*Journal of Elementary Education*
*Volume 36, No. 1, pp.01-26*
*June, 2026*

# Project-Based Steam Education and Collaborative Learning: Effects on Students' Creativity and Academic Achievement

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## Abstract

*In the 21st century, STEAM education plays a vital role in enhancing students' creativity and academic achievement by promoting interdisciplinary and active learning. However, limited quantitative research has examined the combined impact of Project-Based Learning (PBL) and collaborative learning within STEAM contexts. This study employed a quasi-experimental pre-test and post-test control group design involving 300 secondary school students (150 experimental, 150 control). Data were collected using a creativity test, academic achievement test, and structured questionnaires measuring PBL-STEAM engagement and collaborative learning. Statistical analyses, including t-tests, multiple regression, and two-way ANOVA, were conducted. The findings revealed that both PBL-STEAM and collaborative learning significantly improved creativity and academic achievement, with a strong interaction effect indicating enhanced outcomes when both strategies were integrated. These results highlight the effectiveness of combining active and collaborative pedagogies in improving educational quality. The study contributes to achieving Sustainable Development Goal 4 (Quality Education) by promoting innovative and student-centered learning approaches.*

**Keywords:** STEAM Education, Project-Based Learning, Collaborative Learning, Creativity, Academic Achievement, Quantitative Research

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## Introduction

The 21st century education system is shifting towards involving the development of critical thinking, creativity, communication, and collaboration skills that will equip learners with complexities of the global world (Aguilera & Ortiz-Revilla, 2021; Wised & Inthanon, 2024). STEAM education has been at the center of this evolution as it incorporates science, technology, engineering, arts, and mathematics into a holistic learning model (Filipe et al., 2024; Andriyani, 2024). It facilitates interdisciplinary awareness and motivates students to implement knowledge in practical scenarios (Liston et al., 2022; Khalid, Malik, & Malik, 2023). The modern classroom thus becomes no longer teacher-centered but rather learners-centered learning environments where students actively build knowledge (Wilson et al., 2021).

In this paradigm, Project-Based Learning (PBL) can be viewed as a potent instructional method that can stimulate students to solve real-world problems by inquiring, designing, and innovating (Kuo, 2024; Lu et al., 2021). PBL increases the interest of students and enables them to acquire better conceptual abilities by connecting theory and practice (Sucilestari et al., 2023). Previous research indicated that PBL enhanced the motivation levels, problem-solving abilities, and academic performance of students (Mubarok et al., 2025; Suradika et al., 2023).

Equally, Collaborative learning is an instructional strategy that is widely known and acclaimed as a means of interaction, shared responsibility, and collective knowledge construction (Nungu et al., 2023). It helps students to learn through peers, negotiate meaning, and build social and cognitive competencies (Zaqiah et al., 2024). It was found that collaborative learning facilitated communication, as well as fostered higher-order thinking (Ellianawati et al., 2025). Integrated into the context of STEAM, both PBL and collaboration can provide dynamic learning environments that can support creativity and academic success (Chang et al., 2023; Wahyudi et al., 2024).

Although the empirical advantages of PBL and collaborative learning have been identified, their combination in STEAM education is still underrepresented in empirical studies (Agung et al., 2025; Surur et al., 2025). Various studies have been conducted to look at these methods individually but there is a lack of information that can prove how using these methods together can impact students in terms of creativity and academic performance at the same time (Chudhry & Malik, 2019). In addition, the existing results tend to indicate inconsistent or weak relationships between these pedagogical strategies and learning outcomes (Putri et al., 2023; Hsiao et al., 2022), which makes it challenging to extrapolate the findings to educational contexts.

The critical gap in literature related to quantitative and experimental research that investigates the interactive effect of PBL and collaborative learning in STEAM classrooms (Oanh & Dang, 2025; Sangwaranatee et al., 2024). The majority of the previous studies were based on the qualitative or descriptive research methods that restricted the causes (Aguilera & Ortiz-Revilla, 2021). Also, the studies that have been conducted in developing countries are few, particularly in such a scenario like in Pakistan where the educational systems are marked by certain structural and resource requirements (Nisa, 2025). This absence of contextual information limits the extent to which the global results can be generalized to the local education processes.

The study also makes a theoretical contribution, by combining the principles of Constructivism and Social Learning Theory to explain how active, collaborative, and project-based learning environments contribute to improving learning outcomes (Wilson et al., 2021; Nungu et al., 2023). In practice, the results can be useful to teachers, curriculum designers, and policymakers to develop effective teaching strategies that are based on STEAM (Filipe et al., 2024). Also, the research will be in line with the United Nations Sustainable Development Goal 4 (Quality Education) because the study will promote inclusive, equitable, and innovative learning practices that will enhance the competencies of students in future success (Rahman et al., 2025; Martín-Cudero et al., 2024).

## Objectives of the Study

1. To examine the impact of project-based STEAM education on students' creativity and academic achievement.
2. To analyze the effect of collaborative learning on students' creativity and academic achievement within STEAM-based classrooms.
3. To investigate the combined influence of project-based STEAM education and collaborative learning on enhancing students' creativity and academic performance.

