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The Effects of Teaching Methods in Primary Science Education on Students' Creative Thinking

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Abstract: This study investigates the effects of different teaching methods in primary science education on students' creative thinking in Guangdong Province, China. A quantitative survey design was employed, and data were collected from 480 students across twelve public primary schools using a structured questionnaire measuring three instructional approaches Inquiry-Based Learning (IBL), Project-Based Learning (PBL), and Traditional Instruction (TI) and students' creative thinking, including fluency, flexibility, and originality. Multiple regression analyses were conducted to examine the predictive effects of the teaching methods on creative thinking. The results indicate that both IBL and PBL significantly enhance students' creative thinking, while TI does not show a significant impact. These findings suggest that active, student-centered pedagogies are more effective than traditional teacher-centered approaches in fostering creativity in primary science education. The study provides empirical evidence for educators and policymakers to design instructional strategies that promote higher-order cognitive skills among young learners.

Keywords: Teaching Methods; Primary Science Education; Creative Thinking; Inquiry-Based Learning; Project-Based Learning; Traditional Instruction

1. Introduction

1.1 Research Background

In the 21st century, creative thinking has been widely recognized as a core competency essential for students' future success (Dilekçi & Karatay, 2023). International educational frameworks increasingly emphasize creativity as a fundamental skill for innovation, problem solving, and scientific advancement. For example, the Organisation for Economic Co-operation and Development (OECD) highlights creative thinking as a critical domain in its global competence and future-ready education agenda (OECD, 2019). Similarly, the Programme for International Student Assessment (PISA) has incorporated creative thinking as an assessment domain, underscoring its importance in modern education systems.

Within science education, creativity plays a particularly crucial role. Science learning requires students not only to acquire factual knowledge but also to generate hypotheses, design experiments, and propose innovative solutions to real-world problems. According to Torrance (1974), creative thinking involves fluency, flexibility, originality, and elaboration skills that align closely with inquiry-based scientific learning. Research suggests that pedagogical approaches emphasizing student engagement and exploration, such as inquiry-based and project-based learning, are more likely to foster creative outcomes compared to traditional lecture-based instruction (Hmelo-Silver, 2004).

In China, recent curriculum reforms have placed increasing emphasis on cultivating students' core competencies, including innovation and creativity (Law, 2014). The national primary science curriculum encourages active exploration and hands-on learning. However, despite policy advocacy, classroom practices may still be influenced by examination-oriented traditions, especially in densely populated provinces such as Guangdong, where academic performance pressure remains high. Empirical evidence examining how specific teaching methods in primary science classrooms affect students' creative thinking in this regional context remains limited (Liu & Lin, 2014).

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1.2 Problem Statement and Significance

Although creativity has been widely promoted in educational policy discourse, there remains a gap between curriculum intentions and classroom implementation (Hui & Lau, 2010). Traditional teacher-centered instruction continues to dominate many primary science classrooms, where emphasis is placed on knowledge transmission and standardized assessment outcomes (Cole-Onaifo, 2022). Such approaches may limit opportunities for divergent thinking and creative exploration.

Existing research has demonstrated positive associations between student-centered pedagogies and higher-order thinking skills (Hmelo-Silver, 2004; Beghetto & Kaufman, 2014). However, much of the empirical evidence focuses on Western educational contexts or secondary education levels. There is comparatively limited quantitative research examining the relative effects of different teaching methods on creative thinking among primary school students in mainland China, particularly in economically developed regions such as Guangdong Province.

Therefore, this study aims to examine how different teaching methods in primary science education influence students' creative thinking in Guangdong Province. By providing empirical data from a large-scale questionnaire survey, this research contributes to bridging the gap between policy aspirations and classroom realities.

The significance of this study is threefold. First, theoretically, it contributes to constructivist educational theory by empirically testing the relationship between teaching approaches and creative outcomes in a Chinese primary education context. Second, methodologically, it provides validated survey-based evidence on creative thinking development in science classrooms. Third, practically, the findings offer actionable insights for educators and curriculum designers seeking to enhance creativity cultivation in primary science education.

