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The Effect of The Project-Based Learning (PjBL) Model on Students' Cognitive Learning Outcomes

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Abstract: This study investigates the effect of the Project-Based Learning (PjBL) model on students' cognitive learning outcomes, compared with Problem-Based Learning (PBL), in senior high school biology. The research was motivated by persistently low cognitive achievement and teacher-centred practices observed at SMA Negeri 3 Selong, where many Grade X students scored below the minimum mastery criterion and struggled to construct coherent scientific arguments. A quantitative quasi-experimental design with a non-equivalent control group pretest–posttest design was employed. The population consisted of all Grade X students (N = 84), with purposive sampling used to select two intact classes: X-8 as the experimental group (PjBL; n = 21) and X-7 as the control group (PBL; n = 21). The experimental class engaged in an authentic project constructing aquascapes from recycled jars, while the control class followed PBL-based instruction on the same content. Cognitive learning outcomes (C1–C4) were measured using a multiple-choice and an essay test. Assumption checking using the Shapiro–Wilk and Levene's tests indicated that posttest data met the requirements for parametric analysis. An independent-samples t-test on posttest scores revealed a statistically significant difference between groups (p = 0.001), with the PjBL class outperforming the PBL class by an average of 17.476 points. These findings demonstrate that PjBL has a significant and positive impact on students' cognitive learning outcomes in biology and is more effective than PBL in enhancing lower- and middle-order cognitive processes. The study recommends systematic integration of PjBL in science classrooms and further research with larger, multi-site samples, including additional outcome variables such as motivation, critical thinking, and creativity.

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Introduction

Secondary education is increasingly expected to cultivate higher-order thinking, creativity, and problem-solving rather than merely transmitting factual knowledge. International policy documents and comparative studies emphasise the shift from teacher-centred to student-centred pedagogy to prepare learners for the complex demands of the 21st century (Nurazizah et al., 2025). However, large-scale assessments such as PISA 2018 and 2022 show that Indonesian students still perform below the OECD average in reading, mathematics, and science, with a relatively small proportion achieving the minimum proficiency level in all three domains (OECD, 2023). These results indicate that many students have not yet developed robust cognitive competencies, particularly in tasks that require analyzing, evaluating, and applying knowledge in unfamiliar contexts.

Within this landscape, cognitive learning outcomes occupy a central position because they reflect observable changes in students' knowledge and thinking processes resulting from

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instruction. Cognitive learning outcomes are commonly conceptualised using the revised Bloom taxonomy, which organises cognitive processes into hierarchical levels: remember, understand, apply, analyse, evaluate, and create (Adams, 2015). In the Indonesian context, numerous authors explicitly frame cognitive achievement as behavioural change across this continuum, ranging from low-order thinking skills (C1–C3) to high-order thinking skills (C4–C6) (Nurlindayani et al, 2021). Empirical studies have shown that cognitive learning outcomes function not only as indicators of curriculum mastery but also as predictors of students' capacity for critical thinking and scientific reasoning (Khairinaa et al, 2023). Nevertheless, classroom-based research in Indonesia continues to report low levels of cognitive achievement across multiple subjects and grade levels, especially where instruction remains dominated by expository teaching and rote practice (Pertiwi et al, 2020).

Preliminary observations and interviews conducted by the present researcher at SMA Negeri 3 Selong on 31 July 2024 reinforce this broader pattern. In science lessons, many students were unable to formulate coherent arguments or justify their answers using relevant concepts, and summative assessment scores in the observed classes were frequently below the school's minimum mastery criterion (Kriteria Ketuntasan Minimum, KKM) of 70. The learning process was still largely teacher-centred: teachers explained the material, worked through examples, and then assigned short exercises, while students tended to adopt a passive, note-taking role. Such pedagogical practices are consistent with previous findings that teacher-centred instruction tends to generate lower-level cognitive outcomes. In contrast, student-centred approaches are more conducive to conceptual understanding and transfer (Maulana et al, 2024). These local findings suggest an urgent need to redesign classroom learning models to enhance students' cognitive performance across the full range of C1–C6 processes.