## Research Questions

1. What is the effect of project-based STEAM education on creativity and academic achievement?
2. How does collaborative learning influence creativity and academic achievement?
3. What is the combined effect of both approaches?

The current study is based on three complementary theoretical approaches explaining the effect of active, social, and experience-based learning environments on student outcomes (Wilson et al., 2021; Nungu et al., 2023). First, Constructivist Learning Theory is based on the idea that learners actively create knowledge as a result of their interaction with the environment instead of passively receiving information. Inquiry, problem-solving, and reflection activities in STEAM-based classrooms help students to develop conceptual understanding more thoroughly (Filipe et al., 2024). Past research indicated that constructivist learning conditions enhance higher-order thinking and creativity, as they encourage learners to relate prior knowledge with new experiences (Aguilera & Ortiz-Revilla, 2021).

Second, Social Learning Theory stresses that learning takes place in the process of observation, imitation, and interaction with other people. Collaborative learning environments enable students to exchange ideas, develop behaviors, and co-construct knowledge (Zaqiah et al., 2024). Research demonstrated that peer interaction enhances cognitive engagement and social skills, which contribute to improved academic outcomes (Nungu et al., 2023).

Third, Experiential Learning Theory emphasizes on learning as an experience, as something to reflect on, conceptualize, and apply. The STEAM education based on project makes a perfect fit with this theory, since students can learn through doing and reflecting on the tasks they complete in the real world (Kuo, 2024). Previous studies have shown that experiential learning leads to a deeper understanding, innovation, and the ability to retain knowledge in the long term (Lu et al., 2021). Collectively, these theories offer a solid framework of analyzing the effects of project-based and collaborative models on creativity and academic performance.

**Project-Based STEAM Education**

STEAM education is an approach that brings together various disciplines to form meaningful and context-based learning experiences (Andriyani, 2024). Project-Based Learning (PBL) is one of the main pedagogical methods that will be utilized within this framework to address the main objective and ensure the success of the changes implemented (Kuo, 2024; Sangwaranatee et al., 2024). PBL promotes inquiry, innovation and critical thinking, enabling the learners to implement interdisciplinary knowledge.

Empirical research demonstrated that project-based STEAM education can boost the level of student engagement, motivation, and problem-solving skills (Ahmad et al.,

2021; Oanh and Dang, 2025). It also facilitates the aspect of creativity development in that, it allows students to design solutions, experiment with their ideas, and think divergently (Chang et al., 2023). It was found that students of PBL had better academic achievement than those in traditional lecture-based settings (Ndiung & Menggo, 2024). Additionally, the PBL settings based on STEAM would promote the integration of artistic and scientific thinking, which would support the holistic development of thought (Filipe et al., 2024).

Nevertheless, other studies observed the challenges of time, teacher training, and resources especially in the context of developing education (Nisa, 2025). In spite of these issues, the increasing amount of literature confirms the effectiveness of PBL in promoting not only creativity but also academic performance (Sucilestari et al., 2023).

*Collaborative Learning*

Collaborative learning is instructional practices in which learners engage in learning activities in groups (Nungu et al., 2023). It focuses on peer interaction, teamwork, and collectively solving problems. In group environments, learners engage in a dialogue and negotiation, sharing ideas, challenging assumptions, and constructing knowledge (Zaqiah et al., 2024).

Research indicated that collaborative learning improves communication skills, social interaction, and cognitive development (Ellianawati et al., 2025). It also develops a sense of responsibility and accountability to the members of the group. Research has discovered that students who participate in teamwork activities perform better academically compared to students who learn individually (Nungu et al., 2023). Moreover, learning in groups can foster critical thinking and reflection since students are exposed to different points of view (Wised & Inthanon, 2024).

In STEAM education, teamwork is crucial since the real world can be challenging to solve without interdisciplinary teamwork (Rahman et al., 2025). The knowledge construction is supported through collaborative learning as students are able to incorporate a variety of perspectives and approaches (Wahyudi et al., 2024). Nonetheless, to achieve successful implementation, the group should be structured properly, roles should be clear and teacher facilitation is necessary to ensure equal participation and to avoid social loafing.

## Creativity in Education

Modern education systems are fundamentally based on creativity as an outcome that is specifically promoted within the framework of STEAM learning environments (Aguilera & Ortiz-Revilla, 2021). It is defined as the capacity of creating innovative, beneficial, and purposeful concepts. Three important dimensions of creativity are commonly used by educational researchers: fluency, flexibility, and originality.

Fluency is the skill of generating more than one idea or solution to a problem. The ability to solve problems in various ways is called flexibility, whereas the ability to think of ideas that have not been thought of previously is termed as originality. Research indicated that learning environments that support exploration, experimentation, and risk-taking boost these aspects of creativity (Putri et al., 2023).

Learning methods that involve project-based and collaborative are exceptionally effective in enhancing creativity. PBL offers students a chance to work on open-ended activities, whereas collaboration introduces the learners to a variety of different points of view that provoke creative thinking (Chang et al., 2023; Wahyudi et al., 2024). Empirical studies revealed that students in STEAM-based PBL classrooms exhibited a higher degree of creative performance than those in conventional classrooms (Hsiao et al., 2022).