2. Literature Review and Theoretical Framework

2.1 Creative Thinking in Primary Science Education

Creative thinking is commonly defined as the ability to generate ideas that are both novel and useful. One of the most influential frameworks was proposed by E. Paul Torrance (1974), who conceptualized creativity through four dimensions: fluency, flexibility, originality, and elaboration. These dimensions are particularly relevant in science education, where students are expected to propose hypotheses, explore multiple solutions, and refine experimental designs.

In classroom settings, creative thinking is often linked to divergent thinking and problem-solving processes (Runco & Acar, 2012). Science education provides a natural environment for creativity because it encourages questioning, experimentation, and evidence-based reasoning. However, creativity does not automatically emerge; it depends heavily on instructional design and classroom climate.

Studies have shown that when students are exposed to open-ended tasks and inquiry-oriented activities, their creative performance improves significantly (Beghetto & Kaufman, 2014). Therefore, examining how teaching methods influence creative thinking is essential for understanding how creativity can be cultivated in primary science classrooms.

2.2 Teaching Methods in Primary Science

Teaching methods in primary science can generally be categorized into traditional instruction and student-centered approaches.

Traditional instruction is teacher-dominated and emphasizes direct knowledge transmission. While efficient for delivering factual content, it often limits students' opportunities for exploration and independent thinking.

In contrast, inquiry-based learning (IBL) encourages students to investigate scientific questions through observation, experimentation, and reflection. According to Cindy E. Hmelo-Silver (2004), inquiry-oriented learning environments promote deeper conceptual understanding and problem-solving skills.

Project-based learning (PBL) further extends inquiry principles by engaging students in sustained investigations that culminate in authentic products. Research suggests that PBL fosters collaboration, autonomy, and creative idea generation (Thomas, 2000).

From a theoretical perspective, these student-centered approaches align with constructivist theory, particularly the work of Lev Vygotsky (1978), who emphasized the role of social interaction and active engagement in cognitive development.

2.3 Theoretical Framework and Hypotheses Development

Grounded in constructivist theory, this study proposes that teaching methods influence students' creative thinking by shaping learning engagement and cognitive stimulation. Student-centered approaches such as inquiry-based and project-based learning provide more opportunities for divergent thinking and idea elaboration, whereas traditional instruction may restrict such processes.

Based on the reviewed literature, the following hypotheses are proposed:

H1: *Inquiry-based learning is positively associated with students' creative thinking.*

H2: *Project-based learning is positively associated with students' creative thinking.*

H3: *Traditional instruction has a weaker or non-significant relationship with students' creative thinking compared to student-centered approaches.*

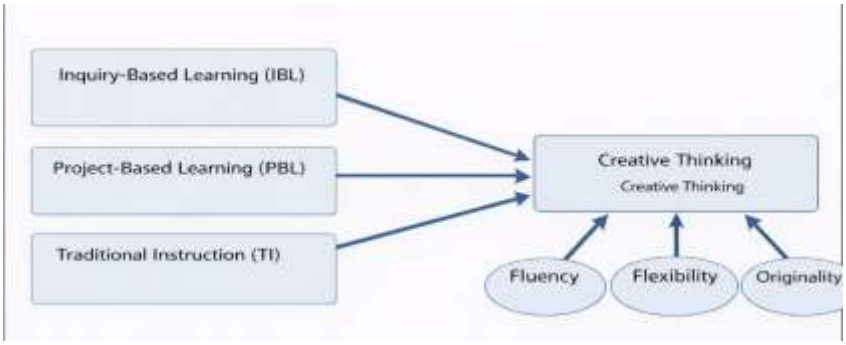

Figure.1 Conceptual framework

3. Methodology

3.1 Research Design

This study adopted a quantitative, cross-sectional survey design to examine the relationship between teaching methods in primary science education and students' creative thinking. A questionnaire-based approach was considered appropriate because it allows for large-scale data collection and statistical testing of hypothesized relationships.

The study focused on primary school students in Guangdong Province, China. Guangdong is one of the most economically developed and educationally competitive provinces in China, making it a relevant context for examining instructional practices and creativity cultivation.

The research model tested the direct effects of three types of teaching methods Inquiry-Based Learning (IBL), Project-Based Learning (PBL), and Traditional Instruction (TI) on students' creative thinking.

