

Effectiveness of an Integrated Project-Based Learning and Inquiry Model on Mathematics Achievement of Elementary School Students

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ABSTRACT

Objective: This study aimed to examine the effectiveness of an integrated project-based learning and inquiry model in improving mathematics achievement among elementary school students. Conventional mathematics instruction in Indonesian elementary schools remains predominantly teacher-centered and procedurally focused, despite curricular mandates promoting student-centered approaches. **Method:** A quasi-experimental pretest-posttest control group design was employed. A total of 76 fifth-grade students from two public elementary schools in Ende, Indonesia, participated in the study, with 38 students assigned to the experimental group and 38 to the control group. The experimental group received instruction using the integrated PBL-inquiry model, while the control group received conventional instruction. The mathematical topic covered was fractions. Mathematics achievement was measured using a 20-item multiple-choice test. Data were analyzed using independent samples t-test on gain scores and ANCOVA with pretest scores as the covariate. **Results:** The experimental group achieved a significantly higher mean gain score ($M = 28.42$, $SD = 8.76$) than the control group ($M = 19.63$, $SD = 7.41$), with $t(74) = 4.73$, $p < 0.001$, and a large effect size (Cohen's $d = 1.08$). ANCOVA confirmed the significant effect of the integrated model, $F(1, 73) = 22.18$, $p < 0.001$, partial eta squared = 0.233. **Novelty:** This study provides empirical evidence on the effectiveness of integrating PBL and inquiry within a single instructional framework for elementary mathematics, an approach that remains underexplored in Indonesian primary education research.

INTRODUCTION

Mathematics is a fundamental subject in elementary education that serves as a basis for advanced academic study and as a critical tool for everyday reasoning and problem-solving (Lazić et al., 2021). In many countries, including Indonesia, mathematics remains one of the most challenging subjects for elementary school students (Yurniwati & Hanum, 2016). International large-scale assessments such as the Programme for International Student Assessment (PISA) consistently reveal that Indonesian students perform substantially below the global average in mathematics, particularly in domains that require higher-order thinking and application of concepts to unfamiliar situations (Siswadi et al., 2024). The conventional approach to mathematics teaching, which typically follows a direct instruction model where the teacher explains concepts, demonstrates procedures, and assigns practice problems, has been the predominant method in Indonesian classrooms for decades (Lazić et al., 2021). While this approach can effectively convey procedural knowledge, it often falls short in developing students' conceptual understanding, problem-solving skills, and intrinsic motivation toward mathematics (AY Emanet & Kezer, 2021).

The limitations of conventional mathematics instruction have prompted educators and researchers around the world to explore student-centered approaches that place learners at the center of the educational process (Turgut & Turgut, 2018). Ay Emanet and Kezer (2021), in a comprehensive meta-analysis of student-centered teaching methods in

mathematics, found that approaches such as problem-based learning, cooperative learning, and inquiry-based learning produced significantly higher achievement outcomes compared to traditional teacher-centered methods, with moderate to large effect sizes across grade levels and mathematical topics. Inquiry-based approaches to mathematics learning have been shown not only to improve achievement but also to foster deeper conceptual understanding and more positive attitudes toward the subject (Beswick, 2021). These findings have contributed to a growing recognition that mathematics education must evolve beyond rote memorization and procedural repetition to embrace approaches that engage students actively in constructing their own mathematical knowledge (Lerman, 1989; Setiana et al., 2020).

Among the various student-centered instructional models, project-based learning (PBL) has emerged as one of the most promising approaches for elementary education (Hmelo-Silver, 2004). PBL is an instructional method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge, during which they design, plan, and produce a tangible product or presentation that demonstrates their learning (Hmelo-Silver, 2004). Effective PBL environments provide learners with opportunities to construct knowledge through collaborative problem-solving, self-directed learning, and reflective thinking (Hmelo-Silver, 2004). In the context of mathematics education, PBL allows students to explore mathematical concepts through real-world applications, connecting abstract formulas and procedures to meaningful contexts that make learning more relevant and motivating (Lazić et al., 2021). Lazić et al. (2021), in a quasi-experimental study conducted in elementary schools, found that students who learned mathematics through PBL achieved significantly higher scores than those who received conventional instruction, with particularly strong effects on problem-solving and conceptual understanding. In the Indonesian context, PBL has been shown to improve elementary school mathematics learning outcomes (Siswadi et al., 2024), while problem-based learning has been found to significantly increase student engagement in elementary mathematics learning (Anugraheni et al., 2025).