Although the topic of measuring creativity is very critical, creativity measurement is rather difficult because it is a subjective issue. To evaluate creative outputs, researchers tend to rely on standardized tests, performance tests, and rubric-based tests.

## Academic Achievement

Academic achievement is that level at which students are achieving learning goals and are demonstrating that they have mastered learning material. It is most commonly assessed by standardized tests, grades and performance evaluation. One of the critical signs of education effectiveness and student success is academic achievement.

Research indicated that innovative teaching approaches, such as project-based and collaborative learning, positively influence academic achievement (Mubarok et al., 2025; Surur et al., 2025). The approaches will encourage active learning, better comprehension, and use of knowledge, which result in better outcomes of learning (Agung et al., 2025). Researchers discovered that students that engaged in PBL, based on STEAM activities, scored higher in science and mathematics than students in traditional teaching environments (Oanh & Dang, 2025).

Additionally, collaborative learning also leads to academic performance as it allows students to support each other and exchange knowledge (Nungu et al., 2023). Group discussions and feedback not only benefit students by improving comprehension and recall of concepts. The effects of these strategies can however differ according to the factors like instruction design, teacher knowledge and classroom atmosphere.

In emerging economies like Pakistan, uplifting the performance in school is a major concern. A combination of project-based STEAM learning with collaborative learning promises to be an effective approach to improving cognitive and creative outcomes (Nisa, 2025). Hence, their joint impacts offer a lot of understanding on how educational practices can be enhanced to achieve sustainable learning outcomes, as per the global standards of educational practices (Rahman et al., 2025).

**Hypotheses Development**

$H^1$: PBL-STEAM significantly affects creativity

$H^2$: PBL-STEAM significantly affects academic achievement

$H^3$: Collaborative learning significantly affects creativity

$H^4$: Collaborative learning significantly affects academic achievement

$H^5$: Combined PBL and collaboration significantly enhance creativity

$H^6$: Combined PBL and collaboration significantly enhance academic achievement

## Conceptual Framework

The conceptual framework of the presented study elucidates the relationships between instructional strategies and student learning outcomes in the context of a learning environment based on STEAM (Filipe et al., 2024; Mart Martin-Cudero et al., 2024). The model recognizes two independent variables such as the Project-Based Learning integrated into the STEAM education and Collaborative learning and investigates their impacts on two dependent variables such as the creativity and academic achievement.

Project-Based STEAM Education is a major instructional strategy, which engages students in solving real-life, cross-disciplinary problems through inquiry, design, and innovation (Kuo, 2024; Rohmaniyah et al., 2024). It is believed that it will directly and

positively affect the level of student creativity by providing them with exploration, experimentation, and idea creation (Chang et al., 2023). Concurrently, it enhances academic performance by fostering a better conceptual and practical mastery of knowledge in one or more subject areas (Agung et al., 2025; Oanh and Dang, 2025).

Collaborative Learning is an auxiliary pedagogical strategy that emphasizes interaction with peers, teamwork, and building knowledge together (Nungu et al., 2023). Group discussions, collaborative tasks, and mutual feedback help students to improve their ability to communicate and enhance their thinking processes (Zaqiah et al., 2024). It should also be expected that this variable will positively directly affect both creativity and academic achievement as interaction with peers will expose learners to different opinions and increase the level of cognitive engagement (Ellianawati et al., 2025; Wahyudi et al., 2024).

It is important to note that the framework takes into account an interactive effect between Project-Based STEAM Education and Collaborative Learning (PBL × Collaborative Learning). The implication of this interaction is that the joint implementation of both the strategies have a greater effect on student outcomes than both the strategies individually (Surur et al., 2025; Hsiao et al., 2022). In a collaborative PBL environment, students are able to collaboratively construct knowledge through social interaction, which not only exposes students to practical projects but also enables them to collaboratively develop knowledge through social interaction, thus yielding the best learning outcomes (Rahman et al., 2025).

As a dependent variable, creativity is conceptualized using such dimensions as fluency, flexibility, and originality (Aguilera & Ortiz-Revilla, 2021), and it is possible to measure academic achievement in the form of the means of performance scores and learning outcomes of students (Ndiung & Menggo, 2024). It is theoretically founded on Constructivism and Social Learning Theory which underlie the active, social, and experiential learning processes (Wilson et al., 2021; Nungu et al., 2023).

Overall, this conceptual model can provide a systematic basis, within which cognitive and creative development can be empirically studied in a school context with the assistance of the integrated instructional strategies. This figure 1 illustrates the direct and interaction effects of Project-Based STEAM Education and Collaborative Learning on two key student outcomes: creativity and academic achievement. Both instructional strategies independently influence the outcomes, while their combined interaction (PBL ×

Collaborative Learning) further enhances students' creative abilities and academic performance within STEAM-based educational environments.