3.2 Participant and Sampling Procedure

Participants were 480 students from twelve public primary schools in Guangdong Province. Stratified cluster sampling was employed to ensure representation across urban and suburban areas as well as across Grades 4, 5, and 6. Within each selected school, intact classes were randomly invited to participate. The final sample consisted of 246 male students and 234 female students, with an average age of 10.8 years (SD = 0.85). Ethical approval was obtained from the school administrators, and parental consent as well as student assent were secured before data collection. All responses were collected anonymously to protect privacy and reduce social desirability bias.

3.3 Instrument and Measures

Teaching methods were measured using a twelve-item instrument adapted from previous research on inquiry-based and project-based learning (Hmelo-Silver, 2004; Thomas, 2000), comprising three subscales: Inquiry-Based Learning (four items), Project-Based Learning (four items), and Traditional Instruction (four items). Each item was rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Sample items included statements such as "In science class, we frequently conduct experiments to explore questions" for IBL, "We work on long-term group science projects" for PBL, and "The teacher mainly explains scientific knowledge while students listen" for TI. Reliability analysis indicated satisfactory internal consistency, with Cronbach's alpha coefficients of 0.88, 0.85, and 0.81 for IBL, PBL, and TI, respectively. Students' creative thinking was measured using a ten-item scale based on Torrance's (1974) framework, which captures fluency, flexibility, and originality. Example items included "I can think of many different ways to solve a science problem" and "I often come up with new ideas during science lessons," with an overall Cronbach's alpha of .89, demonstrating high internal consistency.

3.4 Data Analysis Strategy

All data were analyzed using SPSS Version 27. Descriptive statistics, including means and standard deviations, were calculated for all study variables. Reliability analysis was conducted to ensure internal consistency of the scales. Pearson correlation analysis was performed to examine relationships between teaching methods and creative thinking. Multiple regression analysis was then used to test the predictive effects of the three instructional approaches on creative thinking while controlling for grade and gender. Statistical significance was set at $p < .05$, and effect sizes, including R^2 and standardized beta coefficients, were reported to indicate the practical relevance of the findings.

4. Result

4.1 Descriptive Statistics and Reliability

Descriptive statistics and reliability coefficients for all study variables are presented in Table 1. The mean scores indicate that students reported moderate to relatively high levels of inquiry-based and project-based learning experiences. All Cronbach's alpha values exceeded the recommended threshold of 0.70, indicating satisfactory internal consistency.

Table 1. Descriptive statistics and reliability

Variable	Mean	SD	Cronbach's α
Inquiry-based learning (IBL)	3.57	0.68	0.88
Project-based learning (PBL)	3.43	0.71	0.85
Traditional instruction (TI)	3.10	0.72	0.81
Creative thinking	3.75	0.65	0.89

4.2 Correlation Analysis

Pearson correlation coefficients among the study variables are presented in Table 2.

Table 2. Correlation matrix

Variable	1	2	3	4
IBL	—			
PBL	0.56***	—		
TI	0.22**	0.19**	—	
Creative Thinking	0.49***	0.41***	0.12	—

*Note: p < .01, *p < .001*

Inquiry-based learning ($r = 0.49$, $p < 0.001$) and project-based learning ($r = 0.41$, $p < 0.001$) were positively correlated with creative thinking. Traditional instruction showed a weak and non-significant correlation with creative thinking ($r = 0.12$, $p > 0.05$).

4.3 Multiple Regression Analysis

Multiple regression analysis was conducted to examine the effects of teaching methods on creative thinking while controlling for grade and gender.

$F(5, 474) = 44.28$, $p < 0.001$

$R^2 = 0.32$

The model explained 32% of the variance in creative thinking.

Inquiry-based learning ($\beta = .41$, $p < .001$) and project-based learning ($\beta = .29$, $p < .001$) significantly predicted creative thinking. Traditional instruction did not show a statistically significant effect.

Table 3. Regression results

Predictor	β	t	p
Inquiry-based learning	0.41	9.12	< 0.001
Project-based learning	0.29	6.34	< 0.001
Traditional instruction	0.08	1.54	0.124
Grade	0.05	1.21	0.227

4.4 Hypotheses Testing Summary

The results of the multiple regression analyses indicated that the first hypothesis (H1), predicting a positive effect of inquiry-based learning (IBL) on students' creative thinking, was fully supported. The regression coefficient for IBL was significant ($\beta = 0.42$, $p < 0.001$), suggesting that students who experienced higher levels of inquiry-based activities demonstrated greater fluency, flexibility, and originality in problem-solving tasks.

