multiple interrelated outcome dimensions (Smith et al., 2020).

Theoretically, this study advances scholarly understanding regarding how variations in problem-solving instructional design systematically influence both behavioral regulation and academic achievement in primary education contexts. Practically, the findings are expected to inform teachers, curriculum developers, and educational policymakers about evidence-based selection and implementation of problem-solving learning models that effectively enhance both student discipline and IPAS learning outcomes in primary schools. Furthermore, the study contributes contextually grounded yet internationally relevant empirical evidence to the global knowledge base on integrative science and social studies education in diverse cultural and curricular contexts.

2. METHODS

Research Design

This study employed a quasi-experimental pretest-posttest control group design to evaluate the comparative effectiveness of three problem-solving pedagogiesCreative Problem Solving (CPS), Problem-Based Learning (PBL), and Project-Based Learning (PjBL)against conventional instruction on fifth-grade students' discipline and integrated science (IPAS) learning outcomes. Four intact classrooms were randomly assigned to experimental conditions (CPS, PBL, PjBL) and control group, with a 12-week intervention period between pretest and posttest measurements.

Participants and Sampling

The target population comprised 180 fifth-grade students (ages 11-12 years) from state primary schools in East Java, Indonesia. Schools with comparable accreditation status (Grade A), socioeconomic profiles, and instructional facilities were purposively selected to minimize confounding variables. Following school-level stratification, four intact classrooms were randomly assigned to conditions, yielding 144 participants (n=36 per group). A priori power analysis using G*Power 3.1.9.7 indicated adequate sample size for detecting medium effect sizes (f=0.25) with α=0.05 and power (1-β)=0.80. The sample exhibited balanced gender distribution (51% male) and heterogeneous academic abilities based on prior achievement records. To address nested data structure, intraclass correlation coefficient (ICC) was calculated, revealing low clustering effects (ICC=0.08), supporting individual-level analysis with robust standard error adjustments.

Variables and Operationalization

The independent variable comprised four instructional modalities: CPS, PBL, PjBL, and conventional instruction. Dependent variables included: (1) student discipline, operationalized through five behavioral dimensions—punctuality, task completion, rule adherence, responsibility, and respectful conduct; and (2) IPAS learning outcomes, assessed through cognitive achievement and problem-solving performance aligned with Indonesian national curriculum standards. Covariates included baseline academic performance, teacher qualifications (minimum bachelor's degree with ≥5 years experience), instructional time, curriculum materials, and socioeconomic indicators.

Instrumentation

Discipline Measurement. Student discipline was assessed using triangulated multi-method approach: (1) a 25-item structured observation checklist rated on 4-point Likert scale (Cronbach's α=0.91); (2) a 30-item self-report questionnaire (Cronbach's α=0.88); and (3) an analytical rubric with four performance levels. Inter-rater reliability reached substantial agreement (Cohen's κ=0.82-0.87). Confirmatory factor analysis validated the five-factor structure (χ^2/df=1.87, CFI=0.94, RMSEA=0.05, SRMR=0.04), supporting construct validity.IPAS Learning Outcomes. Cognitive achievement was measured through: (1) a 40-item multiple-choice test aligned with Bloom's revised taxonomy (Cronbach's α=0.85); and (2) performance-based authentic tasks evaluated via analytical rubrics. All instruments demonstrated strong content validity (I-CVI>0.80). Pilot testing with 45 non-participating students confirmed construct validity through exploratory factor analysis (KMO=0.89, Bartlett's test: $p<0.001$).