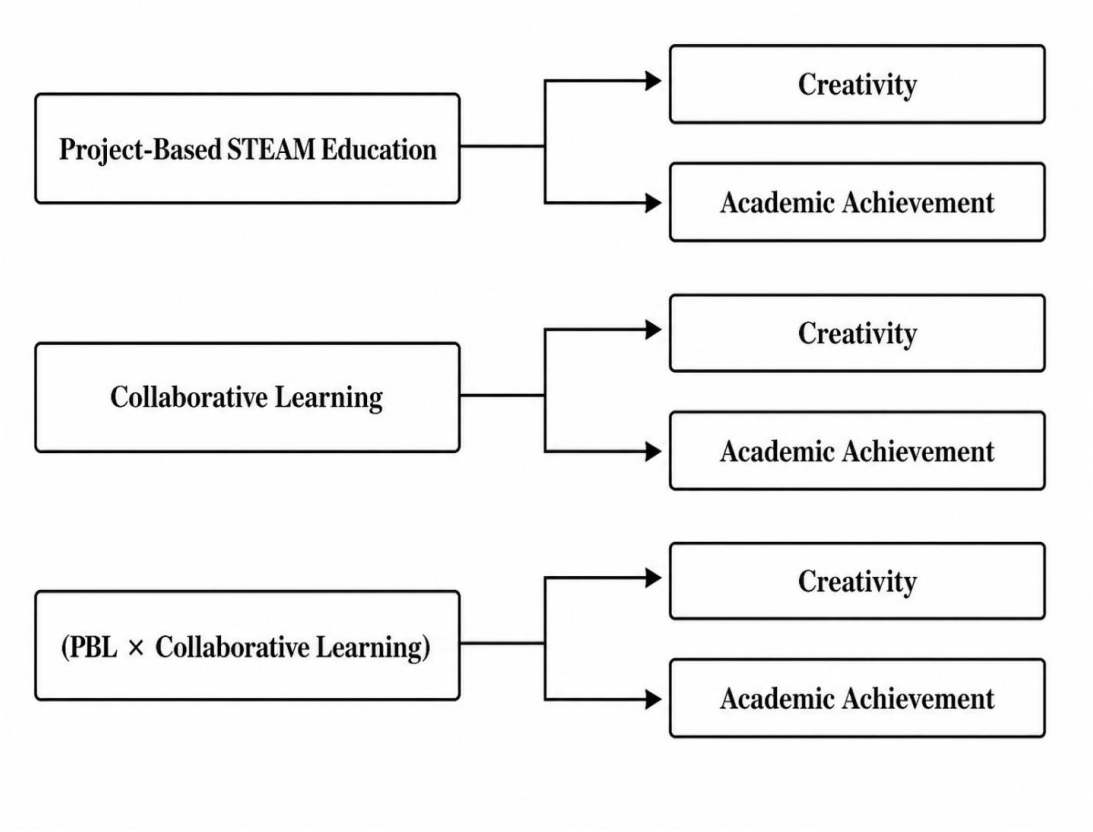


**Figure 1**. *Conceptual Framework of Project-Based STEAM Education, Collaborative Learning, and Their Interaction Effects on Students' Creativity and Academic Achievement.*

## Methodology

The study design used was a quasi-experimental pre-test-post-test control group design to test the effects of instructional strategies on the creativity and academic achievement of the students. The design was chosen in that it allowed the comparison of experimental and control groups over time and taking into consideration differences in the baseline. The fact that both groups were measured before and after the intervention made it possible to measure changes that can be attributed to the treatment and to make causal inferences with higher validity rates than purely descriptive methods.

## Participants and Sampling

The sample size was 300 students in Grades 8-10 in a total of 300 students sampled. Among them, the experimental group was chosen with 150 students; the control group was chosen with 150 students. Stratified random sampling was used to select the participants in order to represent the various grade levels and to have a balanced number of participants to represent the groups. This method made the sample more representative and increased the overall applicability of the results.

## Intervention

Project-Based Learning as the combination of STEAM education and Collaborative learning strategies was applied to the experimental group. Students were actively involved in real-life and structured projects that involved teamwork, inquiry, and problem-solving. In comparison, the control group was taught using the traditional teaching methods, which were lecture based and individual learning tasks. The intervention was introduced and carried over a period of 6 to 8 weeks, during which both groups were subjected to the same content of the curriculum to ensure that there is consistency.

## Instruments

Data were collected using multiple standardized instruments. Measures of creativity involved a standardized test of creativity, like the Torrance Test of Creative Thinking or a modified version that would suit the study context. The criteria used to evaluate academic achievement were subject-based standardized test based on the prescribed curriculum. Moreover, to assess the perceptions of students toward teamwork and peer interaction, a collaborative learning scale, which was based on the Likert-type format, was employed. A PBL-STEAM scale was also given to check the engagement of students and their problem-solving skills in project-based learning settings.