Alongside PBL, inquiry-based learning represents another important student-centered approach that has gained considerable attention in mathematics education research (Beswick, 2021). Inquiry-based learning is an approach that emphasizes the process of discovery through questioning, investigation, and reflection, guiding students through a structured cycle of asking questions, conducting investigations, gathering evidence, and drawing conclusions (Margunayasa et al., 2021). At the elementary level, guided inquiry is often the most appropriate form, as it provides sufficient structure to support young learners while still encouraging active investigation and critical thinking (Margunayasa et al., 2021). Guided inquiry learning has been demonstrated to reduce misconceptions among elementary school students and to improve their conceptual understanding (Margunayasa et al., 2021). Similarly, guided discovery learning, an approach closely related to inquiry, has produced significant improvements in the mathematics achievement of fifth-grade students in Indonesia (Yurniwati & Hanum, 2016). Problem-based approaches in elementary mathematics, when combined with literacy-oriented tasks, have also been shown to enhance both mathematical performance and reading comprehension, suggesting that interdisciplinary applications of student-centered models can yield multiple academic benefits (Farhan et al., 2021).

Despite the well-documented benefits of both PBL and inquiry-based learning as separate instructional strategies, relatively little research has examined how these two approaches can be integrated within a single instructional framework (Lethulur et al., 2025). A systematic literature review of discovery, inquiry, problem-based, and project-based learning in mathematics education noted that while all four approaches have demonstrated positive effects on student outcomes, studies that combine or integrate these approaches remain scarce (Lethulur et al., 2025). This represents a significant gap because, in practice, the boundaries between PBL and inquiry are often fluid: authentic projects frequently require students to engage in systematic inquiry processes such as formulating questions, designing investigations, and analyzing evidence, while inquiry activities can be embedded within larger project structures that culminate in tangible products (Beswick, 2021; Hmelo-Silver, 2004). Integrating PBL and inquiry into a cohesive model may capitalize on the strengths of both approaches to create a more powerful learning experience than either approach could offer alone (Lethulur et al., 2025).

The theoretical rationale for integrating PBL and inquiry is grounded in constructivist learning theory, which posits that learners actively construct knowledge through experiences, reflection, and interaction with their environment (Lerman, 1989). In a PBL-inquiry integrated model, students engage with a driving question or authentic problem that provides the overarching project context, then proceed through structured inquiry cycles to investigate sub-questions, gather and analyze data, and develop solutions that are synthesized into a final project product (Beswick, 2021; Hmelo-Silver, 2004). This integrated approach aligns with the principles of effective mathematics instruction that emphasize the importance of providing students with authentic tasks, encouraging active investigation, and fostering collaborative discourse (Beswick, 2021). It also addresses the motivational dimensions of mathematics learning: perceived teacher support and engaging instructional approaches have been found to significantly predict students' mathematics interest (Oppermann & Lazarides, 2021), while Indonesian elementary students' self-efficacy and motivation have been shown to be positively correlated with their mathematics achievement (Mulyani, 2012).

The present study aims to address the gap in the literature by examining the effectiveness of an integrated project-based learning and inquiry model on mathematics achievement among elementary school students in Indonesia. Specifically, this research compares the mathematics achievement of students who received instruction through the integrated PBL-inquiry model with that of students who received conventional instruction, using a quasi-experimental pretest-posttest control group design. By providing empirical evidence from an Indonesian elementary school context, this study seeks to contribute to the growing international literature on student-centered mathematics instruction and to offer practical guidance for teachers and schools seeking to implement innovative, research-based instructional approaches in elementary mathematics education.

