Asian Journal of Contemporary Education
ISSN(e): 2617-1252
DOI: 10.55493/5052.v9i1.5304
Vol. 9, No. 1, 42-54.
© 2025 AESS Publications. All Rights Reserved.

A quasi-experimental study on projected-based and inquiry-based approaches in fourth-grade mathematics: Effects on teamwork skills and critical thinking

Yongzhi Zhou[1+]
Nirat Jantharajit[2]
Sarit Srikhao[3]

[1,2,3]*Faculty of Education, Nakhon Phanom University, Thailand.*
[1]*Email: 553215751@qq.com*
[2]*Email: n20jann@hotmail.com*
[3]*Email: sarit63@hotmail.com*

(+ Corresponding author)

Article History
Received: 25 November 2024
Revised: 27 January 2025
Accepted: 10 February 2025
Published: 14 February 2025

Keywords
Critical thinking
Inquiry-based learning
Instructional approach
Project-based learning
Teamwork skills.

ABSTRACT

This study scrutinizes the influence of project-based learning (PBL) and inquiry-based learning (IBL) on fourth graders' teamwork skills and critical thinking in math classes. A historical review reveals that while they have positive effects in multiple fields, their sole use in elementary math teaching is yet to be explored. 55 fourth-grade students from Manas No. 1 Primary School in Xinjiang were randomly chosen using a quasi-experimental design. They were divided into experimental and control groups. The experimental group was taught with a combination of PBL and IBL while the control group received traditional teaching. Quantitative assessment of teamwork skills and critical thinking shows that the combined method is more effective. The results emphasize the importance of developing shift-based and inquiry-centered learning programs. Nevertheless, the study has limitations such as a small sample and a short time frame. Further examination in different cultural, educational, subject, and class-level contexts is required for process reliability before generalizing the findings.

Contribution/ Originality: This study's originality lies in being the first to explore PBL and IBL in elementary math. It shows their combined impact on 4th graders' teamwork, critical thinking and filling a research gap.

1. INTRODUCTION

Mathematics plays an integral role in today's educational system as it shapes students into logical thinkers and problem solvers (Szabo, Körtesi, Guncaga, Szabo, & Neag, 2020) as well as builds a strong cognitive basis for their later learning in the natural and social sciences (Maass, Geiger, Ariza, & Goos, 2019). However, traditional mathematics teaching is often teacher-centered excessively emphasizing memorization and rote practice (Dole, Bloom, & Kowalske, 2016). Although it promotes fundamental information, this method does not adequately address the changing educational requirements of the twenty-first century, especially when encouraging collaboration and critical thinking. Therefore, finding more effective and scientific teaching methods has become a central issue in educational reform. In recent years, more scholars have focused on project-based learning (PBL) and inquiry-based learning (IBL), primarily because these methods emphasize active student participation and knowledge construction (Acar & Tuncdogan, 2019; Almulla, 2020). Exploring the application of these methods in elementary mathematics education holds significant value.

Project-based learning (PBL) is a student-centered teaching method characterized by autonomy, constructive inquiry, goal setting, collaboration, communication, and reflection in real-world contexts (Kokotsaki, Menzies, & Wiggins, 2016). Inquiry-based learning (IBL) is defined as a process of formulating and testing hypotheses through

© 2025 AESS Publications. All Rights Reserved.

experiments or observations where students construct knowledge in a manner similar to professional scientists (Pedaste et al., 2015). Research indicates that PBL and IBL demonstrate significant advantages across various disciplines. Simanjuntak, Hutahaean, Marpaung, and Ramadhani (2021) found that PBL significantly improved 10th-grade students' problem-solving and creative thinking skills in physics courses. Rodríguez, Pérez, Núñez, Baños, and Carrió (2019) confirmed that IBL effectively stimulated higher-order thinking, particularly creativity and research skills in biomedical students. Few studies have examined the combined application of PBL and IBL in elementary mathematics, particularly regarding teamwork skills and critical thinking while most related studies focus on science or engineering fields and typically investigate a single teaching method. Therefore, validating the effectiveness and feasibility of combining PBL and IBL at the elementary level is especially important as filling this knowledge gap holds significant implications for educational practice.

This research intends to scrutinize the effects of integrating project-based learning (PBL) and inquiry-based learning (IBL) instructional approaches in the improvement of mathematics skills at the fourth-grade level by assessing their students' teamwork skills and critical thinking component of learning. The assumption would be that combining the PBL and IBL teaching approaches play a significant role in developing students' teamwork and critical thinking skills than traditional teaching methods. A quasi-experimental design was adopted along with two groups chosen randomly from 227 fourth-grade students at Manas No. 1 Primary School based in Xinjiang for comparison purposes. PBL and IBL methods were utilized as the direct instruction literature for the experimental group whereas traditional teaching approaches were employed for the control group to verify this hypothesis. After 20 instructional cycles, a comparison of teamwork skills and critical thinking was made for the two groups through the analysis of quantitative data. It is the initial finding that the included methods of PBL and IBL in teaching yielded a significant increase in the student's teamwork and critical thinking skills in contrast to traditional teaching.

This study fills a research gap in the use of combined PBL and IBL in elementary school and provides useful references for future study in addition to providing empirical support for primary school mathematics education by helping teachers choose more effective teaching methods. Nevertheless, the study has drawbacks such as a small sample size and a limited geographic area which might limit the generalizability of the results. The sample size should be increased in the future.

