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The Effect of Project-Based Learning on the Mathematics Achievement of Fourth-Grade Students in Shaoshan Primary School, Kunming, Yunnan

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Abstract

Background and Aims: The impact of project-based learning (PBL) on mathematics achievement has significant research implications. This learning method emphasizes a project-centered approach to cultivating students' comprehensive abilities and allows them to engage in real-world problem solving. This experimental research aimed to: 1) compare students' mathematics achievement before and after project-based learning; 2) compare mathematics achievement after project-based learning with the predetermined criterion of 70%; and 3) assess students' satisfaction with project-based learning.

Methodology: This study employed cluster random sampling to select 30 fourth-grade students (1 class) from a population of 104 students (2 classes) at Shaoshan Primary School in Kunming, Yunnan Province. Data on mathematics achievement and satisfaction were collected through mathematics achievement tests and questionnaires, respectively. SPSS software was used to analyze the collected data, including item difficulty (p), item discrimination (r), reliability, mean, standard deviation, and one-sample t-test.

Result: The results showed that 1) mathematics achievement test scores of the students after learning through project-based learning (M = 28.47, SD = 3.56) were higher than those before learning (M = 11.83, SD = 3.50) at the 0.01 significance level; 2) the post-test scores were higher than the predetermined criterion of 70% at the 0.01 significance level (M = 28.47, SD = 3.56); and 3) students' satisfaction was at a high level (M = 4.52, SD = 0.97). The findings indicate that using a 4-step project-based learning approach can effectively improve students' mathematics achievement, stimulate their interest in learning, develop their independent learning ability, and meet their personalized learning needs.

Conclusion: According to the research results, we can draw the following conclusions: The average score and standard deviation of fourth-grade students who received project-based

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learning met the 70% criterion at the 0.05 significance level. Project-based learning can enhance students' mathematics achievement.

Keywords: Project-based Learning; Mathematics Achievement; Mathematics Course

Introduction

This study fits into the larger framework of China's continuing educational reform, where active, inquiry-oriented, and competency-based learning approaches are becoming more and more valued in national policies. Official guidelines in 2023 emphasized the value of inquiry-based and heuristic teaching approaches, with a focus on enhancing students' capacity for higher-order thinking and problem-solving. Building on this approach, the Ministry of Education proposed task-based and project-based learning models that take advantage of the special qualities of AI technologies in 2024 and further mandated the gradual adoption of universal artificial intelligence (AI) education by 2030. A favorable policy climate for the implementation of Project-Based Learning (PBL) in primary education has been created by these legislative developments, which clearly indicate a trend away from traditional knowledge transmission and toward student-centered, application-oriented learning paradigms.

Because of its proven ability to increase student engagement and foster deeper learning, PBL has garnered more scholarly attention in recent years (Kokotsaki et al., 2016). According to research, PBL helps students create relevant knowledge by involving them in real-world tasks and ongoing investigation. Nevertheless, despite its acknowledged advantages, research to date has shown a number of enduring obstacles that restrict its broad use and efficacy. These include substantial time and workload pressures for both teachers and students (Habok & Nagy, 2016; Mentzer et al., 2017), high implementation costs and high resource demands (Aldabbus, 2018; Sunismi et al., 2022), and challenges in creating reliable, multifaceted assessment systems that are in line with project-based procedures (Krajcik & Shin, 2014; Wilson, 2021). Additionally, problems with structural limitations and cultural adaptation in various educational environments continue to be major obstacles (Musa et al., 2021; Ning & Fu, 2024). All of these drawbacks hinder the durability and scalability of PBL programs (Kokotsaki et al., 2016; Sumarni & Kadarwati, 2020), highlighting the pressing need for more creative, methodical, and context-sensitive strategies.

There are still urgent pedagogical issues with mathematics instruction at the elementary school level. Conventional teaching methods frequently place an emphasis on rote memorization and repeating exercises, which can lead to what is known as a "memorization trap," in which teachers spend too much time on procedural drills instead of encouraging conceptual comprehension and real-world application. As a result, pupils usually take on passive roles during the learning process and have few chances to use their mathematical knowledge to solve real-

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world situations (Li, 2018). These methods lower students' desire and involvement in learning mathematics and impede the development of higher-order thinking abilities.

By altering current learning paradigms, project-based learning presents a viable answer to these problems. It moves the emphasis from learning discrete facts to using information in relevant circumstances; from solving problems in a particular subject to interdisciplinary inquiry; and from abstract, paper-based exercises to real-world, actual challenges. PBL cultivates critical thinking, problem-solving, creativity, communication, and self-directed learning—skills that are universally acknowledged as vital for the twenty-first century—through extended inquiry, teamwork, and reflection. Examining the successful integration of PBL is an important and timely task, given the changing policy landscape and the pressing need to change primary mathematics teaching.