## Validity and Reliability

In order to guarantee the accuracy and consistency of the instruments, content validity was achieved by expert review where subject specialists assessed the relevance and clarity of the items. The Cronbachs Alpha was used to conduct the reliability analysis, and the instruments were found to be reliable with values at least equal to 0.70. Additionally, factor analysis techniques, such as exploratory factor analysis (EFA) and

confirmatory factor analysis (CFA) were optionally used to evaluate construct validity as well as ensure that measurement scales accurately reflected the intended variables.

## Data Collection Procedure

The data collection process was carried out in three phases. To establish the level of creativity and academic performance at baseline, both experimental and control groups were given pre-tests. Subsequently, the intervention phase was carried out wherein the experimental group participated in project-based STEAM activities with a combination of collaborative learning, whereas the control group was exposed to traditional instructional methods. Post-tests were done on the same groups in the aftermath of the intervention to gauge the change in the dependent variables.

## Data Analysis Techniques

Collected data were analyzed by descriptive and inferential statistics techniques. The data was summarized using descriptive statistics such as the mean and standard deviation. Cronbach's Alpha was used to test the reliability and the Shapiro-Wilk test was used to test the normality of the data distribution. The pre- and post-test scores within groups, and independent sample t-tests between the experimental and control groups were compared using paired sample t-tests and independent sample t-tests, respectively. Pearson correlation analysis was done to analyze the relationship between variables and multiple regression analysis was employed to establish the predictive effects. Besides, a two-way ANOVA was used to determine the overall effect of the instructional strategies. Cohen d and Eta square were used to calculate effect sizes to understand the strength of the observed differences.

## Results

*Demographic Profile*

Table 1

*Demographic Characteristics of Participants*

| Variable | Category | Frequency (f) | Percentage (%) |
|---|---|---|---|
| **Gender** | Male | 158 | 52.7 |
| | Female | 142 | 47.3 |
| **Age** | 13–14 years | 120 | 40.0 |

| | | | |
|---|---|---|---|
| | 15–16 years | 180 | 60.0 |
| **Grade** | Grade 8 | 95 | 31.7 |
| | Grade 9 | 102 | 34.0 |
| | Grade 10 | 103 | 34.3 |

Demographic distribution shows an equal representation of the participants in terms of gender with just a slight majority of the males (52.7%) over the females (47.3%). Most of the participants are between the 15 and 16-year age group (60.0%), and 40.0% were between the 13 and 14-year age category. Moreover, students are evenly dispersed between Grade 8 (31.7%), Grade 9 (34.0%), and Grade 10 (34.3%). Such a balanced work can contribute to the maximum representativeness of the sample and to the overall generalizability of the results.

*Descriptive Statistics*

Table 2

*Descriptive Statistics of Study Variables*

| Variable | Group | Pre-test Mean | Post-test Mean | Std. Deviation |
|---|---|---|---|---|
| **Creativity** | Experimental | 54.32 | 78.45 | 8.12 |
| | Control | 53.88 | 60.21 | 7.95 |
| **Academic Achievement** | Experimental | 56.10 | 81.32 | 7.84 |
| | Control | 55.76 | 64.18 | 8.03 |
| **Collaborative Learning** | Experimental | 3.21 | 4.35 | 0.52 |
| **PBL-STEAM Engagement** | Experimental | 3.10 | 4.48 | 0.49 |

The descriptive statistics show that the experimental group showed significant improvement in creativity and academic performance between pre-test and post-test. In particular, the levels of creativity have improved (54.32 to 78.45), as well as academic achievement (56.10 to 81.32). Conversely, the control group had relatively low gains. Moreover, high post-test means scores on collaborative learning ($M = 4.35$, $SD = 0.52$) and PBL-STEAM engagement ($M = 4.48$, $SD = 0.49$) indicate high levels of student engagement in the intervention. These results indicate that the experimental condition was better in promoting learning outcomes.

*Reliability Analysis*

Table 3:

*Reliability Statistics (Cronbach's Alpha)*

| Scale | No. of Items | Cronbach's Alpha |
|---|---|---|
| **Creativity Scale** | 15 | 0.88 |
| **Academic Achievement Test** | 20 | 0.85 |
| **Collaborative Learning Scale** | 10 | 0.90 |
| **PBL-STEAM Scale** | 12 | 0.92 |

The reliability test shows that all the measurement instruments have high rates of internal consistency. The alpha values of Cronbach are between 0.85 and 0.92 and this is higher than the acceptable level of 0.70. This confirms that the scales to be used in this research are good and can be used to measure the intended constructs.

*Hypothesis Testing*

A. Paired Sample t-test (Pre vs Post)

Table 4:

*Paired Sample t-test (Experimental Group)*

| Variable | Mean Difference | t-value | Sig. (p) |
|---|---|---|---|
| **Creativity** | 24.13 | 18.45 | .000 |
| **Academic Achievement** | 25.22 | 19.10 | .000 |

The results of the paired sample t-test reveal that there is statistically significant growth in the level of creativity as well as academic performance in the experimental group. Creativity showed a mean difference of 24.13, $t = 18.45$, $p < .001$, while academic achievement showed a mean difference of 25.22, $t = 19.10$, $p < .001$. These results confirm the effectiveness of the intervention in enhancing student outcomes.