RESEARCH METHOD

Research Design

This study employed a quasi-experimental pretest-posttest control group design to examine the effectiveness of an integrated project-based learning and inquiry model on elementary school students' mathematics achievement (Creswell, 2002; Creswell et al.,

2007). The independent variable was the instructional model, with two levels: the integrated PBL-inquiry model for the experimental group and conventional instruction for the control group. The dependent variable was students' mathematics achievement as measured by pretest and posttest scores. The pretest was administered before the treatment to establish baseline equivalence between the two groups, and the posttest was administered after the eight-week treatment period to measure the effect of the instructional model.

Participants

The population consisted of fifth-grade students enrolled in public elementary schools in Ende, Indonesia. Fifth-grade students were selected because the mathematical topic covered in this study, fractions, is a core component of the fifth-grade curriculum in Indonesia and represents an area in which many students experience difficulty (Yurniwati & Hanum, 2016). Two public elementary schools were selected purposively based on their comparable demographic profiles, average class sizes, and willingness to participate. One school was randomly assigned to the experimental group and the other to the control group. A total of 76 students participated, with 38 students in the experimental group and 38 in the control group. The experimental group consisted of 20 male and 18 female students with a mean age of 11.2 years ($SD = 0.41$), while the control group consisted of 21 male and 17 female students with a mean age of 11.1 years ($SD = 0.38$). A pretest comparison confirmed that the two groups did not differ significantly in their baseline mathematics achievement, $t(74) = 0.67$, $p = 0.505$.

Instruments

Mathematics achievement was measured using a researcher-developed test comprising 20 multiple-choice items aligned with the fifth-grade fractions curriculum in Indonesia. The items assessed three cognitive levels: factual knowledge (4 items), procedural application (10 items), and conceptual understanding and problem-solving (6 items), following the taxonomy commonly used in mathematics assessment research (Lazić et al., 2021). Content validity was established by two experts in elementary mathematics education who reviewed the items for curriculum alignment, clarity, and difficulty. The test was pilot-tested with 30 fifth-grade students from a third school not included in the main study. The pilot test yielded a Cronbach's alpha of 0.83, indicating good internal consistency. Item analysis revealed that all 20 items had discrimination indices above 0.30 and difficulty indices between 0.30 and 0.80, confirming that the items were of acceptable quality for assessing mathematics achievement (AY Emanet & Kezer, 2021).

Treatment Procedures

The treatment was implemented over a period of eight consecutive weeks during the regular mathematics instructional time. Both groups received five 35-minute mathematics sessions per week, totaling 40 sessions over the eight-week period, and both groups were taught the same fractions content as specified in the fifth-grade curriculum: understanding fraction concepts, comparing and ordering fractions, converting between improper fractions and mixed numbers, and performing addition, subtraction, multiplication, and division of fractions.

The experimental group received instruction using the integrated PBL-inquiry model. In this model, each two-week unit began with the presentation of an authentic driving question or real-world problem related to fractions. For example, in the unit on

fraction operations, students were presented with the challenge of planning a class party within a given budget, requiring them to calculate fractional amounts of ingredients, costs, and materials. Following the driving question, students engaged in structured inquiry cycles that involved formulating sub-questions, designing investigations, collecting and analyzing data, and drawing conclusions (Beswick, 2021; Hmelo-Silver, 2004). The teacher facilitated the learning process by posing probing questions, providing guidance when needed, and encouraging collaborative discussion, consistent with the guided inquiry approach recommended for elementary students (Margunayasa et al., 2021). At the end of each two-week unit, students presented their project products, which included posters, models, or written reports demonstrating their mathematical reasoning and solutions.