Objectives

1. To compare students' mathematics achievement before and after learning through project-based learning.

2. To compare the mathematics achievement after learning through project-based learning learning method with the predetermined criterion of 70 %.

3. To assess students' satisfaction after receiving project-based learning.

Literature Review

In this chapter, the researcher discusses the theoretical foundations of PBL according to the literature and explores the empirical evidence in mathematics education, research gaps, and recent meta-analyses on PBL in mathematics.

1. The history and present situations of questioning methods in foreign countries

Thomas (2000) 1. PBL Theoretical Foundations: Student academic achievement is improved through active engagement in authentic projects. 2. Empirical Evidence in Mathematics Education: PBL has a moderately positive effect on mathematics achievement (Hedges' g = 0.48, 95% CI: 0.31–0.65).3. Research Gaps: The study does not examine how specific PBL design frameworks can be systematically applied to mathematics education. 4. Recent Meta-Analyses on PBL in Mathematics: PBL effectively improves mathematics achievement, with effect sizes consistent with those found in recent meta-analyses (e.g., Gufron et al., 2025).

Carter, 2016， 1.PBL Theoretical Foundations: PBL is effective for advanced mathematics courses.2.Empirical Evidence in Mathematics Education: The PBL group (n = 64) achieved 33.6% more correct answers than the traditional group (n = 58) (M = 71.17 vs. M = 56.98, t = 4.57, p < .001).3.Research Gaps: The study does not examine how PBL design frameworks can be

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systematically applied across diverse educational contexts or grade levels.4.Recent Meta-Analyses on PBL in Mathematics: PBL effectively improves mathematics achievement in advanced courses.

2. The history and present situations of questioning methods in China

Shi Yu (2023):1. PBL Theoretical Foundations: The "Gold Standard PBL" model;2. Empirical Evidence in Mathematics Education: The mixed-methods design adopted (combining case study and document analysis) provides a methodological reference for evaluating PBL effectiveness;3. Research Gaps: Without delving into the contextualized implementation of specific subjects (such as mathematics), 4. Recent Meta-Analyses on PBL in Mathematics: The effectiveness of BIE's "Gold Standard PBL" model in mathematics education;

He & Qi (2017) 1. PBL Theoretical Foundations: The Mathematics project-based curriculum adopts project activities as its organizational form. 2. Empirical Evidence in Mathematics Education: Mathematics achievement improved. 3. Research Gaps: How to adapt to mathematics education in different cultural contexts. 4. Recent Meta-Analyses on PBL in Mathematics: This study provides subject-specific empirical evidence demonstrating that project-based learning in mathematics can effectively improve mathematics achievement.

Conceptual Framework

Based on the content of this study, the independent variable was operationalized according to the revised Bloom's taxonomy framework (Anderson & Krathwohl,2001), which is the instructional management that adopts project-based learning, grounded in Constructivist theory and progressive educational philosophy (Ni, 2021). The dependent variables were operationalized according to the revised Bloom's taxonomy framework (Anderson & Krathwohl,2001), which includes mathematics achievement and student satisfaction.

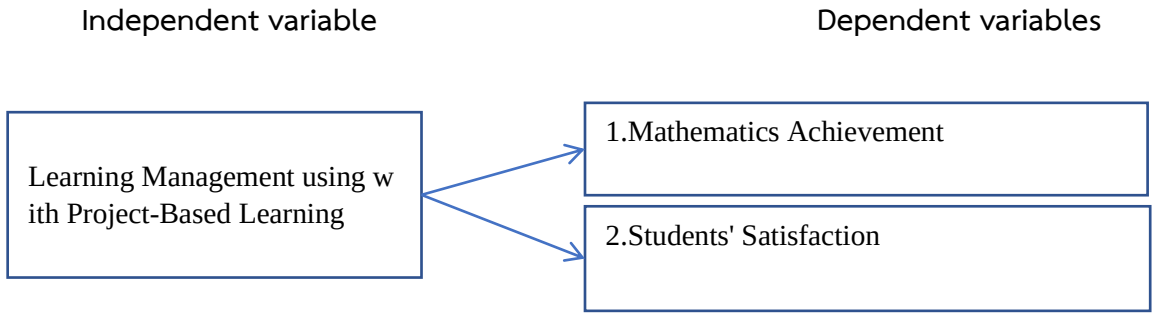


Figure 1 Conceptual Framework

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Mothodology

1. Participants and Sampling

The population in this study is 104 students (2 classes) at Shaoshan Primary School, Kunming City, Yunnan Province. The sample in this study is 30 students (1 classroom) at Shaoshan Primary School, Kunming City, Yunnan Province, selected by cluster random sampling.