2. LITERATURE REVIEW

2.1. Teamwork Skills

Teamwork skills belong to the critical soft skills of the 21st century which play an essential part in a student's achievement in both academic and professional fields. Moreover, collaboration also plays a significant role in determining our success in society. Teamwork skills ensure that both individuals and teams become more efficient and imaginative and this serves as a good basis for finding ways to solve complex problems that are facing us as a result of globalization and all other factors that come with it. In this regard, team play mastery is an increasingly discussed matter in these fields which now form a crucial aspect of school curricula and extracurricular programs (Lincă, Anghel, & Matei, 2023). Teams are made of individuals with unique abilities which should be used effectively to achieve the common goal. Lacerenza, Marlow, Tannenbaum, and Salas (2018) maintain that the teamwork skills involve a variety of competencies needed for people to work together towards shared goals within a team and include communication, conflict resolution, leadership, task assignment and constructive feedback. Schartel, Dawson, and Block (2021) conclude that there are teamwork skills that are a holistic and ever-changing capacity encompassing not only the actual task but also social relationships within the team. Studies imply that such an approach can trigger the development of teamwork skills among students and research helps in defining the characteristics of an effective team. A study done by Barker (2021) that concerned the first-year mineralogy students revealed that training through problem-based learning (PBL) and feedback mechanisms had students

© 2025 AESS Publications. All Rights Reserved.

improve greatly on their teamwork skills. Furthermore, Schartel et al. (2021) observed that business schools provide a curriculum that includes systematic teaching of teamwork skills in lectures which helps the students to engage not only in team activities but also in teamwork as a whole.

2.2. Critical Thinking

Critical thinking is essential in the modern era of information proliferation and intricate decision-making since it not only ensures effective problem-solving but also helps individuals thrive in their communities at work and in school (D'Alessio, Avolio, & Charles, 2019). Beyond this, critical thinking can be described as a virtue that enables people to perceive information from multiple perspectives with the ability to avoid prejudice and base their decisions on critical and analytical judgments (Vitaliy Nadurak, 2022). Critical thinking is also an essential and basic skill that every learner needs during their educational journey and career development.

According to Ghanizadeh et al. (2020) critical thinking is a higher-order cognitive skill that is logic- and evidence-based as it involves the analyzing, evaluating, and reasoning of information to produce clear and rational judgments for problem-solving. Kuhn (2019) makes a point that critical thinking is the second dimension, a dialogic practice by which individuals all the time challenge and determine their notions and hypotheses through verbal engagement with people around them. Furthermore, critical thought includes metacognition which plays the role of the person's self-awareness that allows him to track conscious processes (Nadurak, 2023). Undoubtedly, the design of the context involved an interesting competition development aimed at cultivating critical thought and aligning with Kuhn's theory that was disseminated in 2019. Tang, Vezzani, and Eriksson's (2020) study indicates that the ability to think critically is strongly related to common values such as collaboration and communication among students, thus insisting that interaction and dialogue contribute greatly to understanding of other people's thoughts and optimization of cognitive abilities. Consequently, Kuhn (2019) suggested a new idea of collaborative education using discussion as a significantly more effective one for raising students' critical thinking instead of applying traditional approaches to education based on solitary students' learning.

2.3. Project -Based Learning

PBL is in the 21st-century education development framework as it lays much emphasis on the honing of skills, whereas critical thinking, teamwork skills and complex problem solving qualify as essential competencies (Geisinger, 2016). It is believed that PBL can stimulate these skills as well (Artama, Budasi, & Ratminingsih, 2023). Project-based learning (PBL) is a student-centered method for teaching and learning. It develops the students' core carefully through a method of real-world problems-solving by applying authentic projects. At present, PBL is being implemented in the deepest and widest areas of teaching, including the fields of engineering, math, and biology, and the need to fulfill current students and job requirements is met by this vital way of teaching.

The theoretical basis of PBL, constructivism and social constructivism highlights that learners can actively construct knowledge and gain new cognition through teamwork (Bakare, Ojulokunrin, Jagun, Adedeji, & Olugbenga, 2020; Korkmaz & Kalaycı, 2019). The PBL approach uses real-world "authentic problems" and issues/projects to teach students core knowledge and skills with components that include multi-stage processes and teamwork (Trisdiono, Siswandari, Suryani, & Joyoatmojo, 2019). When a PBL environment is applied to teaching, students get to practice the communication, conflict resolution, and team working skills that are required for effective problem tackling through group assignments. A recent study involving 359 students from two Spanish universities investigated the relationship between teamwork skills and satisfaction with PBL revealing a significant and positive correlation between the two (Melguizo-Garín, Ruiz-Rodríguez, Peláez-Fernández, Salas-Rodríguez, & Serrano-Ibáñez, 2022). Furthermore, PBL mandates students to break different blocks such as analysis, communication, evaluation, and synthesis, when putting together a feasible and doable solution. In this regard, PBL provides a platform for developing critical thinking, a skill that requires collaborative and dialogic environments.

© 2025 AESS Publications. All Rights Reserved.

The research shows that the crucial activity of PBL is when 834 first-year engineering students participate in this type of education, they exhibit high-level improvement in critical thinking during their studies (Cortázar et al., 2021).