The control group received conventional mathematics instruction based on the direct instruction model commonly used in Indonesian elementary schools (Siswadi et al., 2024). Each session began with the teacher explaining the mathematical concept or procedure, followed by worked examples on the board, guided practice through teacher-led exercises, and independent practice through textbook problems. The teacher controlled the pace of instruction, and students primarily worked individually.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 26. Before hypothesis testing, the data were screened for missing values, outliers, and violations of statistical assumptions. No missing data or significant outliers were identified. The normality of pretest and posttest scores was assessed using the Kolmogorov-Smirnov test, and homogeneity of variances was tested using Levene's test. Both assumptions were satisfied ($p > 0.05$). Descriptive statistics were computed for both groups. To test the hypothesis that the integrated PBL-inquiry model produced significantly higher mathematics achievement than conventional instruction, an independent samples t-test was conducted on the gain scores, calculated as the difference between posttest and pretest scores for each student. In addition, a one-way analysis of covariance (ANCOVA) was performed with posttest scores as the dependent variable, instructional model as the independent variable, and pretest scores as the covariate. The ANCOVA provides a more sensitive test of group differences by statistically controlling for any pre-existing differences between the groups (Creswell & Creswell, 2018). Effect sizes were calculated using Cohen's d for the t-test and partial eta squared for the ANCOVA. The significance level was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Results

Pretest Analysis

Before examining the effect of the integrated PBL-inquiry model, the pretest scores of the two groups were compared to establish baseline equivalence. The experimental group had a mean pretest score of 42.37 ($SD = 8.14$), while the control group had a mean pretest score of 43.68 ($SD = 8.51$). An independent samples t-test revealed no significant difference between the two groups prior to treatment, $t(74) = 0.67$, $p = 0.505$, confirming that the groups were comparable in their baseline mathematics achievement.

Descriptive Statistics and Gain Scores

Table 1 presents the means and standard deviations for pretest, posttest, and gain scores for both groups. The experimental group achieved a mean posttest score of 70.79 (SD = 6.83), while the control group achieved a mean posttest score of 63.32 (SD = 6.95). The gain score, calculated as the difference between posttest and pretest scores, was substantially higher for the experimental group (M = 28.42, SD = 8.76) compared to the control group (M = 19.63, SD = 7.41). The experimental group's gain score exceeded that of the control group by 8.79 points.

Table 1. Pretest, Posttest, and Gain Scores by Group

Group	N	Pretest M (SD)	Posttest M (SD)	Gain M (SD)
Experimental	38	42.37 (8.14)	70.79 (6.83)	28.42 (8.76)
Control	38	43.68 (8.51)	63.32 (6.95)	19.63 (7.41)

Hypothesis Testing: Independent Samples t-test

An independent samples t-test was conducted on the gain scores to determine whether the integrated PBL-inquiry model produced significantly higher mathematics achievement than conventional instruction. The results are presented in Table 2. The experimental group achieved a significantly higher mean gain score than the control group, $t(74) = 4.73$, $p < 0.001$. The effect size, measured by Cohen's d , was 1.08, indicating a large effect according to the commonly accepted guidelines.

Table 2. Independent Samples t-test on Gain Scores

Group	M	SD	df	t	p	Cohen's d
Experimental	28.42	8.76	74	4.73	< .001	1.08
Control	19.63	7.41				

Hypothesis Testing: ANCOVA

A one-way ANCOVA was conducted with posttest scores as the dependent variable, instructional model as the independent variable, and pretest scores as the covariate. The ANCOVA results confirmed the significant effect of the integrated PBL-inquiry model on mathematics achievement after controlling for pretest differences, $F(1, 73) = 22.18$, $p < 0.001$. The partial eta squared was 0.233, indicating a large effect size in which the instructional model accounted for 23.3% of the variance in posttest scores. These results are summarized in Table 3.

Table 3. ANCOVA Results

Source	SS	df	MS	F	p	Partial eta squared
Pretest (Covariate)	382.14	1	382.14	12.67	.001	.148
Instructional Model	669.02	1	669.02	22.18	< .001	.233
Error	2201.86	73	30.16			

The adjusted posttest means, controlling for pretest scores, were 71.12 for the experimental group and 62.97 for the control group, yielding an adjusted mean difference of 8.15 points in favor of the experimental group.