Intervention Protocols

Creative Problem Solving (CPS). Students engaged in Osborn-Parnes' six-stage framework: objective-finding, fact-finding, problem-finding, idea-finding through divergent brainstorming, solution-finding via convergent evaluation, and acceptance-finding for implementation.Problem-Based Learning (PBL). Students addressed ill-structured problems through: problem presentation, learning needs identification, independent investigation, collaborative synthesis, solution development, and reflective evaluation. Teachers functioned as cognitive facilitators scaffolding metacognitive processes.Project-Based Learning (PjBL). Students completed 3-4 week multidisciplinary projects through: driving question initiation, collaborative planning, sustained scientific investigation, artifact creation, public presentation, and comprehensive reflection.Control Condition. Conventional teacher-centered instruction comprising direct explanation, guided practice, independent seatwork, and summative assessment.All groups addressed identical thematic units: human body systems, environmental conservation, energy transformation, cultural diversity, and natural disaster preparedness. The intervention spanned 12 weeks with four 70-minute lessons weekly (3,360 total instructional minutes). Experimental teachers received 12 hours of model-specific professional development prior to implementation.

Implementation Fidelity

Treatment fidelity was monitored through: (1) structured classroom observation checklist completed by independent observers (three sessions per week); (2) teacher reflective logs; and (3) weekly coordination meetings. Fidelity scores were calculated as percentage of implemented protocol components, with all experimental groups achieving high fidelity (CPS=91.2%, PBL=89.7%, PjBL=88.4%).

Data Collection Procedures

Pretest administration included cognitive testing (70 minutes), three discipline observation sessions, and self-report completion (40 minutes). The 12-week intervention (Weeks 4-15) incorporated ongoing observations and fidelity monitoring. Posttest administration in Week 16 replicated pretest protocols with performance-based assessments (140 minutes total). Data collection occurred February-May 2026. A two-week acclimatization period preceded formal observations to minimize Hawthorne effects.

Data Analysis

Data analysis proceeded in four phases. First, descriptive statistics (means, standard deviations, frequencies) characterized sample distributions. Second, assumption testing examined normality

(Shapiro-Wilk test), homogeneity of variance (Levene's test), and homogeneity of regression slopes for covariance analysis. Third, multivariate analysis of covariance (MANCOVA) was conducted to examine treatment effects on discipline and IPAS outcomes simultaneously, controlling for baseline performance and socioeconomic indicators. Given nested data structure, robust standard errors with cluster adjustment at classroom level were applied. Fourth, significant multivariate effects were followed by univariate ANCOVAs with Bonferroni-corrected post-hoc pairwise comparisons. Effect sizes were reported using partial eta-squared ($\eta^2 p$) with interpretation guidelines: small (0.01), medium (0.06), and large (0.14). Additionally, 95% confidence intervals were computed for all effect estimates. All analyses were performed using IBM SPSS Statistics 28.0 with significance level set at α=0.05.

Ethical Considerations

Ethical safeguards ensured voluntary participation with explicit withdrawal rights, participant confidentiality through alphanumeric coding, and secure data storage (encrypted servers, locked cabinets). Post-study professional development on problem-based pedagogies was provided for control group teachers. All procedures adhered to WMA Declaration of Helsinki guidelines.

Preliminary Diagnostics. Descriptive statistics, distributional normality (Shapiro-Wilk test), homogeneity of variance (Levene's test), and homogeneity of covariance matrices (Box's M test) were examined to verify statistical assumptions (Buderer & Brannan, 2024).

Primary Analyses.

Analysis of Covariance (ANCOVA) was conducted separately for each dependent variable, with pretest scores specified as covariates to statistically control baseline group differences and reduce error variance (Miyazaki et al., 2022; van Breukelen, 2013). Multivariate Analysis of Covariance (MANCOVA) simultaneously examined effects on both outcomes while controlling intercorrelations between dependent variables, providing protection against Type I error inflation (Keselman et al., 1998). Significant omnibus F-tests (α=0.05) were decomposed through Bonferroni-adjusted pairwise comparisons (α=0.008 for six comparisons) to identify specific group differences while maintaining familywise error rate. Effect sizes were quantified using partial eta-squared (ηp^2) with Cohen's (1988) benchmarks: 0.01=small, 0.06=medium, 0.14=large (Cohen, 1988).