2.4. Inquiry-Based Learning

Inquiry-based learning (IBL) refers to the process of establishing relationships between facts and results where learners propose and investigate their hypotheses through experiments or in-depth field studies hence enabling knowledge construction in the same way professional scientists do (Pedaste et al., 2015). Student-centered learning where students actively participate in problem-solving and knowledge construction is emphasized. The theoretical framework is based on constructivism and social constructivism. In IBL environments, students collaborate and communicate through group task delegation and joint problem-solving, sharing responsibilities which greatly enhances teamwork skills and critical thinking. Related studies support this view. For instance, in chemistry lab courses using IBL, the gap between novice and experienced learners in teamwork and problem-solving significantly narrowed (Huang, 2022). Another study involving 56 seventh-grade students in a quasi-experiment on Science Context Inquiry Learning (SCOIL) revealed significant improvements in students' critical thinking (Pursitasari, Suhardi, Putra, & Rachman, 2020). Certain issues have drawn scholarly attention during the implementation of IBL. For example, Huang (2022) found that more experienced learners might exhibit negative attitudes toward teamwork and problem-solving, recommending differentiated instruction to cater to students' varying experience levels. On the other hand, a meta-analysis by Lazonder and Harmsen (2016) indicated that IBL could be more effective than traditional expository teaching methods, provided students receive adequate support. Recently, De Jong et al. (2023) reaffirmed this perspective demonstrating that combining inquiry and direct guidance is the optimal approach to support student learning. Therefore, when implementing IBL, differences in student experience should be considered and the teacher's guidance role should be maximized to ensure effective learning outcomes.

In a nutshell, previous theoretical and empirical studies have demonstrated the positive impact of PBL and IBL on students' teamwork skills and critical thinking, providing a solid theoretical and practical foundation for this study's feasibility. Teaching is a dynamic process, and no single method is optimal; instead, combining methods may yield better results. Therefore, we employ a project-oriented, inquiry-centered approach, integrating collaboration, communication, and reflection to examine the impact of this teaching strategy on fourth-grade students' teamwork and critical thinking in mathematics classrooms in this study. The methodology section provides a detailed description of the specific procedures for implementing the teaching methods.

3. RESEARCH METHODOLOGY

3.1. Research Design

This research applied a quasi-experimental design with pre- and post-tests to be conducted for the control groups that were set at a 0.05 significance level. These groups were both given pre-tests that showed their very first teamwork and critical thinking abilities conducted for the purpose of a coming comparative analysis. The experimental group applied a combination of project-based learning (PBL) and inquiry-based learning (IBL) within the making of the 20 lessons while the control group engaged in a traditional way of teaching. The post-tests were carried out after the teaching methods to assess the results.

3.2. Research Objectives

To compare the teamwork skills and mathematical critical thinking of fourth-grade students before and after being assigned to teaching methods based on project-based and inquiry-based learning.

To compare the teamwork skills and critical thinking in mathematics of fourth-grade students taught using project-based and inquiry-based learning methods with those taught using traditional methods.

© 2025 AESS Publications. All Rights Reserved.

3.3. Research Variables

In this research, the teaching method that was used is the independent variable, and the two groups, experimental and control groups define it. The experiment group combined problem-based and inquiry-based learning approaches but the control group used conventional teaching. The two independent variables are the teamwork skills and critical analysis in mathematics by the fourth-grade students.

3.4. Definition of Concept

3.4.1. Teamwork Skills

According to Tessier (2021) teamwork skills are a set of skills that individuals need to pursue similar objectives as a group and involve communication, conflict resolution, leadership, task distribution, and response to feedback. This paper defines teamwork skills for students as the ability to work collectively and harmoniously with peers in math classes to achieve a common goal of identical shared learning outcomes. This encompasses communication, collaboration, problem-solving, and adaptability.

3.4.2. Critical Thinking

According to Ghanizadeh et al. (2020) critical thinking is high-level reasoning, rooted in logic and evidence, which involves the analysis, evaluation and reasoning of information that ultimately ends up in making accurate and reasonable judgments to solve the issue. In this study, critical thinking is intended to mean students' capacity to carry on the whole spectrum of higher-order thinking described in terms of mathematical classrooms for the purposes of rational judgment and problem-solving.

3.4.3. Project -Based and Inquiry-Based Learning Approach

Project-based learning (PBL) is a student-centered teaching approach characterized by an emphasis on autonomy, constructive inquiry, goal setting, collaboration, communication, and reflection in real-world contexts (Kokotsaki et al., 2016). Inquiry-based learning is a process of discovering causal relationships where learners formulate and test hypotheses through experiments or observations, constructing knowledge in a manner similar to professional scientists (Pedaste et al., 2015). This study integrates the features of PBL and IBL to design a combined teaching model. The model includes five key elements: authentic context construction, project-driven learning, collaborative in-depth inquiry, dynamic interaction and knowledge sharing, and multidimensional assessment with continuous reflection. Table 1 presents the specific teaching processes and task requirements.

Table 1. Instructional process and task requirements.

Instructional process	Task requirements
Authentic context construction	Teachers introduce real-world problems or contexts related to students' lives to spark their interest and engagement, helping them understand the practical value of knowledge in real-life situations.
Project-driven learning	Teachers design complex and challenging project tasks centered on real-world issues. These projects drive the entire learning process, encouraging students to achieve goals while enhancing their problem-solving abilities.
Collaborative in-depth inquiry	Teachers organize students into groups for inquiry-based exploration. Through the division of tasks, knowledge sharing, and collective decision-making, the process aims to foster teamwork, deepen understanding, and develop critical thinking.
Dynamic interaction and knowledge sharing	Teachers encourage students to exchange, debate, and receive feedback within and beyond their groups. This allows students to showcase their learning outcomes while improving their understanding and solutions from others' perspectives.
Multidimensional assessment with continuous reflection	Teachers guide evaluation through a multidimensional model involving teacher, peer, and self-assessment. This approach helps students identify strengths and weaknesses, consolidate knowledge, and refine strategies through reflection promoting continuous growth.

