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An Experimental Study on the Impact of Project-Based Learning on Primary School Pupils' Problem-Solving Abilities

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Abstract. Against the backdrop of cultivating core competencies, problem-solving ability has become an indispensable quality for the well-rounded development of primary school pupils. However, traditional teaching models exhibit limitations in favoring theory over practice, rendering them inadequate for nurturing this competency. Consequently, this study employed an adopted experimental design involving 60 Year 4 pupils to investigate the impact of project-based learning on primary pupils' problem-solving abilities. Thirty pupils formed the experimental group, undertaking an interdisciplinary project-based learning activity themed around "Designing the Shiziyang Bridge." The remaining thirty pupils constituted the control group, engaging in traditional lecture-based instruction. Both groups received identical teaching content and lesson hours. Data for effectiveness evaluation were collected through scale assessments, observation, and semi-structured interviews. Results showed no significant differences between groups in pre-experiment total problem-solving scores or sub-dimensions ($P>0.05$). Post-experiment, the experimental group demonstrated significantly higher scores than the control group in problem-solving quality ($13.37 \pm 1.829 > 11.23 \pm 1.794$) and significantly outperformed the control group ($P < 0.001$). This study demonstrates that project-based learning effectively improves primary pupils' problem-solving abilities, offering practical guidance for cultivating core competencies and innovating teaching methods.

Keywords: Project-based learning, problem-solving ability, primary pupils, experimental research

1. Introduction

With the implementation of the new curriculum standards for compulsory education, problem-solving ability has become a key capability for enhancing core competency among primary school pupils, as well as a crucial developmental objective in basic education. In 2016, the Ministry of Education's document Core Competencies for Chinese Student Development stressed the importance of cultivating core literacy, specifically the need to develop pupils' problem-solving abilities—namely, the ability to identify and formulate problems in complex contexts and seek effective solutions [1]. Moreover, national educational research consistently recognizes problem-

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solving ability as one of the essential core competencies of 21st-century citizens. Against this backdrop, teaching practices should cultivate problem-solving skills through hands-on activities and experiential learning, thereby nurturing the talent required for the 21st century. However, under the traditional teaching models, its development of problem-solving abilities in primary pupils suffers from shortcomings: it is overly theoretical at the expense of practice, and prioritizes knowledge transmission rather than critical thinking training, rendering it difficult to meet core competency development needs [2]. Therefore, project-based learning—a student-centred, problem-oriented approach—offers opportunities to enhance primary pupils' problem-solving abilities. By creating real scenarios that guide collaborative group exploration, this method can encourage pupils to identify issues, devise solutions, and construct knowledge frameworks [3].

Therefore, the present study aims to enhance primary pupils' problem-solving abilities through project-based learning, which investigates the practical effectiveness of project-based learning in primary education and proposes relevant educational recommendations, which provides insights and references for cultivating pupils' problem-solving abilities and implementing project-based learning in primary schools.

2. Research design

2.1. Research participants

This study selected Q Primary School as the experimental school, a public institution in City S. A total of 60 pupils from two naturally divided Year 4 classes—Class 1 and Class 2—were selected as research subjects, including 30 boys and 30 girls. Class 1 served as the experimental group, while Class 2 served as the control group. Both classes were taught by the same teacher, with consistent teaching schedules and homework assignments to ensure controllability of instructional variables. Before the experiment, both classes underwent assessment using the Problem-Solving Ability Measurement Scale. SPSS 26.0 was used to test homogeneity, which revealed no significant differences between classes in total problem-solving ability scores ($P=0.788>0.05$), attitude towards problems ($P=0.432>0.05$), problem-handling strategies and methods ($P=0.662>0.05$), and problem-solving quality ($P=0.690>0.05$). This compliance with homogeneity requirements satisfied the criteria for subject grouping.

2.2. Research instruments

2.2.1. Problem-solving ability assessment tool for primary school pupils

This study adopted the Problem-Solving Ability Measurement Scale developed by Taiwanese scholars Huang Maozai and Chen Wendi. Based on children's developmental characteristics, it assesses problem-solving ability within three primary dimensions: attitude towards problems, methods and strategies employed, and quality of problem-solving. Following reliability analysis via SPSS, the overall Cronbach's α coefficient reached 0.787, with individual dimension coefficients ranging from 0.718 to 0.724, indicating strong scientific validity and stability. Moreover, this study conducted semi-structured interviews with teachers and students and used a prepared interview outline to gain in-depth insights through their views on project-based learning, experiences during problem-solving processes, and evaluations of teaching effectiveness. During project-based learning activities, the Student Problem-Solving Ability Observation Scale was employed to record student behaviors and supplement both the activity process and assessment scale data.