Various innovative models—such as Problem-Based Learning (PBL), cooperative learning, and inquiry-based approaches—have been proposed to address the persistent gap in cognitive achievement. Classroom action research in Indonesian schools has repeatedly demonstrated that carefully structured cooperative and PBL-type models can raise students' cognitive scores when implemented with sufficient scaffolding and student engagement (Pertiwi et al., 2020). However, recent meta-analyses and survey studies highlight that the effectiveness of PBL is highly contingent on the quality of its implementation. Issues related to teachers' understanding of the model, curriculum alignment, classroom management, and assessment practices often constrain its impact on higher-order cognitive outcomes (Koçoğlu & Kanadlı, 2025). In many classrooms, PBL is applied only superficially—reduced to working on worksheets or discussing textbook problems—so that students remain focused on reproducing information rather than constructing and applying knowledge (Indriyani et al, 2025). These limitations indicate that simply labelling instruction as "PBL" is not sufficient; teachers require models that more explicitly organise learning around authentic tasks, extended inquiry, and the production of tangible artefacts.

Project-Based Learning (PjBL) has emerged as one such model that aligns strongly with these requirements. In PjBL, students engage in sustained projects that begin from meaningful questions or problems and culminate in a concrete product, presentation, or solution. This structure is designed to integrate knowledge acquisition with collaboration, investigation, and reflection, thereby activating multiple levels of the cognitive domain simultaneously (Yusri et al, 2024). Empirical research in Indonesian and international settings consistently reports that PjBL can significantly improve students' cognitive learning outcomes when compared to conventional teaching. Quantitative studies at primary and secondary levels show that PjBL classes achieve higher posttest scores in science process skills and cognitive achievement than control classes taught using traditional lecture methods (Warmadewi et al, 2024). Other investigations reveal

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that PjBL enhances scientific literacy and autonomy (Rusmansyah et al, 2023). strengthens students' ability to integrate concepts in context-rich tasks (Nestiyarum & Widjajanti, 2023) and supports the simultaneous development of creative thinking, motivation, and cognitive performance (Safaruddin et al, 2020). At a broader level, meta-analyses in the international literature conclude that project-based approaches yield statistically significant gains in academic achievement and higher-order thinking relative to traditional instruction. However, effect sizes vary across subjects, age groups, and implementation conditions (Zhang & Ma, 2023).

PjBL has also been endorsed in Indonesia's Merdeka Curriculum as a means to cultivate the Pancasila Student Profile, precisely because it can foster creativity, collaboration, and reflective problem solving through authentic tasks (Iman & Fauziah, 2025). National studies document that project-based learning increases students' engagement and creativity across diverse subjects and school levels (Sastradiharja & Febriani, 2023). Nonetheless, literature reviews and case studies caution that PjBL is not without challenges. Teachers frequently report difficulties with time management, resource constraints, and aligning project work with formal assessment and high-stakes examinations (Syahdia et al., 2024). When these challenges are not addressed, projects risk becoming activity-oriented rather than learning-oriented, and the anticipated improvements in cognitive outcomes may fail to materialise (Meng et al, 2023). In other words, while the theoretical potential of PjBL to raise cognitive achievement is well supported, there remains a need for school-specific empirical evidence on how PjBL influences the full spectrum of cognitive learning outcomes in real classroom conditions, particularly in Indonesian senior high schools.

In the specific context of SMA Negeri 3 Selong, the mismatch between curriculum expectations and students' cognitive performance—evident in their difficulty constructing arguments and their summative scores below the KKM—underscores this gap. Existing studies on PjBL in Indonesia tend to focus on primary schools, single aspects such as creativity or motivation, or specific domains like scientific literacy, with relatively fewer investigations examining its impact on comprehensive cognitive learning outcomes (C1–C6) in senior high school science subjects (Nestiyarum & Widjajanti, 2023). Moreover, there is limited evidence on how PjBL can be systematically integrated into everyday classroom practice in schools outside major urban centres, where resources and teacher professional development opportunities may be more constrained (Syahdia et al, 2024).