© 2025 AESS Publications. All Rights Reserved.

3.4.4. Traditional Approach

Traditional teaching methods are teacher-centered instructional models primarily aimed at knowledge transmission. In this approach, the teacher directs the teaching process while students passively receive knowledge. Classroom interaction is limited and students' engagement and initiative are constrained (Dole et al., 2016). The traditional teaching method employed in this study involved teachers delivering instruction based on problems presented in the mathematics textbook. The process included problem introduction, explanation, student practice and teacher summary and feedback.

3.5. Research Population and Sample

The research population comprised 227 fourth-grade students from Manas No. 1 Primary School in China during the 2024 academic year. The research sample was selected using cluster random sampling from the 227 fourth-grade students at Manas No. 1 Primary School in China. Fifty-five students were randomly selected and assigned to the experimental, control and validation groups. The experimental group consisted of 26 students, while the control group included 29 students. Table 2 presents the number of participants and gender information.

Table 2. Participants' information.

Items	Number	Number (Male)	Number (Female)
Sample size	55	24	31
Experimental group	26	10	16
Control group	29	14	15

3.6. Research Hypothesis

The two research questions examined in this study are as follows:

Is there a significant difference in the teamwork skills and critical thinking among students engaged in the instructional approach based on project-based learning and inquiry-based learning before and after participation?

Is there a significant difference in the teamwork skills and critical thinking between students engaged in the instructional approach based on project-based learning and inquiry-based learning compared to those participating in the traditional teaching approach?

3.7. Research Treatment

In this study, we implemented various rigorous measures to ensure the reliability and validity of the research results. These measures included sample selection, teacher training, teaching consistency control, and implementation of educational interventions.

3.7.1. Sample Selection Method

This study used random sampling to select 55 students from 227 fourth-grade students and randomly assigned them to the experimental and control groups to ensure the representativeness of the sample.

3.7.2. Teacher Training

Six teachers were invited to participate in this study. One teacher was assigned to teach the experimental and control groups to ensure consistency in teaching style and quality. The other five teachers were responsible for assessing students' teamwork skills and critical thinking. The teachers received standardized training to ensure an accurate understanding of the assessment tools and criteria before the study commenced.

3.7.3. Assessment Method

This study used teamwork skills and critical thinking assessment scales in the classroom to evaluate students' performance. Students in the experimental group were divided into five groups, each with four students, except the

© 2025 AESS Publications. All Rights Reserved.

first group which had five students to ensure effective evaluation. Control group students were numbered from 1 to 29. Five teachers were assigned to evaluate the corresponding groups and numbered students as detailed in Figure 1.

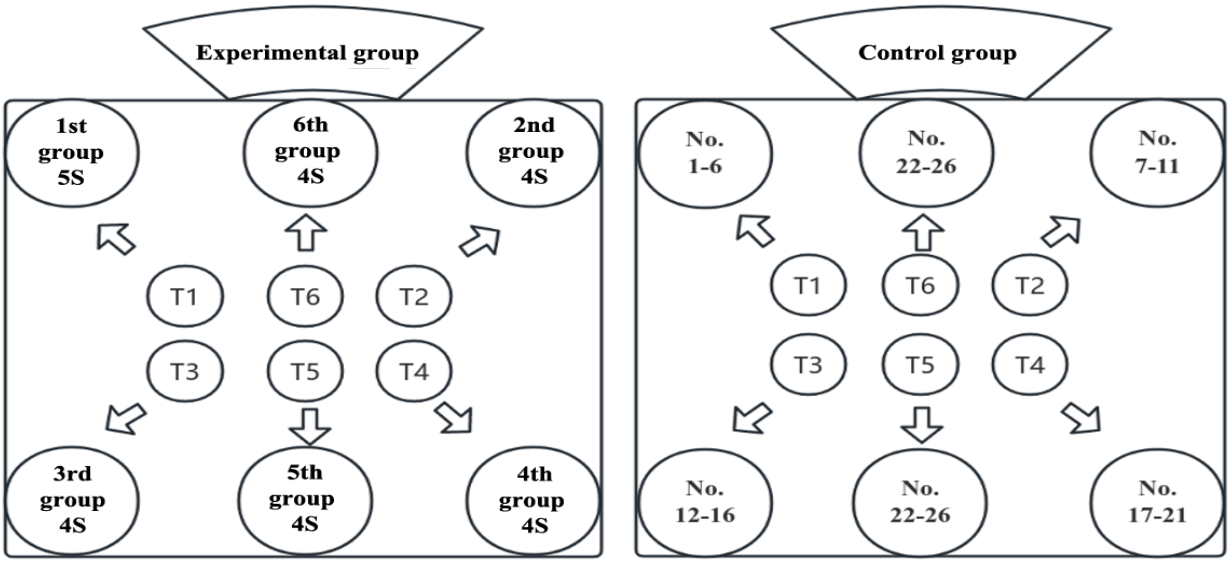

Figure 1. Shows the assessment methods for the experimental and control groups.

Note: T represents teacher, S represents student.