B. Independent Sample t-test (Post-test Comparison)

Table 5:

*Independent Sample t-test (Experimental vs Control)*

| Variable | Mean Difference | t-value | Sig. (p) |
|---|---|---|---|
| **Creativity** | 18.24 | 12.87 | .000 |
| **Academic Achievement** | 17.14 | 11.96 | .000 |

The independent sample t-test indicates that there are significant differences in the scores of the experimental and control groups in the post-test scores. The control group did not outperform the experimental group in terms of creativity ($t = 12.87$, $p < .001$) and academic achievement ($t = 11.96$, $p < .001$). These results are a good indication of the effectiveness of the intervention.

C. Multiple Regression Analysis

Table 6:

*Regression Analysis*

| Predictor | β | t-value | Sig. |
|---|---|---|---|
| **PBL-STEAM → Creativity** | 0.48 | 9.12 | .000 |
| **Collaborative Learning → Creativity** | 0.36 | 7.45 | .000 |
| **PBL-STEAM → Academic Achievement** | 0.51 | 10.02 | .000 |
| **Collaborative Learning → Academic Achievement** | 0.33 | 6.89 | .000 |

## Model Summary

| $R^2$ | Adjusted $R^2$ | F | Sig. |
|---|---|---|---|
| **0.62** | 0.60 | 122.45 | .000 |

The regression shows that both PBL-STEAM and collaborative learning are important predictors of creativity and academic success. The predictive effect ($\beta = 0.48$ and 0.51) of PBL-STEAM is greater, followed by collaborative learning ($\beta = 0.36$ and 0.33). The model explains 62% of the variance ($R^2 = 0.62$) and is statistically significant ($F = 122.45$, $p < .001$). These findings confirm Hypotheses H1, H2, H3 and H4.

*Interaction Effect (Two-Way ANOVA)*

Table 7:

*Two-Way ANOVA Results*

| Source | SS | df | F | Sig. |
|---|---|---|---|---|
| **PBL-STEAM** | 2456.12 | 1 | 85.34 | .000 |
| **Collaborative Learning** | 1987.45 | 1 | 72.11 | .000 |
| **Interaction (PBL × CL)** | 1123.76 | 1 | 41.56 | .000 |
| **Error** | 8432.55 | 296 | | |

**Effect Size**

| Variable | Eta Squared ($\eta^2$) |
|---|---|
| **PBL-STEAM** | 0.29 |
| **Collaborative Learning** | 0.24 |
| **Interaction** | 0.16 |

The results of the two-way ANOVA show that the two main effects of PBL-STEAM and collaborative learning are significant, and the interaction effect of the two variables is also significant ($p < .001$). The effect sizes indicate that PBL-STEAM has a significant effect ($\eta$ 2 = 0.29), collaborative learning ($\eta$ 2 = 0.24) and the interaction effect ($\eta$ 2 = 0.16) also exhibit significant effects. These results suggest that the combined application of both strategies has more powerful results compared to individual strategies, which prove the validity of Hypotheses H5 and H6.

