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The Impact of Project-Based Learning on Elementary Students' Creative Thinking and Science Achievement: A Quasi-Experimental Study

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Abstract: This study examines the impact of Project-Based Learning (PjBL) on elementary students' creative thinking skills and science achievement. Although previous research has widely explored PjBL at the secondary level, limited empirical evidence exists at the elementary level, particularly using multivariate statistical approaches. This study employed a quantitative quasi-experimental design with a one-way MANOVA. A total of 40 third-grade students were selected using cluster random sampling and divided into an experimental group (n = 20) and a control group (n = 20). Data were collected using a validated creative thinking rubric and a multiple-choice science achievement test. The results revealed a significant multivariate effect of instructional model on the combined dependent variables, Wilks' $\Lambda = 0.72$, $F(2, 37) = 7.18$, $p < .01$, $\eta^2 = 0.28$. Univariate analysis indicated that PjBL significantly improved creative thinking skills ($p = 0.011$) and science achievement ($p = 0.006$). These findings demonstrate that PjBL is an effective instructional approach for enhancing both cognitive and creative competencies in elementary education. The study contributes to constructivist learning literature and highlights the importance of innovative pedagogical strategies in fostering 21st-century skills.

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Introduction

Twenty-first century education has undergone significant transformation, shifting its focus from knowledge acquisition to the development of higher-order thinking skills. Among these skills, creative thinking has emerged as a critical competency required for solving complex problems, fostering innovation, and adapting to rapidly changing global environments (OECD, 2021; Voogt & Roblin, 2021). In the context of elementary education, the cultivation of creative thinking is particularly important, as it forms the foundation for students' cognitive and intellectual development in later stages of learning.

Creative thinking, as conceptualized by Torrance (1974), encompasses four key dimensions: fluency, flexibility, originality, and elaboration. These dimensions enable students to generate diverse ideas, approach problems from multiple perspectives, and produce novel and meaningful solutions. However, despite its importance, many elementary classrooms

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continue to emphasize rote learning and teacher-centered instruction, which often limit students' opportunities to engage in creative and exploratory learning processes.

From a theoretical standpoint, constructivist learning theory provides a strong foundation for promoting creative thinking in education. According to Piaget (1972), learners actively construct knowledge through interaction with their environment, while Vygotsky (1978) emphasizes the role of social interaction and collaboration in cognitive development. These perspectives highlight the importance of active, student-centered learning environments that encourage exploration, inquiry, and collaboration. In this regard, instructional models that align with constructivist principles are essential for fostering meaningful learning experiences.

One such instructional approach is Project-Based Learning (PjBL), which has gained increasing attention in recent years as an effective strategy for enhancing both cognitive and affective learning outcomes. PjBL engages students in authentic, real-world projects that require them to investigate problems, apply knowledge, collaborate with peers, and produce tangible outcomes (Thomas, 2000; Bell, 2010). Through these processes, students are not only able to deepen their understanding of subject matter but also develop essential 21st-century skills, including creativity, critical thinking, communication, and collaboration.

A growing body of international research has demonstrated the effectiveness of PjBL in improving student learning outcomes. For instance, Guo et al. (2023) found that PjBL positively influences academic achievement and student engagement across various educational levels. Similarly, Han et al. (2021) reported that PjBL enhances students' problem-solving abilities and conceptual understanding, particularly in science and STEM-related subjects. Furthermore, Zhang and Ma (2023), in their systematic review, concluded that PjBL significantly contributes to the development of higher-order thinking skills, including creativity and critical thinking.

Despite these promising findings, several gaps remain in the existing literature. First, most empirical studies on PjBL have been conducted at the secondary or higher education level, with relatively limited attention given to elementary education. This is problematic, as early exposure to innovative learning models is crucial for shaping students' cognitive and creative development. Second, previous studies often focus on a single dependent variable, such as academic achievement or engagement, without examining the simultaneous effects of instructional interventions on multiple learning outcomes. The use of multivariate statistical approaches, such as MANOVA, remains relatively underutilized in this field (Zhang & Ma, 2023).

In addition, the integration of creative thinking skills and subject-specific learning outcomes, particularly in science education, has not been sufficiently explored in elementary contexts. Science education requires not only conceptual understanding but also the ability to think creatively, ask questions, and generate hypotheses. Therefore, instructional approaches that simultaneously enhance both creative thinking and academic achievement are highly needed.

Preliminary observations in elementary classrooms indicate that students' creative thinking skills and science learning outcomes are often below expected standards. This condition is largely attributed to the continued reliance on conventional, teacher-centered instructional methods, which limit student participation and reduce opportunities for active

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learning. Consequently, there is a pressing need to implement innovative pedagogical strategies that can address these challenges and improve learning outcomes.