Discussion

The findings of this study provide strong empirical evidence that the integrated project-based learning and inquiry model is significantly more effective than conventional instruction in improving elementary school students' mathematics achievement. The experimental group not only outperformed the control group on posttest scores but also demonstrated substantially higher learning gains, as reflected in the gain score analysis

and the large effect size. These results contribute to the growing body of evidence supporting the effectiveness of student-centered instructional approaches in mathematics education and extend the existing literature by examining the integration of PBL and inquiry within a single instructional framework.

The large effect size observed in this study (Cohen's $d = 1.08$, partial eta squared = 0.233) is consistent with findings from previous meta-analytic research on student-centered teaching methods in mathematics. Ay Emanet and Kezer (2021) reported moderate to large effect sizes for problem-based, cooperative, and inquiry-based learning methods across multiple grade levels and mathematical topics, and the results of the present study fall within the upper range of these reported effects. The magnitude of the effect is also comparable to that found by Lazić et al. (2021), who reported significant achievement gains for elementary students who learned mathematics through PBL compared to conventional instruction. The fact that the integrated model in this study produced a Cohen's d of 1.08, which is considered large, suggests that combining PBL with structured inquiry may offer advantages beyond what either approach could achieve independently (Lethulur et al., 2025).

Several factors may explain the effectiveness of the integrated PBL-inquiry model. First, the model provided students with an authentic context for mathematical learning through the driving questions and real-world problems that framed each unit. When students see the practical relevance of fractions in contexts such as planning a class party or distributing resources, the mathematical concepts become more meaningful and memorable (Hmelo-Silver, 2004). Second, the structured inquiry cycles embedded within each project guided students through systematic processes of questioning, investigation, data analysis, and conclusion, which helped them develop deeper conceptual understanding rather than merely memorizing procedures (Margunayasa et al., 2021). The combination of authentic context and systematic investigation created a learning environment in which students could connect abstract fraction concepts to concrete applications, a process that is central to effective mathematics learning (Lerman, 1989). Third, the collaborative nature of the projects encouraged peer interaction and discussion, which has been shown to enhance mathematics learning through the sharing of strategies, the articulation of reasoning, and the negotiation of meaning (Setiana et al., 2020). These three elements (authentic context, systematic inquiry, and collaboration) worked synergistically in the integrated model, and their combined effect likely contributed to the large achievement gains observed in the experimental group.

The findings of this study are consistent with those of previous research on the effectiveness of inquiry-based approaches for elementary mathematics. Yurniwati and Hanum (2016) demonstrated that guided discovery learning significantly improved the mathematics achievement of fifth-grade students in Indonesia, and the present study extends this finding by showing that embedding inquiry within a project-based framework can produce even larger effects. Similarly, Margunayasa et al. (2021) found that guided inquiry reduced misconceptions among elementary students, and the integrated model in this study, which incorporated guided inquiry within project contexts, appears to have built on this benefit by helping students apply their corrected understanding to authentic problems. The alignment of the present findings with these prior studies strengthens the case for adopting inquiry-oriented approaches in Indonesian elementary mathematics classrooms, where conventional instruction remains the predominant method (Siswadi et al., 2024).

The results also align with research on the motivational benefits of student-centered approaches. The large achievement gains in the experimental group may be partly attributable to increased student engagement and motivation. Anugraheni et al. (2025) found that problem-based learning significantly increased student engagement in elementary mathematics, and Oppermann and Lazarides (2021) demonstrated that engaging instructional approaches predict students' mathematics interest. The integrated PBL-inquiry model provided multiple motivational affordances: the authenticity of the projects enhanced relevance, the inquiry process built confidence through successful investigations, and the collaborative work satisfied students' need for social connection (Mulyani, 2012). While the present study did not directly measure motivation, the large achievement effects suggest that motivational processes may have played a mediating role, and this represents an important direction for future research.