3.7.4. Instrumental Reliability and Validity

The teamwork skills and critical thinking assessment scales used in this study were custom-designed. Five experts in related fields were invited to evaluate and review them in terms of content validity, construct validity, reliability, and practicality to ensure the validity of the scales. Additionally, 25 students were randomly selected from the remaining 172 fourth-grade students to form a validation group for reliability and validity testing. The testing results are shown in Tables 3 and 4.

Table 3. Shows results of the expert assessment.

Items	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	MD	SD
Content validity	4 points	4 points	5 points	5 points	4 points	4.4 points	0.49
Construct validity	3 points	4 points	4 points	4 points	3 points	3.6 points	0.49
Reliability	4 points	4 points	4 points	4 points	3 points	3.8 points	0.4
Practicality	4 points	4 points	4 points	4 points	4 points	4 points	0

Note: Each item was rated on a scale of 1 to 5.

Expert evaluation results indicated that the tool is valid and suitable for its intended purpose. The average scores for each dimension ranged from 3.6 to 4 with standard deviations between 0.4 and 0.49 demonstrating consistent expert evaluations, particularly complete agreement on practicality.

Table 4. Cronbach's α coefficient & KMO test and Bartlett test.

Scale	Number of items		Cronbach's α coefficient	
Teamwork skills assessment scale	5		0.782	
Critical thinking assessment scale	5		0.825	
Scale	KMO	df	Bartlett test of sphericity	P
Teamwork skills assessment scale	0.801	66	227.675	0.000***
Critical thinking assessment scale	0.795	66	243.768	0.000***

Note: A p-value of 0.000*** indicates that the result has a statistically significant difference at a very high confidence level. KMO (Kaiser-Meyer-Olkin) is a statistic used to measure whether the data is suitable for factor analysis. It is used to evaluate the partial correlation between variables to determine whether the data is suitable for factor analysis or other related analyses.

© 2025 AESS Publications. All Rights Reserved.

Validation results showed that participants' average scores for teamwork skills and critical thinking were 17.0 (SD = 1.81) and 17.28 (SD = 1.78), respectively. Additionally, Cronbach's alpha and KMO tests were conducted to validate the reliability and validity of the scales. The scales' Cronbach's alpha coefficients were 0.782 and 0.825 and their KMO values were 0.801 and 0.795 indicating good internal consistency and validity.

3.8. Research Instruments

3.8.1. Teamwork Skills Assessment Scale

The teamwork skills assessment scale used in this study was developed to measure the performance of the students in mathematics classes at the fourth grade. The scale includes five dimensions: communication, collaboration, leadership, problem-solving, and flexibility. Each of these dimensions is assigned with point values, going from 1 to 5, where 1 is the sign of bad performance, and 5 is great performance.

For example, a score of 1 in communication means rarely communicating with team members and a score of 5 means the ability to communicate ideas and to stimulate the team members effectively. The study tackles the concept of the scale of measurement as it appears to be based on Tuckman's team development theory and Salas's analysis of teamwork. In the team development process, Tuckman (1965) indicated that a team goes through a journey where it starts with its formation followed by storming, norming, and performing which entails these necessary skills: communication and collaboration. Salas, Sims, and Burke (2005) proposed that teamwork encompasses the following five core elements: team leadership, mutual performance monitoring, backup behavior adaptability, and team orientation.

One of these the "flexibility" dimension as in Salas's perspective. The "flexibility" dimension in this study corresponds to Salas's definition of "adaptability," which focuses on the fact that the person can change the strategy and adapt to new conditions.

3.8.2. Critical Thinking Assessment Scale

The key instrument for evaluating the critical thinking skills of fourth graders during mathematics lessons in this study is the critical thinking assessment scale developed for that purpose. The scale consists of four assessment components which are as follows: problem-solving, reasoning, creativity, and the meta-cognitive aspect. Each dimension is rated from 1 to 5 where 1 indicates weak ability and 5 indicates outstanding performance. For example, in problem-solving skills, a score of 1 indicates difficulty understanding problem requirements while a score of 5 reflects precise use of advanced strategies to solve complex problems. The design of the scale is based on Ennis's research on critical thinking assessment and Paul and Elder's (2019) theory of critical thinking elements. Ennis (1993) emphasized that critical thinking is fundamentally about clarifying issues, reasoning effectively, and systematically evaluating information.

Paul and Elder (2019) proposed that critical thinking involves the following nine elements: purpose, question, information, reasoning, concepts, assumptions, perspectives, interpretations, implications, and standards with particular emphasis on the importance of creativity and meta-cognition.

3.9. Data Collection

This study collected assessment data twice: the first immediately after the initial teaching session and the second after the final teaching session. Detailed collection methods are shown in Figure 1.

3.10. Data Analysis

3.10.1. Homogeneity Testing

This study used an independent samples t-test to statistically analyze the pre-test scores of both groups in teamwork and critical thinking skills to ensure baseline consistency between the experimental and control groups

© 2025 AESS Publications. All Rights Reserved.

and guarantee comparability of subsequent results. According to Table 5, the t-test results (t=1.76, 0.48; p>0.05) did not reach statistical significance indicating that the pre-test differences between the two groups were negligible.

Table 5. Comparison of pre-test.