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2.2.2. Project-based learning teaching scheme

This study utilized Unit 5, "Triangles," from the People's Education Press Primary Mathematics textbook for Year 4, Lower Semester. Considering students' current cognitive development and interests, it employs a project-based learning model guided by the authentic problem: "How to design a robust and appealing Lion Ocean Bridge?" It also creates authentic scenarios involving understanding, exploration, design, construction, and presentation of bridges. This approach reconstructs mathematical knowledge of triangular properties, integrating subjects including mathematics, comprehensive practice, information technology, and art to implement interdisciplinary learning. The five-lesson project-based learning activity aims to enhance students' comprehensive qualities and problem-solving abilities, promoting their holistic development. The overall design and lesson schedule for this project-based learning activity are outlined in Figures 1-2 and Table 1:

Table 1. Objectives and content of the interdisciplinary project-based learning activity "I am a bridge architect"

Project Origin	To improve cross-river transportation safety, promote infrastructure connectivity in the Guangdong-Hong Kong-Macao Greater Bay Area and support regional economic development through the Shiziyang Passage Project.
Driving question	How to design and build a sturdy and beautiful bridge?
Core mission	Propose an ideal design plan for the Lion Ocean Bridge under construction in the Greater Bay Area
Subtask	Activity objectives and content
Get to know the bridge	Explore the history and basic types of bridges through pictures and videos; form project teams and clarify task goals; collect strcutural information with AI support.
Explore the bridge	Analyze bridge cable length and triangular structures; investigate properties of triangles through hands-on activities.
Design the bridge	Collaboratively design bridge models; apply triangle characteristics to draw structural sketches.
Build the bridge	Construct bridge models; conducts load-bearing tests; optimize designs through iterative adjustment
Display the bridge	Present project results; reflect on learning processes; consolidate knowledge and skills

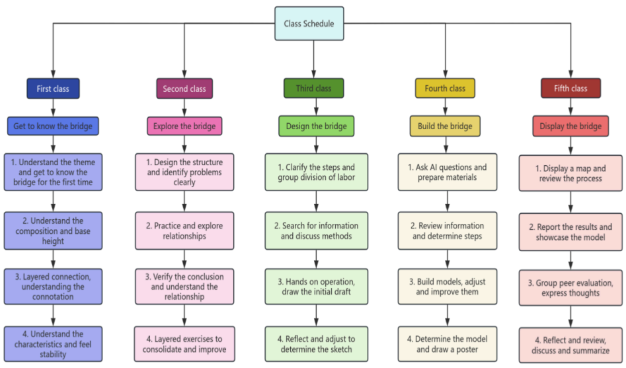

Figure 1. Interdisciplinary project proposal design for "I am a Bridge Architect"

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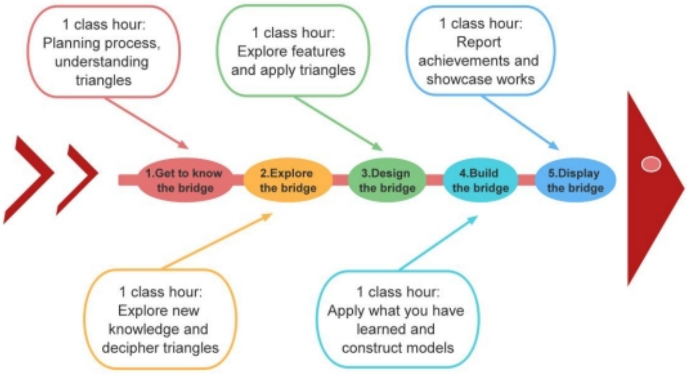

Figure 2. Interdisciplinary project-based learning schedule for "I am a Bridge Architect"

2.3. Research process

2.3.1. Experimental preparation

Before project-based learning, firstly, students in both the experimental and control groups used the Problem-Solving Ability Measurement Scale to test homogeneity during pre-testing. Secondly, observation record sheets and teacher-student interview outlines tailored to the project-based learning activities were developed and refined through the teaching process. Additionally, materials and equipment required for the project-based learning activities were prepared, such as AI devices and construction materials. Teachers in the experimental class were trained to use the equipment proficiently and correctly, and the project-based learning activity schedule was synchronized with the control class, which can avoid interference from additional variables.