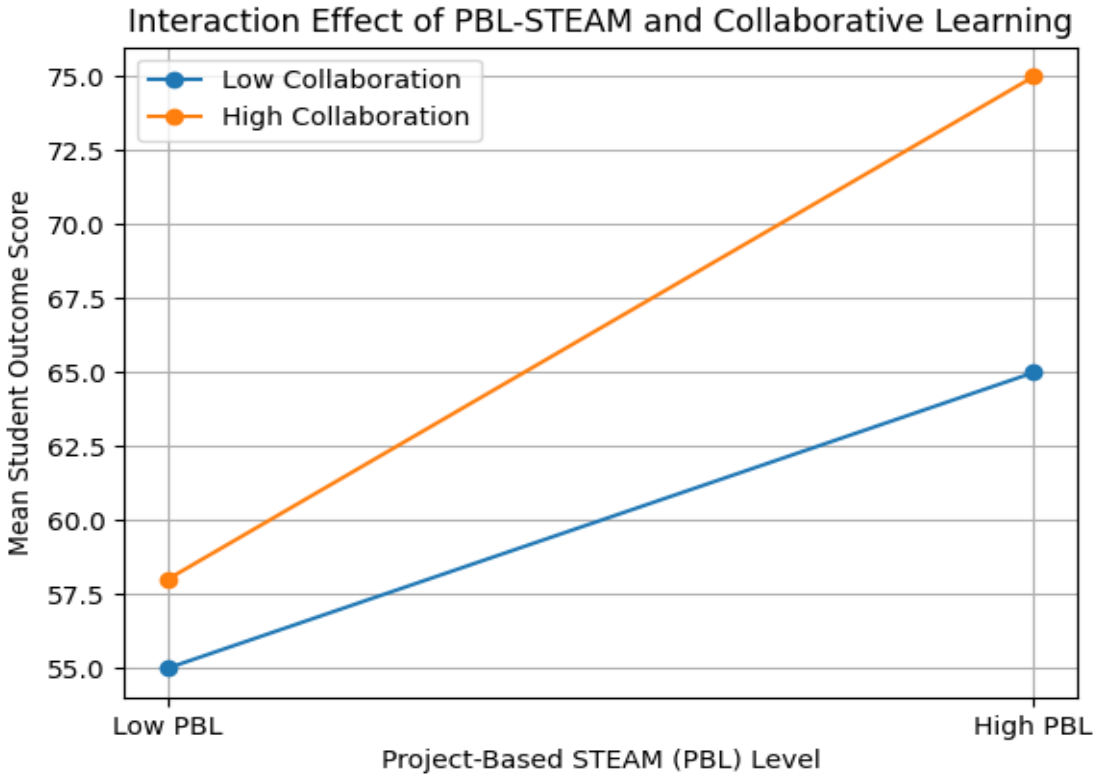


**Figure 2.** ***Interaction Effect of Project-Based STEAM (PBL) and Collaborative Learning on Students' Outcomes.***

The pattern of interaction shows that students who received high PBL-STEAM engagement and high collaborative learning attained the best results in creativity and academic performance. Conversely, lower levels of collaboration reduced the effectiveness of PBL-STEAM. This implies that there is a synergistic association between the two teaching methods. All the findings show conclusively that Project-Based STEAM Education and Collaborative Learning have a significant positive impact on both creativity and academic success. In addition, their interaction effect creates a synergistic effect, which validates that, integrated pedagogical strategies are more effective as compared to isolated strategies.

## Discussion

The current research was investigating the impacts of Project-Based STEAM Education and Collaborative Learning on creativity and academic performance of students

(Ahmad et al., 2021). The results are of great empirical value to the effectiveness of both instructional strategies individually and in combination under the contexts of secondary schools.

**Interpretation of Findings**

The findings show that students who experienced Project-Based STEAM education showed a lot of improvement in creativity and academic performance as compared to the students in conventional learning environments. This implies that not only their conceptual knowledge but also their capacity to come up with innovative ideas are improved when students are engaged in real-world problem-solving, inquiry, and interdisciplinary tasks (Albar & Southcott, 2021; Wannapiroon & Pimdee, 2022). Equally, collaborative learning demonstrated a significant positive effect on both dependent variables, which confirms peer interaction, sharing of knowledge and using a group to solve problems has significant positive effect on the dependent variables.

Notably, the interaction effect between Project-Based STEAM Education and Collaborative Learning was statistically significant, which suggests that the two are related synergistically. This implies that the effectiveness of the two strategies when used together is multiplied. By engaging in project-based studies with one another under collaborative settings, students will experience the best cognitive and creative growth due to exposure to both experiential and social processes of learning.

**Comparison with Previous Studies**

These results align with the findings of previous studies that identify the positive effect of project-based learning on the enhancement of student engagement, problem-solving abilities, and academic performance (Kuo, 2024; Ndiung & Menggo, 2024). The observed increase in creativity is consistent with the results of studies by Chang et al. (2023) and Hsiao et al. (2022) who found that STEAM-based PBL classroom environments can promote greater levels of divergent thinking and innovation.

Equally, the beneficial effect of group learning is conducive to previous studies conducted by Nungu et al. (2023) and Ellianawati et al. (2025), who reported the increase of communication skills, critical thinking, and academic performance through group learning. Nevertheless, this research is an empirical investigation that shows the synergistic effect of these strategies based on a quantitative quasi-experimental design. Although most of the past researches had studied these approaches independently, the current findings

have presented better evidence that these approaches can be used together to produce more powerful education effects, especially in the context of STEAM.

**Theoretical Implications**

The results support the main constructs of Constructivist Learning Theory, Social Learning Theory, and Experiential Learning Theory. According to constructivist point of view, the drastic changes in the student outcomes are a testimony to the fact that knowledge is constructed actively through meaningful engagement and problem-solving processes. The collaborative learning role also supports the Social Learning Theory since it helps in the cognitive development and learning performance.

Moreover, the effectiveness of Project-Based STEAM education can also be associated with Experiential Learning Theory since students learn effectively when they can be directly involved and learn through direct experience, reflection and application. The fact that the interaction effect between PBL and collaborative learning is significant offers theoretical progress since it leads to the assumption that the process of learning is most effective when cognitive, social, and experiential processes are combined. This helps to argue that multi-dimensional learning set-ups are critical in creating 21st-century competencies.

**Practical Classroom Implications**

In terms of practical implications, this study offers valuable information to teachers, curriculum developers and policy-makers. A project-based activity based on project-based STEAM activities, which require solving a problem in the real world, interdisciplinary integration, and creativity should be considered in the program of teachers. In addition, systematic incorporation of the structured collaborative learning strategies which involve group projects, peer discussions, and cooperative tasks should also be systematically incorporated in classroom instructions.

The educators must also ensure that they have created a proper group, assigned roles and also facilitated the group to ensure that they do not face the challenges of having unequal participation in the group. The teacher training programs also ought to concentrate on acquisition of skills in implementation of PBL and collaborative strategies successfully.