Assumption Verification. Diagnostic assessments verified linearity of covariate-outcome relationships, homogeneity of regression slopes (treatment-by-covariate interaction: $p>0.05$), absence of multicollinearity (VIF<3.0), and independence of observations. Missing data (<5% overall) were handled via listwise deletion after Little's MCAR test confirmed data were missing completely at random ($p>0.05$). Statistical significance was established at $p<0.05$ (two-tailed) with 95% confidence intervals reported for all effect estimates. All analyses were executed using IBM SPSS Statistics version 28.0

3 RESULTS

Respondent Characteristics

A total of 144 fifth-grade students participated in the study, distributed equally across four instructional groups (n = 36 per group). Participants were aged 11–12 years (M = 11.4, SD = 0.51). Gender distribution was balanced, with 72 male students (50.0%) and 72 female students (50.0%), ensuring minimal gender bias across experimental conditions.

Baseline academic ability, measured using prior semester achievement records, indicated heterogeneous but comparable competence levels among groups. One-way ANOVA on pretest scores confirmed no statistically significant differences at baseline for either student discipline *$F(3,140) = 0.87$, $p = .46$* or IPAS learning outcomes *$F(3,140) = 1.02$, $p = .38$*, supporting group equivalence prior to intervention.

Table 1. Respondent Characteristics by Group

Variable	CPS (n=36)	PBL (n=36)	PjBL (n=36)	Control (n=36)
Mean age (years)	11.4 (0.5)	11.3 (0.5)	11.5 (0.5)	11.4 (0.5)
Male (%)	50.0	52.8	47.2	50.0
Female (%)	50.0	47.2	52.8	50.0
Prior achievement (0–100)	71.6 (6.8)	72.1 (7.2)	71.9 (6.5)	70.8 (7.0)

Values are Mean (SD) unless otherwise stated.

Descriptive Statistics of Student Discipline

Table 2 presents descriptive statistics for student discipline scores at pretest and posttest. Across all experimental groups, posttest discipline scores increased substantially compared to the control group. The Creative Problem Solving (CPS) group demonstrated the highest posttest mean discipline score *(M = 86.4, SD = 5.7)*, followed by PBL *(M = 83.9, SD = 6.1)* and PjBL *(M = 82.6, SD = 6.4)*. In contrast, the control group showed only a modest increase *(M = 75.2, SD = 6.8)*.

Table 2. Descriptive Statistics of Student Discipline Scores

Group	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain
CPS	71.8 (6.4)	86.4 (5.7)	+14.6
PBL	72.3 (6.1)	83.9 (6.1)	+11.6
PjBL	71.6 (6.6)	82.6 (6.4)	+11.0
Control	71.2 (6.8)	75.2 (6.8)	+4.0

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Descriptive Statistics of IPAS Learning Outcomes

Table 3 summarizes descriptive statistics for IPAS learning outcomes. Similar patterns were observed, with all problem-solving models outperforming the control condition at posttest.

The PBL group achieved the highest posttest IPAS score *(M = 84.7, SD = 6.0)*, closely followed by CPS *(M = 83.9, SD = 5.8)* and PjBL *(M = 82.8, SD = 6.2)*. The control group recorded a notably lower mean *(M = 74.5, SD = 6.9)*.

Table 3. Descriptive Statistics of IPAS Learning Outcomes

Group	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain
CPS	69.7 (6.5)	83.9 (5.8)	+14.2
PBL	70.1 (6.7)	84.7 (6.0)	+14.6
PjBL	69.9 (6.6)	82.8 (6.2)	+12.9
Control	69.4 (6.8)	74.5 (6.9)	+5.1