Against this backdrop, the present study seeks to examine the effect of the Project-Based Learning (PjBL) model on students' cognitive learning outcomes at SMA Negeri 3 Selong. By comparing the cognitive achievement of students taught using PjBL with that of students taught through conventional, teacher-centred methods, this research aims to provide empirically grounded evidence on whether and how PjBL can enhance performance across the different levels of the cognitive domain. The findings are expected to contribute both theoretically—by enriching the empirical base on PjBL and cognitive learning outcomes in the Indonesian senior-secondary context—and practically, by offering insights for teachers and school leaders who are seeking to implement project-based approaches to raise students' cognitive achievement and better meet national curriculum goals.

Research Method

Research design

This study adopted a quantitative quasi-experimental approach with a non-equivalent control-group pretest–posttest design (Campbell & Stanley, 2015). Such designs are widely used in educational research when random assignment to conditions is impractical and intact classes must be retained, while still allowing comparison between an experimental and a control group measured before and after the intervention (Hastjarjo, 2019). Within the family

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of quasi-experimental designs, the pretest–posttest control-group structure is recommended to strengthen internal validity by enabling statistical control of initial group differences (Shadish et al, 2002). The design in this study can be symbolically represented in Table 1.

Table 1. Research design

Group class	*Pretest*	Treatment	*Postest*
Experiment	O_1	X_1	O_2
Control	O_1	X_2	O_2

Where O_1 and O_2 denote pretest and posttest measurements of students' cognitive learning outcomes, X_1 denotes instruction using the Project-Based Learning (PjBL) model, and X_2 denotes instruction using the Problem-Based Learning (PBL) model.

Population and Sample

The target population comprised all Grade X students at SMA Negeri 3 Selong in the 2024/2025 academic year (N = 84). In line with common practice in school-based quasi-experimental research, intact classes were used as sampling units because administrative and pedagogical constraints made random reassignment of individual students infeasible (R Gay et al, 2021). A purposive sampling strategy was employed to select two classes with comparable academic profiles and teacher characteristics to serve as the experimental and control groups (Fraenkel & Wallen, 1990). Class X-8 (n = 21) was assigned as the experimental group and taught using the PjBL model, whereas class X-7 (n = 21) served as the control group and was taught using the PBL model. The use of purposive sampling with intact groups is considered appropriate in quasi-experimental school research, provided that researchers carefully document classroom characteristics and seek baseline equivalence through pretest data (Abraham & Supriyati, 2022).

Instructional Treatments

In the experimental class, the PjBL model was implemented through a project in which students collaboratively designed and constructed an aquascape using recycled glass jars (toples bekas) and readily available materials. The project was structured around core phases of project-based pedagogy—orientation to the problem, planning, implementation, monitoring, product presentation, and reflection—so that students engaged in extended inquiry and production of a tangible artefact (Creswell & Creswell, 2017). This structure is consistent with recommendations that PjBL be organised around authentic tasks, collaborative work, and iterative feedback to support higher-order cognitive processes (Creswell & Creswell, 2017). In the control class, the same curriculum content was taught using the PBL model. Students were presented with problem scenarios, guided to identify what they needed to learn, and engaged in group discussion to propose solutions, while the teacher facilitated and clarified key concepts. PBL is widely regarded as a student-centred model that organises learning around ill-structured problems. Still, in this study, it served as a comparative instructional approach to determine whether the more product-oriented structure of PjBL produced differential effects on cognitive learning outcomes (Campbell & Stanley, 2015). The duration of the intervention for both groups was aligned with the school's lesson schedule, ensuring equivalent exposure time and content coverage across conditions.

Instruments

Students' cognitive learning outcomes were assessed using a researcher-developed test consisting of multiple-choice items and essay questions aligned with the relevant curriculum standards and covering levels C1–C4 of the revised Bloom taxonomy (remembering, understanding, applying, and analysing). Instrument development followed established procedures in educational measurement: defining the construct and content domain, drafting items based on a table of specifications, and obtaining expert review from subject-matter specialists to ensure content validity (Fraenkel & Wallen, 1990). The emphasis on clear construct definition and alignment with curricular objectives is consistent with contemporary standards for educational and psychological testing.