Item classification	Groups	M	SD	t	df	P
Teamwork skills	Experimental group	16 points	1.98	1.76	53	0.084
	Control group	16.9 points	1.90			
Critical thinking	Experimental group	16.35 points	1.74	0.48	53	0.632
	Control group	16.58 points	1.77			

3.10.2. Comparative Analysis

A paired samples t-test was used in this study to analyze the pre- and post-test scores of the experimental group in teamwork skills and critical thinking. This analysis tested the hypothesis: "Is there a significant difference in the teamwork skills and critical thinking among students engaged in the instructional approach based on project-based learning and inquiry-based learning before and after participation?"

An independent samples t-test was used in this study to analyze the post-test scores of the experimental and control groups in teamwork skills and critical thinking. This analysis tested the hypothesis: "Is there a significant difference in the teamwork skills and critical thinking between students engaged in the instructional approach based on project-based learning and inquiry-based learning compared to those participating in the traditional teaching approach?"

3.11. Ethical Affirmation

This research project, titled "*A Quasi-Experimental Study on Project-Based and Inquiry-Based Approaches in Fourth-Grade Mathematics: Effects on Teamwork Skills and Critical Thinking*," strictly adhered to ethical requirements and the Ethical Committee of Nakhon Phanom University, Thailand approved this study on November 5, 2024 (Ref. No.HE1168).

4. RESULTS

4.1. Hypothesis 1 Test

Is there a significant difference in the teamwork skills and critical thinking among students engaged in the instructional approach based on project-based learning and inquiry-based learning before and after participation?

Table 6. Comparison of pre-test and post-test in the experiment group.

Students' scores in different tests	M	SD	t	df	p
Pre-test of teamwork skills	16	1.98	-23.57	25	0.000*
Post-test of teamwork skills	19.41	1.86			
Pre-test of critical thinking	16.34	1.74	-25.15	25	0.000*
Post-test of critical thinking	19.97	3.03			

Note: * P<0.05.

A paired samples t-test was conducted on the pre- and post-test data of the experimental group to evaluate significant differences between the two assessments. According to Table 6, the paired t-test results indicate significant differences between the two tests, $t(25) = -23.57$ and -25.15, $p < 0.05$. Students' average scores in the second test showed significant improvement compared to the first test. According to Cohen's (1988) criteria, the mean differences (MD) were 3.41 and 3.63 with pooled standard deviations (SD) of approximately 1.92 and 2.39 and

© 2025 AESS Publications. All Rights Reserved.

effect sizes (d) of 1.78 and 2.00, respectively indicating large effect sizes. Therefore, students using project-based and inquiry-based learning performed significantly better in teamwork skills and critical thinking before the intervention.

4.2. Hypothesis 2 Test

Is there a significant difference in the teamwork skills and critical thinking between students engaged in the instructional approach based on project-based learning and inquiry-based learning compared to those participating in the traditional teaching approach?

Table 7. Comparison of post-test between two groups.

Item classification	Group	M	SD	t	df	p
Teamwork skills	Experimental group	19.41	1.86	-5.3	53	0.0012*
	Control group	17.62	2.02			
Critical thinking	Experimental group	19.97	1.88	-3.43	53	0.000*
	Control group	17.27	1.89			

Note: * P<0.05.

An independent samples t-test was conducted on the post-test data of the experimental and control groups to evaluate whether significant differences existed between the two groups. Table 7 shows that the independent t-test results for different teaching methods revealed significant differences, $t(53) = -5.3$ and -3.43, $p < 0.05$. The assessment scores of the experimental group were significantly higher than those of the control group. According to Cohen's (1988) criteria, the mean differences (MD) were 2.21 and 2.70 with pooled standard deviations (SD) of approximately 1.94 and 1.89, and effect sizes (d) of 0.93 and 1.43 indicating large effect sizes. Consequently, the involvement of project- and inquiry-based methods of learning was found to be superior to traditional education methods in enhancing students' mindsets and thought processing skills.

5. DISCUSSION

This research aimed to compare the effectiveness of merging project-based learning (PBL) and inquiry-based learning (IBL) to increase the teamwork skills and critical thinking of fourth-grade students in elementary math classrooms. Results showed a noticeable increase in the teamwork and critical thinking skills of students who incorporated PBL and IBL in comparison with traditional teaching methods. This is a fact that shows the trend towards experiential-based and story-centered teaching methodologies that lay emphasis on collaborating, communicating, and self-reflecting among students to develop leadership and problem-solving abilities.

The results of the present study are consistent with the previous literature to a significant extent, especially as social constructivism emphasises that such abilities are placed in real-life conversations and activities with peers. It argues that critical thinking is constructed- based on the verbal interactions with others and also oneself, as a cognitive skill (Kuhn, 2019; Tang et al., 2020). On the other hand, studies about the design of the curriculum centered on a problem-issue orientation and feedback mechanism have demonstrated to be effective in creating cooperative learning skills among the students (Barker, 2021; Schartel et al., 2021). The problem-oriented, inquiry-centered, and collaborative approach which consists of communication and reflection are all conceptually well-aligned with the above perspectives. Therefore, this paper demonstrated the proof for the relevance of PBL and IBL to the students' teamwork and critical thinking that were directed towards the previous practice research. For instance, Melguizo-Garín et al. (2022) and Cortázar et al. (2021) reported that the level of students' teamwork skills was significantly improved through the integrated adoption of PBL. In the same way, Huang (2022) and Pursitasari et al. (2020) affirmed the effectiveness of IBL as an integrative instructional strategy.

High-quality teaching requires students to talk about information relating to fact, emotion, and identity in digital media, which makes them able to go through the intricacies of the world (Chinn, Barzilai, & Duncan, 2021).