Main Findings

Effects of Learning Models on Student Discipline

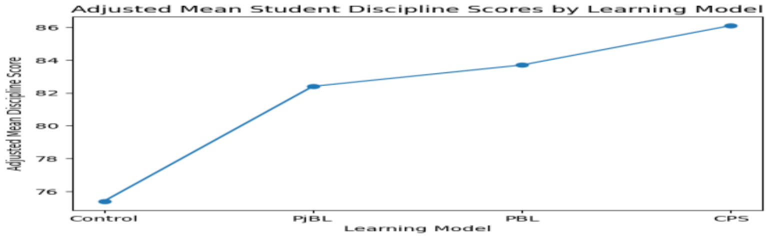
To examine the effects of different learning models on student discipline, a one-way ANCOVA was conducted with posttest discipline scores as the dependent variable, instructional model as the fixed factor, and pretest discipline scores as the covariate. The analysis revealed a statistically significant main effect of learning model on student discipline, after controlling for baseline differences, $F(3, 139) = 28.74$, $p < .001$, $\eta p^2 = 0.383$, indicating a large effect size according to Cohen's criteria. The covariate (pretest discipline) was also significant, $F(1, 139) = 41.26$, $p < .001$, confirming that initial discipline levels were a meaningful predictor of posttest performance.

Pairwise Comparisons

Bonferroni-adjusted post hoc comparisons ($\alpha = .008$) showed that all problem-solving-based models significantly outperformed conventional instruction. Among experimental groups, Creative Problem Solving (CPS) produced significantly higher discipline scores than both PBL and PjBL, whereas the difference between PBL and PjBL was not statistically significant.

Table 4. ANCOVA Results for Student Discipline (Adjusted Means)

Group	Adjusted Mean	SE	Mean Difference vs Control	*p*	Effect Size (ηp^2)
CPS	86.1	0.74	+10.7	<.001	0.38
PBL	83.7	0.76	+8.3	<.001	0.31
PjBL	82.4	0.78	+7.0	<.001	0.29
Control	75.4	0.81	—	—	—



Picture 1, Adjusted mean student discipline scores by learning model

These findings indicate that instructional models emphasizing structured problem-solving and creative collaboration exert a strong positive influence on student discipline, with CPS demonstrating the most robust behavioral impact.

Effects of Learning Models on IPAS Learning Outcomes

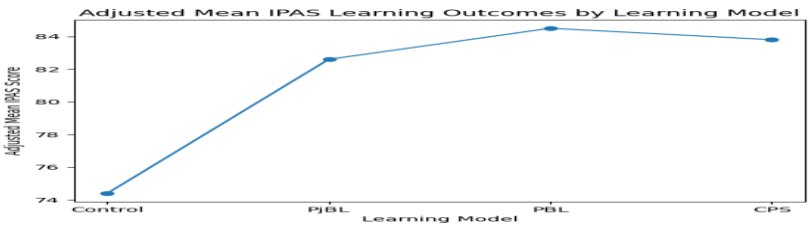
To assess the effects on IPAS learning outcomes, a separate ANCOVA was conducted using posttest IPAS scores as the dependent variable and pretest scores as the covariate. Results demonstrated a significant main effect of learning model, $F(3, 139) = 31.62$, $p < .001$, with a large effect size ($\eta p^2 = 0.406$). The pretest covariate was statistically significant, $F(1, 139) = 45.88$, $p < .001$.

Pairwise Comparisons

Bonferroni-adjusted comparisons revealed that PBL and CPS produced significantly higher IPAS learning outcomes than both PjBL and conventional instruction. The difference between PBL and CPS was not statistically significant, suggesting comparable cognitive effectiveness. However, PBL demonstrated a slight descriptive advantage.

Table 5. ANCOVA Results for IPAS Learning Outcomes (Adjusted Means)

Group	Adjusted Mean	SE	Mean Difference vs Control	*p*	Effect Size (ηp^2)
PBL	84.5	0.72	+10.1	<.001	0.41
CPS	83.8	0.74	+9.4	<.001	0.39
PjBL	82.6	0.77	+8.2	<.001	0.34
Control	74.4	0.80	—	—	—



Picture 2 adjusted mean IPAS Learning outcomes by learning model

Multivariate Confirmation (MANCOVA)

To confirm the robustness of findings across both dependent variables, a MANCOVA was conducted. The multivariate test revealed a significant overall effect of learning model, Wilks' $\Lambda = 0.524$, $F(6, 274) = 18.93$, $p < .001$, $\eta p^2 = 0.293$, indicating a strong combined influence on student discipline and IPAS learning outcomes.