Data Collection Procedures

Data collection was conducted in three main stages. First, all participating students in the experimental and control classes completed the cognitive test as a pretest (O_1) under standardised conditions before any instructional treatment was delivered. Pretesting is critical in quasi-experimental designs to document initial equivalence and control for pre-existing differences between groups (Campbell & Stanley, 2015). Second, the respective instructional treatments (PjBL and PBL) were implemented by the same teacher, using lesson plans collaboratively developed with the researcher to minimise variability attributable to instructor effects. Third, after completing the instructional sequence, students in both classes took the same cognitive test as a posttest (O_2). Using parallel pretest–posttest instruments allows estimation of learning gains attributable to the intervention while maintaining comparability across measurement occasions. Throughout the study, standard ethical procedures were observed: permission to conduct the research was obtained from the school administration, students were informed about the purpose and voluntary nature of participation, and test scores were treated confidentially and reported only in aggregate form. These procedures are in line with established ethical guidelines for educational research (Creswell & Guetterman, 2024).

Data Analysis

Quantitative data analysis was performed using IBM SPSS Statistics version 25. Before hypothesis testing, the assumptions underlying parametric tests were examined. Normality of the pretest and posttest score distributions in each group was assessed using the Shapiro–Wilk test, which is recommended for small to moderate sample sizes due to its high power to detect deviations from normality (Mishra et al, 2024). Homogeneity of variances between the experimental and control groups was evaluated using Levene's test for equality of variances, a robust procedure for assessing whether group variances can be assumed equal in the context of ANOVA and t-tests (George & Mallery, 2024).

After these assumptions were verified, differences in posttest cognitive scores between the PjBL and PBL groups were analysed using an independent-samples t-test at $\alpha = 0.05$. The independent t-test is appropriate for comparing the means of two unrelated groups when the dependent variable is continuous and assumptions of normality and homogeneity of variance are reasonably met (Nayeri et al., 2023). In addition to significance testing, expert recommendations emphasise the importance of considering effect sizes and confidence intervals to interpret the practical significance of observed differences in educational interventions, even when the primary analytic technique is the t-test (Miller et al., 2020)

By combining a non-equivalent control-group pretest–posttest design, standardised administration procedures, validated measurement instruments, and appropriate inferential statistics, this study sought to generate credible evidence on the comparative effect of PjBL and PBL on students' cognitive learning outcomes in the context of SMA Negeri 3 Selong.

Result and Discussion

Assumption checking for this quasi-experimental comparison of Project-Based Learning (PjBL) and Problem-Based Learning (PBL) at SMA Negeri 3 Selong was conducted using the Shapiro–Wilk test to examine the distribution of students' cognitive learning scores in each group, consistent with recommendations for small to moderate samples in educational research (Ghasemi & Zahediasl, 2012). The pretest scores of the PjBL class showed a significant departure from normality (p = 0.015). In contrast, the posttest scores for the PjBL class and both pretest and posttest scores for the PBL control class yielded non-significant Shapiro–Wilk statistics (p > 0.05), indicating approximately normal distributions in those three cases (Razali & Wah, 2011). Because the main inferential analysis was conducted on posttest scores—where both groups satisfied the normality assumption—and because simulation studies indicate that independent-samples *t*-tests are reasonably robust to modest deviations from normality in educational datasets, parametric procedures were retained (Adhikari et al, 2023). Levene's test of homogeneity of variances produced a non-significant result (p = 0.093), supporting the assumption of equal variances required for independent-samples *t*-tests in mean-comparison studies of instructional interventions (Okoye & Hosseini, 2024). With these assumptions met, an independent-samples *t*-test comparing posttest scores showed a statistically significant difference in favour of the PjBL class (p = 0.001, two-tailed), with the experimental group outperforming the PBL control group by an average of 17.476 points on the cognitive achievement measure (Faizin et al, 2017). This statistically and substantively meaningful gap is consistent with the view that significant *t*-test differences in carefully controlled quasi-experimental designs reflect genuine improvements in academic performance between treatment and comparison groups (Akpan & Clark, 2023).