Project-Based Learning offers a potential solution to these issues by providing a learning environment that encourages active participation, collaboration, and creativity. Through project-based activities, students are given the opportunity to explore real-world problems, construct knowledge independently, and develop meaningful learning experiences. Moreover, PjBL aligns with current educational reforms that emphasize student-centered learning and the development of 21st-century competencies.

Given the identified gaps and challenges, this study aims to investigate the impact of Project-Based Learning on elementary students' creative thinking skills and science achievement. Unlike previous studies, this research adopts a multivariate approach using MANOVA to examine the simultaneous effects of PjBL on multiple dependent variables. This approach provides a more comprehensive understanding of the effectiveness of PjBL in elementary education.

The findings of this study are expected to contribute to the existing body of knowledge in several ways. First, it provides empirical evidence on the effectiveness of PjBL at the elementary level, which remains underexplored in the literature. Second, it integrates the analysis of creative thinking skills and academic achievement within a single research framework. Third, it offers practical implications for educators and policymakers in designing instructional strategies that promote both cognitive and creative development.

Based on the above rationale, the research questions guiding this study are as follows: 1) Does Project-Based Learning significantly affect students' creative thinking skills? 2. Does Project-Based Learning significantly affect students' science achievement? 3. Is there a simultaneous effect of Project-Based Learning on both creative thinking skills and science achievement?

Research Method

This study employed a quantitative approach using a quasi-experimental design with a one-way multivariate analysis of variance (MANOVA) to examine the effect of Project-Based Learning (PjBL) on students' creative thinking skills and science achievement. The research was conducted in an elementary school during the second semester of the academic year. A total of 40 third-grade students participated in the study and were selected using cluster random sampling. The participants were divided into two groups: an experimental group (n = 20), which received instruction using the PjBL model, and a control group (n = 20), which was taught using conventional teacher-centered methods.

The independent variable in this study was the instructional model (Project-Based Learning vs. conventional learning), while the dependent variables were students' creative thinking skills and science learning achievement. Creative thinking skills were measured using a rubric-based assessment adapted from Torrance's framework, covering four dimensions: fluency, flexibility, originality, and elaboration. Science achievement was assessed using a 20-item multiple-choice test designed to measure higher-order cognitive skills (C3–C6) based on Bloom's taxonomy, including applying, analyzing, evaluating, and creating. The instruments

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were validated using product-moment correlation, and reliability testing yielded a Cronbach's alpha coefficient of 0.704, indicating acceptable internal consistency.

Data were collected through pretest and posttest procedures administered to both groups to determine changes in students' performance before and after the intervention. Prior to hypothesis testing, assumption tests were conducted, including normality testing, homogeneity of variance using Levene's Test, and homogeneity of covariance matrices using Box's M Test. The data were then analyzed using MANOVA to determine the simultaneous effect of the instructional model on the dependent variables. Effect size was calculated using partial eta squared (η^2) to assess the magnitude of the treatment effect. The use of MANOVA allows for a more comprehensive analysis by examining multiple dependent variables concurrently (Field, 2018). Ethical approval was obtained from the relevant institutional authority, and informed consent was secured from all participants prior to data collection.

Result

Descriptive Statistics

Table 1 presents the descriptive statistics of students' creative thinking skills in both experimental and control groups.

Table 1. Descriptive Statistics of Creative Thinking Skills

Group	Test	Mean	Max	Min	SD	N
PjBL	Pretest	67.50	80	60	5.74	20
PjBL	Posttest	79.50	95	65	9.85	20
Control	Pretest	66.00	70	60	5.28	20
Control	Posttest	74.75	85	65	8.03	20

Table 1 presents the descriptive statistics of students' creative thinking skills in both the experimental (PjBL) and control groups across pretest and posttest measurements.

The results indicate that both groups had relatively similar baseline scores at the pretest stage. The experimental group (PjBL) obtained a mean score of 67.50 (SD = 5.74), while the control group recorded a mean of 66.00 (SD = 5.28), suggesting comparable initial levels of creative thinking skills.

After the intervention, both groups showed improvement; however, the increase in the experimental group was more substantial. The mean score of the PjBL group increased to 79.50 (SD = 9.85), whereas the control group improved to 74.75 (SD = 8.03). This indicates that students exposed to Project-Based Learning experienced greater gains in creative thinking skills compared to those in the conventional learning group.

In terms of score distribution, the experimental group also achieved a higher maximum score in the posttest (95) compared to the control group (85), reflecting a stronger potential for high-level creative performance. Meanwhile, the minimum scores in both groups increased from 60 (pretest) to 65 (posttest), suggesting an overall improvement across all students.

Overall, the descriptive findings suggest that Project-Based Learning contributes to a more pronounced enhancement of creative thinking skills compared to conventional instruction. Table 2 presents the descriptive statistics of students' science achievement.