© 2025 AESS Publications. All Rights Reserved.

The major difference between the traditional teacher-centered instructional strategies in this study and the project and inquiry-based learning strategies is the high level of engagement of the students. For example, setting up project scenarios with close links to the students' lives can be seen as a very positive motivation-inspiring device. This approach adopts teams as learning units to expand the sharing as well as communication among students through the same team activities. It also features a further phased scheme of task deconstruction, breaking learning projects into several interconnected and gradually expanding stages, allowing learners to systematically achieve their learning objectives. Subsequently, the teachers, both of whom are the designers and facilitators of the learning activities become the ones leading the way as they expect the children to deliberate, chat, and think critically; thus, individuals need to be followed as the learning is going ahead.

In the recent years, the limits of a one teaching style approach have been acknowledged by the educational community. There is an emerging trend in favor of applying various teacher methodology strategies to enhance teaching outcome evaluation (Connolly, Logue, & Calderon, 2023; Sanchez-Gomez, 2022). Project-based learning highlights the understanding of knowledge by engaging yourself in the work; it is about facilitating the students to improve their practical and teamwork experience through learning by doing. As for inquiry-based learning, the process of developing students' rational logic, critical thinking, and creative science will be the aim of the lesson. However, the unique strengths of both are taken into account as a teaching method by combining the two approaches. The present study gives these approaches new empirical support and proves the utility of the blend of problem-based learning and inquiry-based learning method; hence teachers are well guided in the selection of the method. Nevertheless, the present research has some weaknesses such as the sample size being too small, the being distributed over a single geography, short- term for the implementation period as well as the teaching training being low. In the future research, we plan to analyze the enduring educational advantages of this PBL approach and then construct models that unite this method with IBL that are appropriate for the different levels of education and for the different subjects.

6. CONCLUSION

The current study investigated project-based learning and inquiry-based learning implications in fourth-grade classrooms for the elementary mathematics subject specifically focusing on teamwork skills and critical thinking. These results revealed that the students who participated in PBL and IBL together demonstrated significantly better team works and critical thinking skills than the ones in traditional classes. Thus, this research not only aligns with the previous studies on the efficiency of the integrated learning methods in preparing students for real-life challenges but also serves as an important resource for new studies concerning learning strategies. It is recommended that future research may focus on applying the strategies to different subjects while also assessing their long-term effects on learning outcomes due to the limitations of the study, including a relatively small sample size, geographical distribution in a single place, and the short implementation period.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethical Committee of the Nakhon Phanom University, Thailand has granted approval for this study (Ref. No. HE1168).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Acar, O. A., & Tuncdogan, A. (2019). Using the inquiry-based learning approach to enhance student innovativeness: A conceptual model. *Teaching in Higher Education*. https://doi.org/10.1080/13562517.2018.1516636

© 2025 AESS Publications. All Rights Reserved.

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *Sage Open*, *10*(3), 2158244020938702. https://doi.org/10.1177/2158244020938702

Artama, K. K. J., Budasi, I. G., & Ratminingsih, N. M. (2023). Promoting the 21st century skills using project-based learning. *Language Circle: Journal of Language and Literature*, *17*(2), 325-332. https://doi.org/10.15294/lc.v17i2.39096

Bakare, S. F., Ojulokunrin, R. W., Jagun, Z. T., Adedeji, O. O., & Olugbenga, A. (2020). The mediating impact of assessment process in the relationship between project-based learning and teamwork skills' development. *Journal of Management Info*, *7*(4), 248-258.

Barker, A. K. (2021). Developing teamwork skills in a course on ore deposits. *Mineralogia*, *52*(1), 43-48. https://doi.org/10.2478/mipo-2021-0005

Chinn, C. A., Barzilai, S., & Duncan, R. G. (2021). Education for a "post-truth" world: New directions for research and practice. *Educational Researcher*, *50*(1), 51-60. https://doi.org/10.3102/0013189x20940683

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Connolly, C., Logue, P. A., & Calderon, A. (2023). Teaching about curriculum and assessment through inquiry and problem-based learning methodologies: An initial teacher education cross-institutional study. *Irish Educational Studies*, *42*(3), 443-460. https://doi.org/10.1080/03323315.2021.2019083

Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). Promoting critical thinking in an online, project-based course. *Computers in Human Behavior*, *119*, 106705. https://doi.org/10.1016/j.chb.2021.106705

D'Alessio, F. A., Avolio, B. E., & Charles, V. (2019). Studying the impact of critical thinking on the academic performance of executive MBA students. *Thinking Skills and Creativity*, *31*, 275-283. https://doi.org/10.1016/j.tsc.2019.02.002

De Jong, T., Lazonder, A. W., Chinn, C. A., Fischer, F., Gobert, J., Hmelo-Silver, C. E., . . . Linn, M. C. (2023). Let's talk evidence–The case for combining inquiry-based and direct instruction. *Educational Research Review*, *39*, 100536. https://doi.org/10.1016/j.edurev.2023.100536

Dole, S., Bloom, L., & Kowalske, K. (2016). Transforming pedagogy: Changing perspectives from teacher-centered to learner-centered. *Interdisciplinary Journal of Problem-Based Learning*, *10*(1), 1. https://doi.org/10.7771/1541-5015.1538

Ennis, R. H. (1993). Critical thinking assessment. *Theory into Practice*, *32*(3), 179-186.