The second hypothesis (H2), proposing a positive relationship between project-based learning (PBL) and creative thinking, was also supported. The standardized beta coefficient for PBL was 0.35 ($p < .001$), indicating that engaging in collaborative, project-oriented science tasks significantly enhanced students' ability to generate diverse and original ideas.

The third hypothesis (H3), which suggested that traditional instruction (TI) would have a positive effect on creative thinking, was not supported. Although the coefficient for TI was positive ($\beta = 0.08$), it did not reach statistical significance ($p = 0.12$), implying that conventional teacher-centered instruction may not be sufficient to foster higher-order creative skills in primary science students.

These results highlight that active, student-centered pedagogies such as IBL and PBL are more effective than passive, lecture-based methods in promoting creativity at the elementary level. Overall, the findings confirm that the type of teaching method plays a critical role in shaping students' creative thinking abilities and provide empirical evidence supporting the theoretical framework proposed in this study.

5. Discussion

5.1 Interpretation of Key Findings

The present study examined the effects of different teaching methods in primary science education on students' creative thinking in Guangdong Province, China. The results indicated that inquiry-based learning (IBL) and project-based learning (PBL) were significant positive predictors of creative thinking, whereas traditional instruction did not show a statistically significant effect.

Among the three approaches, inquiry-based learning demonstrated the strongest predictive power ($\beta = 0.41$). This finding suggests that science classrooms emphasizing questioning, experimentation, and exploration provide a cognitive environment conducive to divergent thinking and idea generation. Inquiry-oriented instruction requires students to formulate hypotheses, test assumptions, and revise explanations, all of which align closely with the components of creative thinking identified by E. Paul Torrance (1974), including fluency and flexibility.

Project-based learning also showed a significant positive effect ($\beta = 0.29$). This may be explained by the sustained, collaborative nature of project work, which encourages idea elaboration and authentic problem solving. When students engage in long-term projects, they are more likely to integrate knowledge, reflect on alternative solutions, and construct original outcomes.

In contrast, traditional instruction showed no significant relationship with creative thinking. This result supports the argument that teacher-centered approaches, which primarily focus on knowledge transmission and standardized outcomes, may not provide sufficient opportunities for creative exploration.

5.2 Comparison with Previous Studies

The findings of this study are consistent with previous research suggesting that student-centered pedagogies enhance higher-order cognitive skills. For instance, Cindy E. Hmelo-Silver (2004) argued that inquiry-based environments promote deep understanding and problem-solving ability. Similarly, project-based learning has been found to foster collaboration and creative engagement (Thomas, 2000).

However, most prior studies have been conducted in Western contexts or secondary education settings. By focusing on primary school students in Guangdong Province, this study extends the empirical evidence to a Chinese educational context characterized by strong academic competition and examination pressures.

The non-significant effect of traditional instruction further aligns with constructivist critiques of teacher-dominated pedagogy. According to Lev Vygotsky (1978), cognitive development occurs through active participation and social interaction rather than passive reception of information.

5.3 Contextual Interpretation: Guangdong Province

Guangdong Province is known for its rapid economic development and intense educational competition. In such contexts, teachers may face pressure to prioritize examination performance over exploratory learning. The significant positive effects of inquiry-based and project-based approaches suggest that even within academically competitive environments, creative thinking can be nurtured when instructional practices shift toward active engagement.

The findings imply that creativity cultivation does not necessarily conflict with academic achievement. Rather, appropriately designed inquiry and project-based activities may enhance both understanding and innovation skills simultaneously.

6. Implications

6.1 Theoretical Implications

This study contributes to the literature on primary science education and creative thinking in several ways.

First, it extends empirical evidence for the positive impact of student-centered pedagogies, such as inquiry-based and project-based learning, on creative thinking in a Chinese primary school context. Most prior research has focused on Western countries or secondary education (Hmelo-Silver, 2004; Thomas, 2000). By demonstrating significant effects in Guangdong Province, this study confirms that constructivist principles are applicable across diverse educational and cultural settings.