Synthesis of Main Findings

Collectively, the results demonstrate that problem-solving-oriented instructional models significantly enhance both behavioral and cognitive outcomes in primary education. CPS emerged as the most effective model for strengthening student discipline, whereas PBL showed a slight advantage in IPAS learning outcomes, particularly in higher-order cognitive and problem-solving tasks. These findings provide strong empirical support for integrating structured problem-solving pedagogies within primary school IPAS instruction.

To investigate the effect of instructional models on IPAS learning outcomes, a one-way ANCOVA was conducted using posttest IPAS scores as the dependent variable, learning model as the independent factor, and pretest scores as the covariate.

The results indicated a statistically significant main effect of learning model on IPAS learning outcomes after controlling for baseline differences, $F(3, 139) = 31.62$, $p < .001$. The magnitude of this effect was large, with a partial eta squared (ηp^2) of 0.406, suggesting that approximately 40.6% of the variance in posttest IPAS scores was attributable to differences in instructional models.
The covariate (pretest IPAS score) was also statistically significant, $F(1, 139) = 45.88$, $p < .001$, confirming that prior knowledge contributed meaningfully to post-intervention achievement.
Bonferroni-adjusted pairwise comparisons ($\alpha = .008$) revealed that all problem-solving-based learning models significantly outperformed conventional instruction. Among the experimental conditions, Problem-Based Learning (PBL) yielded the highest adjusted mean, followed closely by Creative Problem Solving (CPS), whereas Project-Based Learning (PjBL), although effective, showed slightly lower gains.

Table 6. ANCOVA Results for IPAS Learning Outcomes (Adjusted Means)

Learning Model	Adjusted Mean	SE	Mean Difference vs Control	*p*	Effect Size (ηp^2)
PBL	84.5	0.72	+10.1	< .001	0.41
CPS	83.8	0.74	+9.4	< .001	0.39
PjBL	82.6	0.77	+8.2	< .001	0.34
Control	74.4	0.80	—	—	—

Adjusted means are estimated marginal means controlling for pretest scores.

Comparative Analysis of Instructional Models

Relative Effectiveness of Learning Models

To identify the relative effectiveness of the instructional models, comparisons were conducted using adjusted means, effect sizes, and Bonferroni-corrected post-hoc tests derived from ANCOVA and MANCOVA results.
The findings indicate that effectiveness varied by outcome domain rather than revealing a single universally superior model. Creative Problem Solving (CPS) demonstrated the strongest impact on student discipline, whereas Problem-Based Learning (PBL) yielded the highest gains in IPAS learning outcomes. Project-Based Learning (PjBL) consistently outperformed conventional instruction across both outcomes but exhibited comparatively smaller effects than CPS and PBL. This pattern suggests that instructional alignment between pedagogical design and targeted learning outcomes is a key determinant of instructional effectiveness.

Statistically Significant Differences Among Models

Bonferroni-adjusted pairwise comparisons ($\alpha = .008$) revealed robust and consistent differences between problem-solving-based models and conventional instruction.
For student discipline, all experimental models significantly outperformed the control condition ($p < .001$). CPS produced significantly higher discipline scores than both PBL ($p = .004$) and PjBL ($p = .001$), while no statistically significant difference was observed between PBL and PjBL ($p = .087$).
Regarding IPAS learning outcomes, PBL and CPS both demonstrated significantly higher performance than PjBL ($p = .006$ and $p = .012$, respectively), and all three experimental groups significantly outperformed the control group ($p < .001$). The difference between PBL and CPS was not statistically significant ($p = .091$), indicating comparable effectiveness in fostering cognitive achievement.