Geisinger, K. F. (2016). 21st century skills: What are they and how do we assess them? *Applied Measurement in Education*, *29*(4), 245-249. https://doi.org/10.1080/08957347.2016.1209207

Ghanizadeh, A., Al-Hoorie, A. H., Jahedizadeh, S., Ghanizadeh, A., Al-Hoorie, A. H., & Jahedizadeh, S. (2020). *Higher order thinking skills. In: Higher order thinking skills in the language classroom: A concise guide. Second language learning and teaching*. Cham: Springer. https://doi.org/10.1007/978-3-030-56711-8_1.

Huang, Y. (2022). Effectiveness of inquiry-based science laboratories for improving teamwork and problem-solving skills and attitudes. *Journal of Research in Science Teaching*, *59*(3), 329-357. https://doi.org/10.1002/tea.21729

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267-277.

Korkmaz, G., & Kalaycı, N. (2019). Theoretical foundations of project based curricula in higher education. *Cukurova University Faculty of Education Journal*, *48*(1), 236-274.

Kuhn, D. (2019). Critical thinking as discourse. *Human Development*, *62*(3), 146-164.

Lacerenza, C. N., Marlow, S. L., Tannenbaum, S. I., & Salas, E. (2018). Team development interventions: Evidence-based approaches for improving teamwork. *American Psychologist*, *73*(4), 517. https://doi.org/10.1037/amp0000295

Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research*, *86*(3), 681-718. https://doi.org/10.3102/0034654315627366

Lincă, F. I., Anghel, G. A., & Matei, F. L. (2023). Teamwork skills in the Romanian academic environment. *Journal of Education, Society & Multiculturalism*, *4*(2), 1-14. https://doi.org/10.2478/jesm-2023-0014

Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *Zdm*, *51*, 869-884. https://doi.org/10.1007/s11858-019-01100-5

© 2025 AESS Publications. All Rights Reserved.

Melguizo-Garín, A., Ruiz-Rodríguez, I., Peláez-Fernández, M. A., Salas-Rodríguez, J., & Serrano-Ibáñez, E. R. (2022). Relationship between group work competencies and satisfaction with project-based learning among university students. *Frontiers in Psychology, 13*, 811864. https://doi.org/10.3389/fpsyg.2022.811864

Nadurak, V. (2022). Critical thinking: Concepts and practice. Filosofiya osvity. *Filosofiya Osvity. Philosophy of Education, 28*(2), 129-147. https://doi.org/10.31874/2309-1606-2022-28-2-7

Nadurak, V. (2023). Dual-process theory and two types of metacognitive monitoring and control processes. *Integrative Psychological and Behavioral Science, 57*(4), 1273-1283. https://doi.org/10.1007/s12124-023-09771-2

Paul, R., & Elder, L. (2019). The miniature guide to critical thinking concepts and tools. In (pp. 37-47). Lanham, MD: Rowman & Littlefield.

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., . . . Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003

Pursitasari, I., Suhardi, E., Putra, A., & Rachman, I. (2020). Enhancement of student's critical thinking skill through science context-based inquiry learning. *Jurnal Pendidikan IPA Indonesia, 9*(1), 97-105. https://doi.org/10.15294/jpii.v9i1.21884

Rodríguez, G., Pérez, N., Núñez, G., Baños, J.-E., & Carrió, M. (2019). Developing creative and research skills through an open and interprofessional inquiry-based learning course. *BMC Medical Education, 19*, 1-13. https://doi.org/10.1186/s12909-019-1563-5

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a "big five" in teamwork? *Small Group Research, 36*(5), 555-599. https://doi.org/10.1177/1046496405277134

Sanchez-Gomez, C. A. (2022). Implementing a joint learning method (PBL and EBL) to innovate the development of mechanical engineering technical and non-technical skills. *International Journal of Mechanical Engineering Education, 50*(1), 176-196. https://doi.org/10.1177/0306419020950751

Schartel, D. S., Dawson, M., & Block, B. (2021). Teaching teamwork in the business school. *Journal of Education for Business, 96*(6), 381-386. https://doi.org/10.1080/08832323.2020.1840322

Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of problem-based learning combined with computer simulation on students' problem-solving and creative thinking skills. *International Journal of Instruction, 14*(3), 519-534.

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability, 12*(23), 10113. https://doi.org/10.3390/su122310113

Tang, T., Vezzani, V., & Eriksson, V. (2020). Developing critical thinking, collective creativity skills and problem solving through playful design jams. *Thinking Skills and Creativity, 37*, 100696. https://doi.org/10.1016/j.tsc.2020.100696

Tessier, V. (2021). *A model for learning teamwork skills.* Paper presented at the DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021), VIA Design, VIA University in Herning, Denmark. 9th-10th September 2021. https://doi.org/10.35199/EPDE.2021.5.

Trisdiono, H., Siswandari, S., Suryani, N., & Joyoatmojo, S. (2019). Multidisciplinary integrated project-based learning to improve critical thinking skills and collaboration. *International Journal of Learning, Teaching and Educational Research, 18*(1), 16-30. https://doi.org/10.26803/ijlter.18.1.2

Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychological Bulletin, 63*(6), 384. https://doi.org/10.1037/h0022100

Views and opinions expressed in this article are the views and opinions of the author(s), Asian Journal of Contemporary Education shall not be responsible or answerable for any loss, damage or liability etc. caused in relation to/arising out of the use of the content.

© 2025 AESS Publications. All Rights Reserved.