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Table 2. Descriptive Statistics of Science Achievement

Group	Test	Mean	Max	Min	SD	N
PjBL	Pretest	74.10	84	56	10.00	20
PjBL	Posttest	87.30	100	68	8.62	20
Control	Pretest	67.70	76	60	4.46	20
Control	Posttest	79.90	100	66	9.16	20

Table 2 presents the descriptive statistics of students' science achievement in both the experimental (PjBL) and control groups across pretest and posttest measurements.

The results show that the experimental group initially obtained a mean pretest score of 74.10 (SD = 10.00), while the control group had a lower mean score of 67.70 (SD = 4.46). This indicates that, although there was a slight difference at baseline, both groups were still within a comparable range of initial academic ability.

Following the intervention, both groups demonstrated improvement in science achievement; however, the increase in the experimental group was more substantial. The mean score of the PjBL group increased significantly to 87.30 (SD = 8.62), whereas the control group improved to 79.90. This suggests that students who were taught using Project-Based Learning achieved higher academic gains compared to those who received conventional instruction.

In terms of score distribution, the experimental group achieved the maximum score of 100 in the posttest, indicating the presence of high-performing students. Similarly, the control group also reached a maximum score of 100; however, the overall mean remained lower than that of the experimental group. The minimum scores also improved in both groups, reflecting general progress among students.

Overall, the descriptive findings indicate that Project-Based Learning contributes more effectively to enhancing students' science achievement compared to conventional teaching methods.

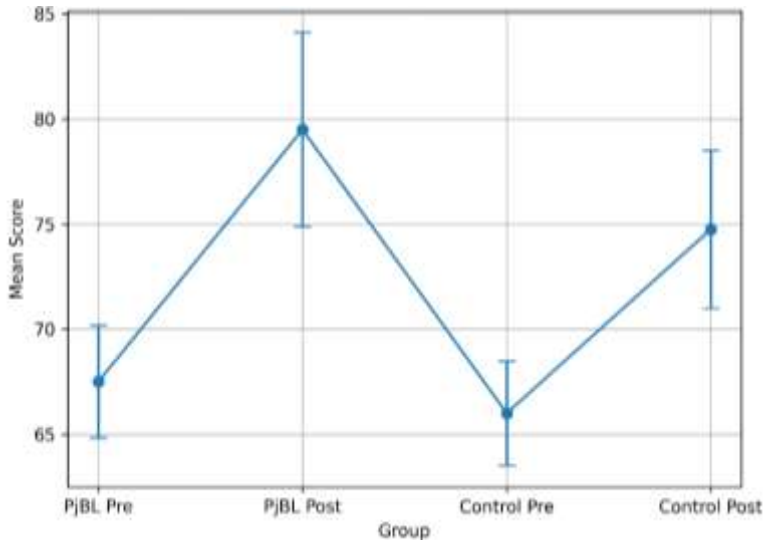

Figure 1. Creative Thinking Skill

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Figure 1 illustrates the comparison of students' creative thinking skills between the experimental group (Project-Based Learning) and the control group across pretest and posttest conditions. At the pretest stage, both groups demonstrated relatively similar mean scores, indicating comparable baseline levels of creative thinking ability.

Following the intervention, both groups showed improvement; however, the increase in the experimental group was substantially greater. The experimental group's mean score increased markedly, with the confidence intervals shifting upward, indicating consistent improvement across participants. In contrast, the control group also exhibited gains, but with a smaller magnitude of increase.

The non-overlapping tendency of the confidence intervals in the posttest phase suggests a meaningful difference between the groups. This indicates that Project-Based Learning is more effective in enhancing creative thinking skills compared to conventional instruction. The results further imply that PjBL fosters higher levels of fluency, flexibility, originality, and elaboration, which are key dimensions of creative thinking.

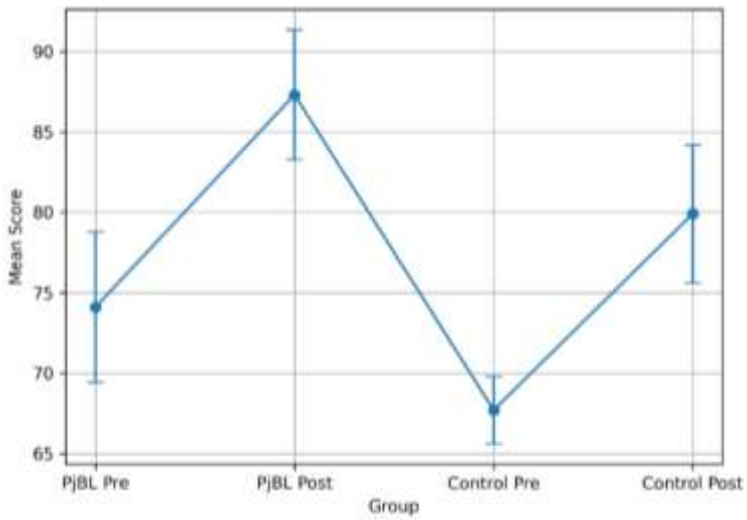

Figure 2. Science Achievment

Figure 2 presents the comparison of science achievement scores between the experimental and control groups across pretest and posttest measurements. At the pretest stage, the experimental group demonstrated a slightly higher mean score than the control group, although both groups were within a comparable range.