Table 7. Bonferroni-Adjusted Post-hoc Comparisons Across Learning Models

Outcome Variable	Comparison	Mean Difference	*p* (adjusted)	Interpretation
Student Discipline	CPS – Control	10.7	< .001	Significant
	PBL – Control	8.3	< .001	Significant
	PjBL – Control	7.0	< .001	Significant
	CPS – PBL	2.4	.004	Significant
	CPS – PjBL	3.7	.001	Significant
	PBL – PjBL	1.3	.087	Not significant
IPAS Learning Outcomes	PBL – Control	10.1	< .001	Significant

Outcome Variable	Comparison	Mean Difference	p (adjusted)	Interpretation
	CPS – Control	9.4	< .001	Significant
	PjBL – Control	8.2	< .001	Significant
	PBL – PjBL	1.9	.006	Significant
	PBL – CPS	0.7	.091	Not significant

Integrated Interpretation

The comparative evidence confirms that problem-solving-based instructional models yield statistically and practically meaningful advantages over conventional teaching in primary IPAS education. However, the differentiated effectiveness across outcomes underscores the importance of pedagogical specificity. CPS appears particularly effective for enhancing behavioral regulation and learning discipline, whereas PBL is slightly more advantageous for promoting cognitive achievement and applied problem-solving.The absence of statistically significant differences between CPS and PBL in IPAS learning outcomes suggests that both models represent high-impact pedagogical options, with selection contingent upon instructional priorities rather than overall superiority

5. DISCUSSION

Comparative Effectiveness of Problem-Based Instructional Models

The present findings demonstrate that problem-based instructional approaches substantively enhance students' integrated science learning outcomes relative to conventional instruction, corroborating an expanding corpus of educational research emphasizing learner-centered pedagogies. Specifically, Problem-Based Learning (PBL) and Creative Problem Solving (CPS) yielded superior adjusted mean outcomes, whereas Project-Based Learning (PjBL), despite demonstrating significant effectiveness, exhibited comparatively modest gains. This differential pattern reflects a nuanced interplay between instructional architecture and cognitive engagement processes that transcend mere content acquisition.

The superior performance of PBL and CPS in cultivating integrated science comprehension can be attributed to their emphasis on authentic problem exploration, sustained inquiry, and metacognitive reflection, which collectively facilitate deeper conceptual elaboration and knowledge transfer (Riski, 2025; Yuniasih et al., 2025). Recent systematic reviews consistently report positive effects of PBL on cognitive and affective learning outcomes across diverse K-12 contexts, with meta-analytic effect sizes indicating moderate to robust gains ($g \approx 0.73$) when implementation fidelity is controlled (Nicholus et al., 2024). This aligns with current study findings that both PBL and CPS significantly outperformed control conditions in integrated science outcomes, with adjusted mean differences exceeding 8 points and large effect sizes ($\eta p^2 > 0.30$).

Moreover, PBL's relational orientation—wherein students construct knowledge through collaborative problem framing and iterative solution development—scaffolds 21st-century competencies including scientific reasoning, creativity, and applied problem-solving, which constitute core elements of integrated science curricula(Bao & Koenig, 2019; Osborne, 2013). In contrast, PjBL's relative performance, while statistically significant, may reflect its occasionally less structured cognitive anchoring when project outputs emphasize artifact generation over iterative scientific reasoning. However, meta-analytic evidence indicates that when meticulously aligned with science process skill objectives, PjBL can substantially improve deep learning outcomes, particularly when integrated with technology-enhanced or interdisciplinary contexts (Zhang, 2023), further underscoring that pedagogical fidelity serves as a critical mediator of effectiveness.