2. Research Instruments

Research instruments are the tools for collecting data. The research instruments that were used in this study are (1) Project-Based Learning Lesson plans. (2) The Mathematics Achievement Test. (3) Questionnaire for students' satisfaction.

2.1 Project-Based Learning Lesson Plans: The fourth-grade mathematics curriculum plan at Shaoshan Primary School consists of a total of 6 lessons, each lasting 2 class hours, for a total of 12 class hours. The specific arrangement is shown in the table below:

Table 1 Course content sheet

Lesson Plan	Topic	Time Duration
1	Family Budget Manager	2 hours
2	Junior Designer: Design My Room	2 hours
3	Junior Architect: Designing an Amusement Park	2 hours
4	Junior Meteorologist: Recording Weather Changes	2 hours
5	Beginner Travelers: Planning a Family Trip	2 hours
6	Junior Architect: Build 100 square centimeters	2 hours

The draft lesson plans are evaluated by three experts regarding the appropriateness of each component. The instrument used for evaluating appropriateness is a five-point rating scale that ranges the level of appropriateness from a very high level, high level, moderate level, low level, and very low level.

The appropriateness data collected from the evaluation form is analyzed by calculating mean scores and is assigned the interpretation of appropriateness level as follows:

Table 2 Evaluating appropriateness was a points rating scale Instrument for collecting data

Mean Scores	Interpretation of Appropriateness Level
4.51-5.00	Very high level
3.51-4.50	High level

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Mean Scores	Interpretation of Appropriateness Level
2.51-3.50	Moderate level
1.51-2.50	Low level
1.00-1.50	Very low level

2.2 The Mathematical achievement test form: The achievement test form had a total of 30 items. The index of Item Objective Congruence (IOC) value of the 30 items in the achievement test form was 0.60at the lowest and 1.00 at the highest. The result of analyzing the IOC index showed that all the items were appropriate and could be used in the achievement test form. Analyze the item of the achievement test form and find out that the item Reliability (0.941) is more than 0.70. This showed that the quality of the mathematical achievement test form was good. (Kuder & Richardson. 1937: 681-687)

2.3 Questionnaire for students' satisfaction: The questionnaire was provided to 3 experts for content validity checks and suggestions. The results of analyzing the IOC index (0.60-1.00) showed that all test items were appropriate and could be used in the test. The Cronbach's Alpha coefficient of the reliability of the student satisfaction questionnaire is 0.842, which is greater than 0.70. Therefore, the reliability of the student satisfaction questionnaire meets the requirements (Cronbach, 1951)

3. Data Collection

The procedures of data collection are as follows:

1) The sample was pretested using a designed instrument to measure mathematics achievement.

2) The sample was taught using a project-based learning approach.

3) After completing the instruction, the subjects took a posttest using the same instrument used in the pretest.

4) The sample was administered a student satisfaction questionnaire.

4. Data Analysis

In this study, data were analyzed using a statistical program according to the research objectives.

1) Compare students' mathematics achievement before and after receiving project-based learning strategies by using a t-test for dependent samples.

2) Compare students' mathematics achievement with the determined criteria set at 70 percent by using a t-test for one sample.

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3) Assess the students' satisfaction with project-based learning strategies by using arithmetic mean and standard deviation.

Results

In this study, data were analyzed using statistical methods according to the research objectives: (1) to compare changes in students' mathematics achievement before and after using the project-based learning system; (2) to compare students' mathematics achievement with the established 70% criterion; and (3) to evaluate student satisfaction.

Table 3 The results of comparing the mean scores of students' mathematics achievement before and after learning through the implementation of project-based learning.

Group	n	Pretest scores		Posttest scores		t	p
		M	S.D.	M	S.D.		
Experimental group	30	11.83	3.50	28.47	3.56	21.747	.000

**p＜.01

As presented in Table 3, the mean scores of the pretest of students' mathematics were 11.83 (S.D. = 3.50), and the posttest of students' project-based learning was 28.47(S.D. =3.56). On average, Posttest scores were 16.64 points higher than pretest scores. Moreover, it aimed to examine the mean score before and after the implementation of project-based learning in a mathematics course to enhance Students' mathematics achievement. The result of this table showed that after learning through the implementation of project-based learning in a mathematics course in the classroom, posttest scores of students' mathematics achievement was higher than pretest scores at .01 level of statistical significance (t_{29} =21.747, p < .01). The average scores of the study developed increasingly higher than pretest.