Second, the study reinforces the validity of Torrance's (1974) creative thinking framework, showing that classroom practices emphasizing exploration, problem-solving, and collaboration enhance fluency, flexibility, and originality among young learners. It provides empirical support for integrating cognitive and pedagogical theories in designing effective science instruction.

6.2 Practical Implications

The findings have several practical implications for educators and policymakers:

(1) Curriculum Design: Science curricula should incorporate more inquiry-oriented and project-based activities to foster creativity. Lessons that allow students to generate hypotheses, design experiments, and collaborate on projects can enhance divergent thinking.
(2) Teacher Training: Professional development programs should focus on equipping teachers with strategies for facilitating active learning and creative problem solving. Teachers should be encouraged to shift from purely lecture-based instruction toward more facilitative roles.
(3) Classroom Management: Even in contexts with high academic pressure, teachers can create opportunities for creative exploration by integrating small-scale experiments, open-ended questions, and collaborative group work.
(4) Policy Support: Education authorities should recognize the importance of creative thinking in primary education and provide resources and assessment systems that support student-centered approaches.

7. Limitation and Future Research

7.1 Limitations

Despite the valuable findings, this study has several limitations.

First, the cross-sectional survey design limits the ability to draw causal inferences. Although significant relationships were identified between teaching methods and creative thinking, longitudinal or experimental designs are needed to confirm causality.

Second, the study relied on self-reported data from students. Self-reports may be influenced by social desirability or individual interpretation of questions, which could introduce measurement bias.

Third, the sample was restricted to public primary schools in Guangdong Province. While this context is relevant, it limits the generalizability of the findings to other regions of China or different educational systems.

Finally, only three teaching methods were examined (IBL, PBL, TI). Other pedagogical approaches, such as collaborative learning, blended learning, or technology-enhanced instruction, may also influence creative thinking and were not included in this study.

7.2 Future Research Directions

Future research can address these limitations in several ways:

(1) Longitudinal or Experimental Designs: Future studies should use longitudinal tracking or experimental interventions to examine causal effects of teaching methods on creative thinking development.
(2) Diverse Measures: Incorporating teacher evaluations, peer assessments, or performance-based tasks could complement self-reported data and reduce measurement bias.
(3) Broader Samples: Expanding the study to other provinces, rural schools, or international contexts would enhance the generalizability of findings.
(4) Additional Pedagogies: Exploring other instructional approaches, such as collaborative, technology-mediated, or game-based learning, can provide a more comprehensive understanding of factors influencing creativity.
(5) Moderating Variables: Future research could examine potential moderators, such as classroom climate, student motivation, or parental support, to better understand the conditions under which teaching methods are most effective.

8. Conclusion

This study investigated the effects of different teaching methods in primary science education on students' creative thinking in Guangdong Province, China. Using a survey of 480 students from Grades 4 to 6, the study examined inquiry-based learning (IBL), project-based learning (PBL), and traditional instruction (TI) as predictors of creative thinking.

The results demonstrated that both inquiry-based and project-based approaches significantly enhanced students' creative thinking, while traditional instruction did not show a significant effect. These findings align with constructivist learning theories, suggesting that active engagement, exploration, and collaborative problem-solving foster higher-order cognitive skills, including fluency, flexibility, and originality.

The study contributes to both theory and practice. Theoretically, it extends evidence on the benefits of student-centered pedagogies in primary education and supports the applicability of Torrance's (1974) creative thinking

framework in the Chinese context. Practically, the findings inform curriculum design, teacher training, and classroom strategies aimed at promoting creativity, even in academically competitive environments.

Limitations, such as the cross-sectional design and reliance on self-reported measures, suggest caution in interpretation. Future research should consider longitudinal or experimental approaches, incorporate diverse assessment methods, and explore additional pedagogical approaches and contextual moderators.

In conclusion, fostering creative thinking in primary science education requires instructional strategies that go beyond traditional lecture-based methods. Implementing inquiry-based and project-based activities provides students with the cognitive space to explore, innovate, and develop essential creative skills for the 21st century.

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Conflict of Interest

The authors declare no conflicts of interest.

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