2.3.2. Implementation of the experiment

This teaching activity comprises five lessons. The experimental class adopted project-based learning, while the control class employed traditional teaching methods. Both classes covered the topic of 'Triangles' with identical lesson times. The experimental class employed a Lion Ocean Bridge design project as the context to drive its five-lesson program: recognize the bridge to stimulate inquiry interest, explore the bridge and do practical activities to clarify triangular properties, design the bridge to sketch using AI tools, construct the bridge to test structural models, and present the bridge through group collaboration and discussion. The control class employed traditional lecture-based teaching. The teacher introduced the lesson contextually before explaining key concepts such as the definition of a triangle, its characteristics, the relationship between its three sides, and stability. Knowledge points were applied through example problems, and homework was assigned to consolidate. The researcher used an observation record to record the experimental class students' performance during the project-based learning process, simultaneously recording classroom behavior and homework completion rates for both classes. To ensure validity, all teaching conditions remained consistent except for the instructional approach.

2.3.3. Post-experiment assessment

At the quantitative dimension, after the project-based learning phase, the Problem-Solving Ability Measurement Scale was used to assess problem-solving in both groups for post-test evaluation.

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SPSS 26.0 statistical analysis examined whether project-based learning enhanced problem-solving capabilities. At the qualitative dimension, semi-structured interviews were conducted with students and teachers from different ability levels and analyzed perceptions of project-based learning, and the effectiveness of problem-solving skills, and offered targeted recommendations.

3. Research findings

3.1. Comparison of problem-solving ability scores between the two groups prior to the experiment

Before the project-based learning, this study adopted the Problem-Solving Ability Measurement Scale to conduct a pre-test of the two groups' problem-solving abilities across three dimensions: attitude, strategies and methods, and quality. Normality tests were performed on both samples using SPSS 26.0, confirming that both datasets conformed to a normal distribution. An independent samples t-test was subsequently conducted, with the results presented in Table 2:

Table 2. Comparison of differences in problem-solving abilities between the two groups of participants before the experiment

	Control group pre-test		Experimental group post test		t	p
	M	SD	M	SD		
Attitude towards problems	11.10	1.125	10.83	1.464	-0.791	.432
Strategies and methods for handling problems	15.47	1.697	15.67	1.826	0.440	.662
Quality of problem-solving	11.00	1.800	10.83	1.392	-0.401	.690
total score	37.57	3.081	37.33	3.585	-0.270	.788

Note:*p<0.05 **p<0.01 ***p<0.001

From table 2 we can see that before the experiment, there was no significant difference between the two groups of participants in terms of overall problem-solving ability (P=0.788>0.05). Across individual dimensions, the experimental and control groups showed no significant differences in their attitudes towards problem-solving (P=0.432>0.05), strategies and methods employed (P=0.662>0.05), and the quality of problem-solving outcomes (P=0.690>0.05). Therefore, before the intervention, both groups exhibited comparable overall levels of problem-solving ability and consistent performance across dimensions, demonstrating strong homogeneity. This provides a reliable foundation for subsequent comparisons of teaching intervention outcomes.

3.2. Comparison of differences in problem-solving abilities between experimental group participants before and after the experiment

After the five-lesson project-based learning activity, the researchers conducted a post-test of problem-solving abilities on the experimental group students. The results were subjected to a difference test against the pre-test data. The analysis findings are shown in Table 3:

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Table 3. Comparison of differences in problem-solving abilities among experimental group participants before and after the experiment

	Experimental group pre-test		Experimental group pre-test		t	p
	M	SD	M	SD		
Attitude towards problems	10.83	1.464	14.10	1.729	-7.897	0.000***
Strategies and methods for handling problems	15.67	1.826	19.23	2.388	-6.499	0.000***
Quality of problem-solving	10.83	1.392	13.37	1.829	-6.038	0.000***
total score	37.33	3.585	46.70	4.356	-9.094	0.000***

Note:*p<0.05 **p<0.01 ***p<0.001

The results indicate that the experimental group students gained higher post-test scores than pre-test scores in their overall problem-solving ability. Extremely significant differences were observed in all dimensions: overall scores, attitudes towards problem-solving, strategies and methods employed, and the quality of problem-solving (P=0.000<0.001). Consequently, it can be concluded that students' problem-solving abilities were notably enhanced following the project-based learning.