Table 4 The results of comparing the mean score of students' mathematics achievement after learning through the implementation of project-based learning in the mathematics course with the determined criterion set at 70 percent of full scores

Group	N	Full score	Criteria score	M	S.D.	t	p
Experimental group	30	30	21	28.47	3.56	11.489	.000

**p＜.01

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As shown in the table, out of a possible full score of 30, the mean score of the students' academic achievement after learning through project-based learning was 28.47 points with a standard deviation of 3.56 points, which is statistically higher than the 70% criterion (t=11.489, p=.000< .01).

This shows that the mathematics achievement of the students who received project-based learning was higher than 70%.

According to the research results, we can draw the following conclusions: Based on the results of the study, we can conclude that the mean scores and standard deviations of students who use project-based learning in teaching mathematics courses are higher than the 70% norm and are statistically significant at the 0.05 level. Project-based learning can improve students' mathematics achievement.

Table 5 The results of research to assess the students' satisfaction with the Implementation of project-based learning in mathematics courses

Items	M	SD	Satisfaction level
Satisfaction with Content			
1. Relevance and authenticity of PBL course content to real-world Mathematics practice (e.g., design tasks, creative projects)	4.50	0.68	Very high level
2. Challenging and inspiring nature of PBL course content	4.33	0.84	high level
3. Extent to which PBL content helped improve my Mathematics Achievement	4.43	0.85	high level
4. Extent to which PBL content helped improve my Mathematics Application Skills (e.g., transforming creative ideas into a measurable indicator + mathematical model + visual story)	4.50	0.86	Very high level
total	**4.44**	**0.81**	**high level**
Satisfaction with the learning management process			
5. Experience of self-directed inquiry and Mathematics problem-solving in PBL	4.67	0.75	Very high level
6. Experience of group collaboration and interactive communication in PBL	4.60	0.67	Very high level

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Items	M	SD	Satisfaction level
7. The extent to which PBL stimulated my interest and initiative in Mathematics learning	4.77	0.50	Very high level
Total	**4.68**	**0.64**	**Very high level**
Satisfaction with instructor support			
8. Timeliness and effectiveness of guidance and feedback provided by the teacher during PBL	4.57	0.72	Very high level
9. Helpfulness of the teacher's support (e.g., Mathematics resources, technique suggestions, creative strategies	4.70	0.53	Very high level
10. Teacher's effectiveness in fostering positive classroom interaction and a creative atmosphere	4.33	0.95	high level
Total	**4.53**	**0.74**	**Very high level**
Satisfaction with evaluation and evaluation			
11.Fairness and transparency of PBL assessment methods (e.g., formative assessment, work presentation, creative report)	4.27	1.08	high level
12. The extent to which the PBL assessment accurately reflected my improvement in Mathematics Achievement	4.53	0.81	Very high level
13. My satisfaction level with the mathematics outcomes (works/projects/presentations) accomplished through PBL	4.63	0.85	Very high level
14. Extent to which PBL helped develop my Interdisciplinary Integration Skills (e.g., connecting Mathematics with knowledge from other disciplines)	4.47	0.93	high level
15. The extent to which PBL has a positive impact on my future artistic learning or career development	4.47	0.86	high level
Total	**4.47**	**0.90**	**high level**
Over all	**4.52**	**0.97**	**Very high level**

The overall results of the high level by experts are high level with (M=4.52, S.D. = 0.97). Thus, it was concluded that students' satisfaction after receiving a high level was high.

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Discussion

The results of this study offer compelling empirical evidence that Project-Based Learning (PBL) improves students' performance in mathematics. The statistically significant improvement in students' conceptual comprehension and problem-solving skills from the pre-test (M = 11.83, SD = 3.50) to the post-test (M = 28.47, SD = 3.56) suggests that the PBL intervention significantly enhanced students' abilities. This outcome is in line with past studies showing PBL's beneficial effects on academic performance. According to Thomas (2000), for instance, well-designed project-based learning environments encourage more in-depth learning and improved academic achievement. According to Carter (2016), pupils who participated in PBL had greater levels of motivation and achievement than those who received traditional education.