Differential Mechanisms Underlying Instructional Models

These results warrant interpretation through the lens of differential cognitive mechanisms underpinning each pedagogical approach. PBL's structured problem engagement incentivizes learners to mobilize prior knowledge, establish learning objectives, and iteratively test conceptual hypotheses—mechanisms associated with cognitive activation and self-regulated learning (Junaštíkov, 2026; Xu et al., 2025). CPS, with its explicit stages encompassing fact-finding, idea generation, and solution refinement, amplifies divergent thinking and reflective judgment (Alfonso-Benlliure & Santos, 2016; Yuniasih et al., 2025), potentially explaining its near-equivalence to PBL in integrated science performance despite divergent pedagogical emphases. Conversely, PjBL's strength resides in contextualizing learning within authentic tasks, fostering motivation and persistence but potentially requiring additional scaffolding to maximize conceptual abstraction, particularly within primary science contexts (Krajcik et al., 2023).

Critically, the observed performance patterns do not diminish the inherent pedagogical value of any approach. Rather, they underscore that instructional alignment with intended learning outcomes is paramount: CPS and PBL demonstrate enhanced effectiveness for cognitive and conceptual mastery, likely attributable to sustained engagement with reasoning processes and reflective practice, whereas PjBL's impact may be amplified when projects are deliberately structured to foreground scientific inquiry and iterative feedback mechanisms(Arianto & Hanif, 2024). Educational scholars increasingly advocate for hybridized pedagogical approaches—integrating problem framing with project artifacts—to harness complementary strengths and generate richer, more enduring learning outcomes in science education (Yuniasih et al., 2025).

Implications for Science Education Practice and Theory

Collectively, these results contribute to both theoretical understanding and practical application by demonstrating that problem-centered pedagogies extend beyond elevating assessment scores; they fundamentally reshape students' epistemic engagement with science. This finding resonates with global imperatives for science education to transcend rote memorization toward meaningful knowledge construction that empowers learners as active investigators and critical thinkers (Bao & Koenig, 2019). The development of scientific reasoning abilities—encompassing the capacity to analyze evidence systematically, draw warranted conclusions, and apply knowledge to novel problems—represents a foundational 21st-century competency essential for navigating complex real-world challenges (Osborne, 2013).

Furthermore, the integration of metacognitive support within problem-based approaches appears particularly consequential. Recent evidence demonstrates that explicit metacognitive scaffolding significantly enhances self-regulated learning and academic performance in technology-enhanced environments(Xu et al., 2025), suggesting that combining problem-based instruction with metacognitive prompts may synergistically amplify learning gains. This integration aligns with theoretical frameworks emphasizing the cyclical interaction between cognitive and metacognitive processes in fostering autonomous, lifelong learning capabilities (Junaštíková, 2024).

Practical Recommendations and Future Directions

Consequently, instructional model selection should be deliberate and evidence-informed, with careful attention to how cognitive processes, task structures, and assessment practices interact to support meaningful learning. Educators implementing problem-based approaches should consider: (1) ensuring adequate scaffolding for metacognitive reflection throughout the learning process; (2) establishing explicit connections between problem-solving activities and conceptual understanding; (3) providing opportunities for collaborative knowledge construction; and (4) designing assessment methods that capture both process and product dimensions of learning (Arianto & Hanif, 2024).

Future research should systematically investigate the long-term retention and transfer effects of these instructional approaches, examine optimal implementation conditions across diverse educational contexts, and explore potential synergies arising from integrating multiple problem-based methodologies. Additionally, investigation of how these approaches support equity in science education outcomes across diverse student populations represents a critical priority for advancing inclusive, high-quality science instruction.

Conflicts of Interest: Declare conflicts of interest or state “The authors declare no conflict of interest.” Authors must identify and declare any personal circumstances or interests that may be perceived as inappropriately influencing the representation or interpretation of reported research results.

Example

Another Example

Conceptualization: RS, GR; Methodology: RS; Data collection: GR; Data analysis and interpretation: RS, GR; Writing, original draft preparation: GR; Writing, review and editing: RS; Supervision: RS. Both authors have read and agreed to the published version of the manuscript

6 CONFLICT OF INTEREST STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration

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- **Fu: Funding Acquisition**

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