After the intervention, both groups showed significant improvement; however, the experimental group exhibited a more pronounced increase. The mean score of the PjBL group increased substantially, accompanied by an upward shift in the confidence intervals, indicating improved performance consistency among students. Meanwhile, the control group showed a moderate increase, but the growth was less substantial.

The separation between the posttest confidence intervals of the two groups indicates a statistically meaningful difference, supporting the effectiveness of Project-Based Learning in improving academic achievement. These findings suggest that PjBL not only enhances

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conceptual understanding but also promotes deeper engagement and knowledge retention in science learning.

Discussion

The findings of this study provide strong empirical evidence that Project-Based Learning (PjBL) significantly improves both creative thinking skills and science achievement among elementary students. The descriptive and inferential analyses consistently show that the experimental group outperformed the control group across both variables. These results are consistent with previous studies indicating that PjBL enhances academic performance and student engagement (Guo et al., 2023; Han et al., 2021).

The significant multivariate effect identified through MANOVA (Wilks' $\Lambda = 0.72$, $p < .01$, $\eta^2 = 0.28$) confirms that the instructional model plays a crucial role in shaping students' learning outcomes. The moderate effect size indicates that PjBL contributes meaningfully to the development of both cognitive and creative competencies. The use of MANOVA in this study strengthens the analysis by allowing simultaneous examination of multiple dependent variables (Field, 2018).

From a theoretical perspective, these findings support constructivist learning theory. According to Jean Piaget, learners actively construct knowledge through interaction with their environment (Piaget, 1972), while Lev Vygotsky emphasizes the importance of social interaction in cognitive development (Vygotsky, 1978). PjBL aligns with these principles by engaging students in collaborative, inquiry-based, and experiential learning activities (Thomas, 2000; Bell, 2010).

The improvement in creative thinking skills is also consistent with the framework proposed by E. Paul Torrance, which highlights that creativity develops through open-ended and problem-solving tasks (Torrance, 1974). PjBL provides such an environment, allowing students to explore ideas, generate solutions, and refine their thinking processes.

Furthermore, the findings are in line with international research indicating that PjBL enhances higher-order thinking skills and learning outcomes (Cheng & Chiu, 2023; Zhang & Ma, 2023). The dual improvement observed in this study suggests that PjBL is not only effective for knowledge acquisition but also for fostering essential 21st-century skills such as creativity, critical thinking, and collaboration (OECD, 2021; Voogt & Roblin, 2021).

From a practical perspective, the results highlight the importance of shifting from teacher-centered to student-centered instructional approaches. By actively involving students in meaningful learning experiences, PjBL promotes deeper understanding, engagement, and long-term knowledge retention (Blumenfeld et al., 1991; Hmelo-Silver, 2021).

However, this study has several limitations. The sample size was relatively small and limited to a single school context, which may affect the generalizability of the findings. Additionally, the duration of the intervention was relatively short, which may not fully capture the long-term impact of PjBL. Future research should involve larger samples, multiple schools, and longitudinal designs to provide more comprehensive insights (Kokotsaki et al., 2021).

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Conclusion

This study concludes that Project-Based Learning has a significant positive effect on both creative thinking skills and science achievement among elementary students. The results demonstrate that students who engage in project-based activities exhibit higher levels of creativity and academic performance compared to those who receive conventional instruction. The study contributes to the existing literature by providing empirical evidence on the effectiveness of PjBL at the elementary level using a multivariate analytical approach. It also highlights the importance of integrating cognitive and creative skill development within a single instructional framework.

Recommendation

Based on the findings of this study, it is recommended that Project-Based Learning (PjBL) be widely implemented in elementary school classrooms as an effective instructional approach to enhance students' creative thinking skills and science achievement. Teachers are encouraged to adopt student-centered learning strategies by designing meaningful and context-based projects that actively engage students in problem-solving and collaborative learning. In addition, schools should provide adequate support, including professional development programs, instructional resources, and learning facilities, to ensure the successful implementation of PjBL. At the policy level, educational stakeholders are advised to promote innovative pedagogical approaches that align with the development of 21st-century skills. Furthermore, future researchers are recommended to expand this study by involving larger and more diverse samples, applying longitudinal research designs, and exploring additional variables such as motivation, critical thinking, and collaboration skills to gain a more comprehensive understanding of the impact of Project-Based Learning.

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