The reported benefits are also consistent with the findings of Kokotsaki et al. (2016), who found in their literature review that PBL improves content understanding when projects are organized around authentic tasks and well-defined learning objectives. Mentzer et al. (2017) highlighted that inquiry-driven and design-oriented learning settings enhance students' higher-order thinking abilities in the context of mathematics education, which probably helped explain the notable performance improvements seen in this study. Additionally, Sumarni and Kadarwati (2020) showed that project-based learning (PBL) can greatly enhance higher-order thinking abilities (HOTS), bolstering the claim that PBL promotes both cognitive and knowledge acquisition.

The practical value of the intervention is further highlighted by the substantial difference ($p < .01$) between the students' post-test performance and the established 70% proficiency threshold. This result builds on the findings of He and Qi (2017), who highlighted the value of organized project design in creating resources for mathematics curricula. The current study shows that PBL can raise student performance from below-proficient levels to above-standard achievement when it is implemented systematically. Furthermore, Shi (2023) emphasized the "Gold Standard PBL" tenets of authenticity, reflection, and persistent inquiry, which offer a theoretical justification for the notable progress found in this investigation.

The findings theoretically align with constructivist learning principles found in Bloom's taxonomy (Bloom et al., 1956) and its updated framework (Anderson & Krathwohl, 2001). PBL settings help students move from memorization and comprehension to application, analysis, evaluation, and creation—higher levels of cognitive engagement necessary for learning mathematics in a meaningful way. Furthermore, Aldabbus (2018) pointed out that real-world problem-solving situations increase student ownership and involvement, which could account for the high success and motivational results in this study.

The results also concur with more extensive worldwide studies that demonstrate PBL's efficacy in a variety of educational settings (Musa et al., 2021; Ning & Fu, 2024). According to this

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research, PBL results in quantifiable gains in academic achievement when it is properly applied with explicit instructional scaffolding and coordinated evaluation techniques. Additionally, Habok and Nagy (2016) contended that mixed-method assessments of PBL demonstrate both affective and cognitive benefits, confirming the multifaceted influence of this teaching strategy.

Furthermore, when analyzing attainment increases, dependability considerations are crucial. Internal consistency reliability theory (Cronbach, 1951; Richardson & Kuder, 1939) argues that structured assessment tools are a valid way to gauge learning progress. The study's significant effect sizes imply both statistical significance and a significant educational benefit.

All things considered, the current research adds to the increasing amount of evidence that Project-Based Learning is a successful teaching method for raising primary school students' proficiency in mathematics. PBL fosters higher-order cognitive growth and academic competence by combining reflective practice, systematic direction, and authentic inquiry. These findings encourage the wider deployment of PBL in mathematics education by showing that its systematic application can raise students' competency levels above minimal requirements.

Recommendation

Enhancing the successful application and ongoing development of Project-Based Learning (PBL) in various educational situations is the goal of the following suggestions.

First, curriculum design should methodically incorporate PBL. To guarantee coherence and academic rigor, project-based approaches should be in line with learning objectives, instructional activities, and assessment techniques. Students can gain a better conceptual grasp and develop critical thinking, teamwork, creativity, and problem-solving skills—all of which are crucial 21st-century competencies—by incorporating realistic, real-world challenges into the curriculum.

Second, organizations ought to give teachers ongoing opportunities for professional growth. In order to create relevant projects, encourage student inquiry, oversee collaborative learning environments, and apply proper evaluation procedures, teachers require ongoing training and assistance. Teachers' confidence and efficacy as educators in PBL settings can be further enhanced by ongoing professional learning communities.

Third, there should be more cooperation with outside groups and industrial partners. Collaborations with experts and community members can offer exposure to real-world applications, mentorship possibilities, and authentic project contexts. Students' educational experiences are enhanced, and the applicability of academic material is reinforced by such participation.

Fourth, it is necessary to design and improve assessment techniques that are in line with PBL concepts. It's possible that project-based learning fosters competencies that are not

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sufficiently captured by traditional exams. Thus, it is necessary to include rubrics, portfolio assessments, performance-based evaluations, and authentic assessments. These techniques make it possible to assess students' knowledge, abilities, and teamwork in a more thorough manner.

Fifth, pupils should be encouraged to engage in reflective behaviors. Journals, self-evaluations, and peer reviews are examples of structured reflection exercises that assist students in tracking their development, identifying their areas of strength and growth, and cultivating the metacognitive abilities necessary for lifelong learning.

To help with PBL implementation, technology-enhanced learning resources should also be incorporated. Multimedia presentation tools, data analysis software, simulation tools, and digital collaboration platforms can all increase learning opportunities and promote creativity and communication. Future research on the topic of technology's role in project-based learning is equally crucial.

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