The findings to policymakers are that they need to establish and implement STEAM-based programs and provide resources, infrastructure and professional development opportunities to teachers. By adopting these strategies, it is aligned with

Sustainable Development Goal 4 (Quality Education) by promoting inclusive, innovative and student-centered learning experiences.

Overall, the research shows that the incorporation of Project-Based STEAM Education with Collaborative Learning is a potent tool to use in improving both creativity and the level of academic performance, which can become a viable channel of improving the quality of education in modern classrooms.

## Conclusion

The findings of this study were that Project-Based STEAM Education and Collaborative Learning were found to have significant impact on improving the creativity of students and their academic performance at the secondary school level. The results indicated that students who attended project-based STEAM programmes performed better as compared to the students who were taught using the conventional way. The experimental group showed better post-test scores in creativity and academic achievement, as active, inquiry-based, and interdisciplinary learning produces more powerful educational results. Correspondingly, collaborative learning had a positive impact on the performance of students because they interacted with their peers, worked in teams, shared responsibility, and solved problems together.

The research also established the fact that the integration of Project-Based STEAM Education and Collaborative Learning had a more significant impact than the application of these two strategies by themselves. The great interaction effect showed that students were at the highest levels of creativity and academic performance when they were involved in both project-based activities and collaborative learning activities. This observation underscores the need to incorporate experiential learning with socialization in contemporary classrooms.

By presenting quantitative data supporting the idea that project-based and collaborative models can make STEAM learning more efficient, purposeful, and student-centered, the study will contribute to STEAM education. It reinforces the thesis that STEAM education should not merely be confined to subject integration alone, but should also extend to active pedagogical practices that can allow students to explore, design, create and solve real-life problems.

Additionally, the research highlights how Project-Based STEAM Education contributes to the enhancements in the creativity of students via fluency, flexibility and originality. Simultaneously, it enhances academic performance through a greater degree of

comprehension, application, and the ability to retain information in the long term. Thus, the combination of Project-Based STEAM Education and Collaborative Learning can be viewed as an effective instructional method to enhance the quality of learning, help to promote 21st-century skills, and contribute to the achievement of the objectives of inclusive and innovative education.

## Implications

### Theoretical Implications

The theoretical implications of the study are significant as they expand the knowledge of constructivist, social, and collaborative model forms of learning in STEAM education. The results are supported by Constructivist Learning Theory since it is confirmed that students learn more effectively when they actively construct knowledge through inquiry, experimentation, and solving problems in the real world. Project-Based STEAM Education enables students to relate their previous experiences with new experiences, which enhances the conceptual understanding and encourages creativity.

The research also builds upon Social Learning Theory and collaborative learning theories by demonstrating that peer interaction, teamwork, discussion and shared responsibility are very useful in improving academic and creative performance by students. The high interaction effect between Project-Based STEAM Education and Collaborative Learning suggests that learning is more effective when personal exploration is supported by group knowledge building. Thus, in this research, the contribution to the theory is shown by demonstrating that in addition to the results of active learning, creativity and achievement are also formed under a strong influence of social participation, cooperation, and reflective engagement.

### Practical Implications

The results provide practical implications of use by teachers, school leaders, curriculum developers, and policy makers. To begin with, Project-Based STEAM Education, collaboration learning strategies, facilitation in classroom, project design, assessment rubrics, group management should be included in practical modules of teacher training programs. To design interdisciplinary projects, facilitate inquiry-based learning and ensure equal participation of every student in collaborative efforts, teachers require professional development.

Second, curriculum developers ought to incorporate STEAM-based projects in regular classroom instruction as opposed to using STEAM as an extracurricular activity. Real-life problems should be used to interrelate science, technology, engineering, arts, and mathematics as a way of encouraging creativity, innovation and academic knowledge. Learning resources, flexible classroom layouts, and assessment systems that facilitate project-based learning and collaborative learning should also be provided in schools. Overall, the research indicates that successful implementation of STEAM programs involves the presence of trained teachers, supportive curricula, as well as classroom practices that integrate practical projects with meaningful collaboration.

**Limitations and Future Research**

This research has a number of limitations which must be taken into consideration when explaining the research results. First, the sample size was restricted to one region and therefore it can influence the generalization of the findings to other education settings. The variations in the school environment, teaching methods, and availability of resources across regions could affect the success of Project-Based STEAM Education and Collaborative Learning.

Second, the intervention was rather brief (6 8 weeks). Although the results indicated that there were significant improvements in creativity and academic achievement, a longer period would have provided more insights into the sustainability and long-term effect of these instruction strategies. Short-term research might not be able to fully represent the long-term learning outcomes or development of skills.

It is suggested that future studies should help overcome these limitations by making longitudinal studies that investigate the long-term outcomes of STEAM-based project learning and collaboration. Further, the investigators ought to contemplate the use of larger and more heterogeneous samples across regions or countries to enhance external validity. Mixed-method methods, which combine quantifiable data with qualitative methods like interviews, observations, and student reflections, would give a better idea on how these strategies are influencing the learning processes. These studies would reinforce the evidence base and provide more insightful information on the further development of STEAM education.

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