3.3. Comparison of differences in problem-solving abilities between control group participants before and after the experiment

A difference test was conducted on the pre- and post-test data of problem-solving abilities for control group participants. The analysis results are presented in Table 4:

Table 4. Comparison of differences in problem-solving abilities between control group participants before and after the experiment

	Control group pre-test		Control group post test		t	p
	M	SD	M	SD		
Attitude towards problems	11.20	1.125	11.57	1.135	-1.599	0.115
Strategies and methods for handling problems	14.60	1.886	14.70	1.932	-0.203	0.840
Quality of problem-solving	11.00	1.800	11.23	1.794	-0.503	0.617
total score	36.70	2.914	37.50	2.825	-1.080	0.285

Note:*p<0.05 **p<0.01 ***p<0.001

The test results indicate that after five lessons of traditional lecture-based instruction, there was no significant overall difference in problem-solving ability between the control group participants (P=0.285>0.05). Moreover, also no significant differences were observed across three dimensions: attitude towards problems (P=0.115>0.05), strategies and methods for problem handling (P=0.840>0.05), and quality of problem solving (P=0.617>0.05).

However, we can see that post-test scores were slightly higher than pre-test scores within three dimensions: attitude towards problems (M=11.57>11.20), strategies and methods for problem

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handling (14.70>14.60), and quality of problem solving (11.23 > 11.00). This may be attributed to primary pupils' increasing curiosity and exploration with increasing age, leading them to actively engage in critical inquiry and mental exercise during practical activities. Concurrently, through participating in routine family and school activities—such as household chores or group collaboration—pupils devise solutions to achieve objectives. This practice cultivates greater flexibility and innovation in their thinking, thereby laying the foundation for enhanced problem-solving capabilities.

3.4. Comparison of differences in problem-solving ability between experimental and control groups at post-test

After the project-based learning programme, this study used the Problem-Solving Ability Measurement Scale to conduct a post-test assessment of the two groups' problem-solving ability across three dimensions. The independent samples t-test was performed, with the analysis results presented in Table 5:

Table 5. Comparison of differences in problem-solving abilities between two groups of participants after the experiment

	Control group post test		Experimental group post test		t	p
	M	SD	M	SD		
Attitude towards problems	11.57	1.135	14.03	1.721	6.522	0.000***
Strategies and methods for handling problems	14.70	1.932	19.21	2.426	7.907	0.000***
Quality of problem-solving	11.23	1.794	13.38	1.860	4.511	0.000***
total score	37.50	2.825	46.62	4.411	9.490	0.000***

Note:*p<0.05 **p<0.01 ***p<0.001

The test results show that the post-test scores of the experimental group were significantly higher than those of the control group. There were highly significant differences (P=0.000<0.001) between the two groups in terms of total scores, attitudes towards problem-solving, strategies and methods employed, and the quality of problem-solving. Therefore, it can be concluded that the problem-solving abilities of students in the experimental group were significantly superior to those in the control group. This approach can effectively enhance students' problem-solving capabilities.

4. Discussion

This study compares and analyzes pre- and post-test data on problem-solving abilities between experimental and control group students, and finds that project-based learning effectively enhances students' problem-solving capabilities. During the project-based learning process, behavioral observation records showed significant improvements in students' teamwork skills, verbal expression abilities, and critical thinking. Consequently, the reasons for this can be attributed as follows: Firstly, it relates to the inherent characteristics and methodology of project-based learning. The core of project-based learning is authentic, meaningful problems or tasks. When applied to mathematics teaching, it means designing thematic, contextualized, and integrated knowledge tasks for pupils based on textbook content, thereby mitigating learning difficulty [4]. Transforming textbook knowledge into genuine, complex real-world problems and scenarios stimulates pupils'

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desire for inquiry. Using authentic problems to propel exploration aligns with primary pupils' cognitive development characteristics.