The superiority of the PjBL group over the PBL control in this study aligns with a growing body of quasi-experimental evidence demonstrating that PjBL yields higher cognitive learning outcomes than more conventional or teacher-centered instruction in secondary science and biology. Warmadewi et al. (2024) report that junior secondary students taught science through PjBL achieve significantly higher cognitive scores and science-process skills than peers taught through traditional approaches. Similarly, et al (2017) show that PjBL on the human respiratory system leads to significantly greater gains in students' cognitive test scores than conventional teaching, with large improvements in normalized gain for the experimental class. At the same educational level, Mahfuzah and Mayasari (2018) find that PjBL on the human coordination system produces higher biology cognitive scores (M = 86.95) than the control class (M = 76.76), confirming a significant positive effect of PjBL on senior high school students' cognitive outcomes. In more recent work, Aurelya and Carolina (2024) report that a PjBL-integrated STEM model substantially improves Grade X students' cognitive learning in biology, while Tampubolon and Sipahutar (2024) show that project-based modules enhance learning outcomes, critical thinking, and problem-solving skills in an animal development course. Additional quasi-experimental and review studies similarly conclude that PjBL consistently improves learning outcomes and higher-order thinking skills across diverse science topics and grade levels, reinforcing the generalizability of the present findings beyond a single school or concept (Azzahra et al, 2023). Widarbowo et al. (2023) report high average effect sizes of PjBL on learning outcomes, creativity, and reasoning across Indonesian contexts, while Desyafrianti and Aini (2024) find substantial positive effects of PjBL on students' chemistry achievement.

The advantage of PjBL over PBL observed here is theoretically plausible, as PjBL structures learning around extended, product-oriented projects that require students to integrate conceptual understanding with procedural skills, collaboration, and self-regulation—factors strongly associated with higher cognitive performance (Martiana & Rokhmat, 2024). Classroom studies repeatedly show that PjBL environments foster greater behavioural engagement, autonomy, and responsibility for learning compared with more teacher-directed formats or short-cycle problem-solving tasks, therefore providing richer opportunities for students to practice higher-order processes such as analysis, synthesis, and evaluation (Warmadewi et al, 2024). In biology and science education specifically, authentic project work—such as designing and constructing products or artefacts—helps students connect abstract concepts to real-world applications, improves retention across lower- and higher-order cognitive levels (C1–C4), and supports deeper conceptual restructuring than is typically achieved through conventional assignments or isolated problem sets (Faizin et al, 2017). Nevertheless, as a quasi-experimental study using purposively selected intact classes from a single school with relatively small sample sizes, the present research remains limited in its ability to rule out all potential confounding variables, so future work should employ multi-site designs, larger samples, and complementary analyses (e.g., ANCOVA or multilevel modelling) to test further the robustness and generalizability of the PjBL advantage over PBL in diverse instructional settings (Widarbowo et al, 2023).

Conclusion

Based on the data analysis and discussion, it can be concluded that the implementation of the Project-Based Learning (PjBL) model has a significant and positive effect on students' cognitive learning outcomes in Grade X at SMA Negeri 3 Selong, as evidenced by substantially higher posttest mean scores in the experimental class compared with the control class taught using Problem-Based Learning (PBL), indicating that PjBL is more effective in fostering students' cognitive abilities at the levels of remembering, understanding, applying, and analysing. Accordingly, it is recommended that teachers, particularly in biology and science subjects, systematically integrate PjBL into lesson planning and classroom practice through authentic projects that are relevant to students' real-life contexts (such as the aquascape project), supported by well-structured teaching materials and assessment instruments; that schools and education authorities provide continuous professional development to strengthen teachers' competence in designing and managing project-based instruction; and that future researchers replicate and extend this study in different schools, subjects, and grade levels with larger samples and more rigorous designs, while also incorporating additional variables such as motivation, critical thinking skills, and creativity to obtain a more comprehensive picture of the impact of PjBL on various dimensions of student learning outcomes.

Recommendation

Based on the research findings indicating that the Project-Based Learning (PjBL) model is significantly more effective than Problem-Based Learning (PBL) in improving students' cognitive learning outcomes at the levels of remembering, understanding, applying, and analysing, it is recommended that PjBL be adopted as a primary instructional approach, particularly in biology and science subjects. The implementation of PjBL through authentic projects relevant to students' real-life contexts has been shown to optimize students' cognitive achievement and therefore merits wider application and further development in classroom practice to enhance the quality of student learning outcomes.

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