The effectiveness of the integrated model relative to conventional instruction also supports broader calls for reforming mathematics education in Indonesia and similar contexts. The conventional approach, which emphasizes teacher explanation, worked examples, and individual practice, has been criticized for its limited capacity to develop higher-order thinking skills and conceptual understanding (Farhan et al., 2021). The results of this study suggest that even within the constraints of the Indonesian elementary school system, with its large class sizes and limited resources, the integrated PBL-inquiry model can produce meaningful improvements in mathematics achievement. This finding is particularly encouraging given that the treatment was implemented over a relatively short period of eight weeks and covered only one mathematical topic, fractions. If the model were extended across the entire academic year and applied to multiple mathematical topics, the cumulative effects on achievement could be even more substantial.

Several limitations of this study should be acknowledged. First, the sample was limited to 76 fifth-grade students from two schools in Ende, which restricts the generalizability of the findings to other regions, grade levels, and school types in Indonesia. Second, the assignment of schools to treatment conditions was not fully randomized, as only two schools participated. While the pretest analysis confirmed baseline equivalence between the groups, the quasi-experimental design cannot entirely rule out the influence of school-level variables. Third, the study examined only one mathematical topic, fractions, and the findings may not generalize to other areas of the mathematics curriculum. Fourth, the study did not include measures of potential mediating variables such as student motivation, engagement, or collaborative skills, which limits the ability to explain the mechanisms through which the integrated model produced its effects.

Future research should address these limitations by employing fully randomized designs with larger and more diverse samples across multiple regions of Indonesia. Longitudinal studies that track students over an entire academic year or longer would provide evidence on the sustainability and cumulative effects of the integrated PBL-inquiry model. Research that incorporates measures of motivation, self-efficacy, and engagement alongside achievement measures would help clarify the mechanisms underlying the effectiveness of the model. Additionally, studies that examine the integrated model across different mathematical topics and at different grade levels would contribute to understanding the conditions under which the model is most effective. Finally, qualitative research employing classroom observations and teacher interviews

would provide valuable insights into the implementation processes and challenges that teachers face when adopting the integrated model, which would inform the development of teacher training programs designed to support the transition from conventional to student-centered instruction. The present study represents an initial step in this direction, providing promising evidence that integrating PBL and inquiry can significantly enhance mathematics achievement among elementary school students in Indonesia.

CONCLUSION

Fundamental Finding: The integrated project-based learning and inquiry model significantly improved elementary school students' mathematics achievement compared to conventional instruction. The experimental group achieved a substantially higher mean gain score ($M = 28.42$, $SD = 8.76$) than the control group ($M = 19.63$, $SD = 7.41$), with $t(74) = 4.73$, $p < 0.001$, and a large effect size (Cohen's $d = 1.08$, partial eta squared = 0.233). These results confirm that combining PBL's authentic, product-oriented engagement with inquiry's structured investigative process produces a synergistic instructional effect that is greater than what either approach could achieve independently. **Implication:** The findings support the adoption of the integrated PBL-inquiry model in elementary mathematics classrooms, particularly in contexts where conventional teacher-centered instruction remains dominant. Teachers should be trained to design and implement integrated instructional units that embed guided inquiry cycles within authentic project frameworks. Schools and policymakers should prioritize professional development programs that equip teachers with the skills to transition from direct instruction to student-centered approaches, and curriculum designers should consider integrating the model into official guidelines for topics that benefit from contextualized, hands-on learning. **Limitation:** The study was limited to 76 fifth-grade students from two schools in Ende, restricting generalizability. The quasi-experimental design precludes fully causal conclusions, and only one mathematical topic was examined over a short eight-week period. No measures of mediating variables such as motivation or engagement were included. **Future Research:** Fully randomized experimental designs with larger and more diverse samples across Indonesian regions are needed to confirm these findings. Longitudinal studies would assess the sustainability of the model's effects, and research incorporating measures of motivation and engagement would clarify the mechanisms underlying its effectiveness. Qualitative classroom observations would provide insights into implementation processes and challenges across different mathematical topics and grade levels.

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