Secondly, fragmented knowledge is one of the cognitive barriers of problem-solving among primary pupils. Project-based learning can break down disciplinary barriers and integrate knowledge across subjects. Through completing project tasks, pupils can use knowledge according to problem requirements, engage in collaborative exchange, mutually validate insights, and integrate knowledge from diverse domains [5]. Through the project-based learning activity and subsequent teacher-student interviews, pupils can proactively link knowledge across disciplines to tackle problems, gaining continuous improvement in their ability to apply knowledge holistically. Crucially, the essence of project-based learning is not the final product but the process itself. Through planning, designing solutions, hands-on implementation, refinement, and presentation, pupils experienced the problem-solving sequence: identifying issues, investigating causes, formulating hypotheses, validating approaches, and resolving challenges [6]. Through investigating bridge characteristics, drafting bridge designs, refining sketches, and presenting final outcomes, students identified problems, analyzed causes, and made iterative adjustments, which cultivated their problem-solving competencies greatly.

Finally, it relates to shifts in teaching philosophy. Compared to traditional teaching models, project-based learning assigns educators multiple roles. This identity transition compels teachers to rethink instructional methods and approaches. Through transitioning from knowledge "transmitters" to problem "facilitators," teachers in project-based learning refrain from providing direct answers. Instead, they act as "scaffolders," providing provocative questions to stimulate student inquiry, guiding independent thinking, and helping learners acquire problem-solving methods to develop autonomous problem-solving competencies [7]. During project-based learning, teachers provide differentiated instructional guidance. For students who find tasks daunting, teachers assist by breaking down projects to reduce complexity. For more capable learners, teachers propose advanced questions to enhance their problem-solving abilities. This personalized approach enables students to achieve maximum development within their respective zones of proximal development, thereby improving their problem-solving competencies [8].

5. Educational recommendations

About the classroom content, fostering students' willingness to "want to ask" and "dare to ask" should be key learning objectives, cultivating their habit and awareness of posing questions [9]. Through current student learning patterns, they spent too much time during lessons identifying, formulating, and resolving problems. To address these questions, teachers may implement pre-learning activities and encourage independent preparation before class to identify issues and explore solutions beforehand. This approach enables students to think deeply with specific questions in class and can make students have a positive influence on their problem awareness and resolution capabilities.

At the teaching level, educators need to strengthen their interdisciplinary knowledge base and explore connections between subjects and pedagogical approaches. This enables flexible integration of multidisciplinary resources during integrated teaching, helping students overcome cognitive barriers when solving problems. Additionally, it is a good idea to design a step-by-step problem-training system to enhance the coherence and depth of students' thinking.

Regarding project-based learning implementation, emphasis should be placed on scientifically designing motivational problem scenarios, rationally defining target solutions, and highlighting practical application and innovation [10]. It is crucial to conduct in-depth research into pupils'

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interests and life experiences to understand their current concerns, and integrating these into project themes enhances engagement. Furthermore, potential project challenges and contingency plans should be anticipated before launch, thoroughly considered for difficulties, and formulated into targeted strategies to ensure smooth project progression. Concurrently, throughout project execution, post-subtask analysis and summary should be prioritized to adjust subsequent implementation plans, thereby enhancing the efficacy of project-based inquiry.

6. Conclusion

This study investigated the impact of project-based learning on primary pupils' problem-solving abilities through a comparative experiment involving an experimental class (project-based learning) and a control class (traditional teaching), conducted with 60 Year 4 pupils at Q Primary School in S City. Results indicated there is no significant difference in problem-solving abilities between the two groups before the experiment. After five lessons of project-based learning, the experimental class showed significantly better performance against the control class across three dimensions: attitude towards problems, strategies and methods for problem-solving, and quality of problem-solving. This confirms that project-based learning effectively improves primary pupils' problem-solving abilities. By creating authentic problem scenarios, introducing core drivers, integrating interdisciplinary content, and providing a complete inquiry process, project-based learning offers an effective path for cultivating pupils' problem-solving abilities through its pedagogical model, transformed teacher roles, and differentiated guidance.

However, this study has limitations: the sample originated solely from a single primary school, limiting its representativeness; the project duration of five lessons is short, we cannot assess the long-term effects on pupils' problem-solving abilities. Therefore, to address these issues, future research should expand the sample scope to include multiple schools of varying types, ensuring greater representativeness. Extending the project duration could incorporate follow-up assessments to investigate the long-term retention of skills. Additionally, broaden the research perspective to explore the integration of project-based learning with other teaching models. It can provide more comprehensive practical guidance for cultivating problem-solving abilities in primary education.

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