ASEAN Journal of
Physical Education and Sport Science

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajopess

Developing Students' Physical and Technical Abilities through the STEAM Approach: Methodology and Implementation

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A B S T R A C T

This study presents a methodology for developing students' physical and technical abilities through the STEAM (Science, Technology, Engineering, Arts, Mathematics) approach. The research aims to integrate theoretical knowledge with practical applications by implementing project-based learning. Students from grades 7 to 9 were divided into experimental and control groups to assess the effectiveness of STEAM-oriented education. The experimental group engaged in creative problem-solving tasks and hands-on projects, leading to significant improvements in technical skills, critical thinking, and collaboration. Pre- and post-test results showed a 9.02% increase in the experimental group's performance compared to a 1.09% increase in the control group. The findings highlight the importance of integrating STEAM education to make learning more engaging and applicable to real-life situations. This methodology not only enhances students' technical competencies but also fosters creativity, motivation, and teamwork, contributing to the development of future-oriented, innovative learners.

A R T I C L E I N F O

Article History:
Submitted/Received 10 Nov 2024
First Revised 15 Dec 2024
Accepted 09 Feb 2025
First Available online 10 Feb 2025
Publication Date 01 Mar 2025

Keyword:
Innovative pedagogy,
Physical-technical skills,
Project-based learning,
STEAM education,
Student creativity.

1. INTRODUCTION

In the era of rapid technological development, the role of education is no longer limited to delivering theoretical knowledge but extends to preparing students with practical skills and competencies relevant to real-life situations. Among these competencies, the development of students' physical and technical abilities has become increasingly essential. Physical and technical abilities refer to students' capacity to understand, interpret, and apply scientific and technological principles in practice (Usarov *et al*., 2024). This includes the skills needed to conduct experiments, create technical models, solve engineering problems, and integrate theoretical concepts into real-world applications. However, conventional teaching methods often emphasize memorization and theoretical learning, leaving students with limited opportunities to engage in creative problem-solving or hands-on technical activities. This gap between knowledge and application necessitates an innovative educational approach that bridges theory and practice, fosters creativity, and prepares students for the demands of a technology-driven society (Mukhamedov *et al*., 2024; Kodirova *et al*., 2024; Buriyeva & Omonovich, 2024).

This study focuses on the methodology and implementation of a STEAM-based educational model specifically designed to enhance students' physical and technical abilities. The methodology employs project-based learning (PBL), a student-centered instructional strategy that allows learners to actively explore real-world problems and challenges. Students participate in collaborative projects that require them to apply scientific theories, use technological tools, and develop practical solutions to physical and engineering problems. The implementation of this model involves structured stages, starting with the identification of a problem, followed by theoretical exploration, project design, construction of physical models or systems, and the presentation of outcomes (Apriyatna *et al*., 2023; Coyoca *et al*., 2022). Throughout this process, students improve not only their technical knowledge and practical skills but also their creativity, teamwork, communication, and critical thinking abilities (Saodat *et al*., 2023; Babalola & Oludare, 2024; Marcaida, 2022; Hidayatullah *et al.,* 2022).

The main objective of this research is to design, implement, and evaluate a STEAM-based methodology for developing students' physical and technical competencies. The study involves assessing the effectiveness of this approach by comparing the performance of students engaged in STEAM-based learning with those taught using traditional methods. The evaluation process includes pre-tests and post-tests, project assessments, interviews, and observations to measure improvements in technical skills, problem-solving abilities, and creative thinking. The ultimate goal is to demonstrate that integrating STEAM into physics and technology education can significantly enhance students' learning experiences, foster innovation, and prepare them to meet the challenges of the 21st century. This research contributes to the broader educational discourse by providing a practical model that supports the development of future generations equipped with the interdisciplinary skills necessary for success in a complex, technology-oriented world (Sohlberg *et al*., 2015).

2. METHODS

To evaluate the effectiveness of the STEAM-based approach in developing students' physical and technical abilities, this study employed an experimental research design with a mixed-methods strategy combining both quantitative and qualitative data. The research aimed not only to implement a new teaching methodology but also to assess its practical outcomes in real classroom settings, specifically in physics and technology education.

The study involved students from grades 7 to 9 in general secondary schools. Participants were selected through random sampling to ensure balanced representation in terms of age, gender, and prior academic performance. The students were divided into two distinct groups: an experimental group and a control group. The experimental group engaged in the STEAM-based learning model using project-based learning (PBL) methods, while the control group continued their studies using traditional instructional methods. The detailed composition of the research participants is presented in **Table 1**.

Table 1. Research participants.

Grade level	Program	Gender		Σ
		Male	Female	
7-grade	Experimental group	19	18	37
	Control group	16	17	33
	Total	35	35	70
8-grade	Experimental group	13	17	30
	Control group	17	16	33
	Total	30	33	63
9-grade	Experimental group	20	15	35
	Control group	19	16	35
	Total	39	31	70
Total		**104**	**99**	**203**

2.1. Implementation of the Educational Process

The experimental group participated in a STEAM-based learning process structured through project-based learning (PBL). The lessons were designed to guide students in solving real-world problems by integrating concepts from science, technology, engineering, arts, and mathematics. Each project began with problem identification, where students were introduced to physical or technical challenges reflective of real-life scenarios. This was followed by collaborative exploration, where students researched theoretical concepts and brainstormed possible solutions in groups.

Subsequently, students moved to the practical implementation stage, constructing physical models or devices to apply the theories they had learned. Projects included building simple electrical generators, mechanical models, or physics demonstration tools using accessible materials. Finally, students presented their projects to peers and teachers, allowing for feedback, reflection, and refinement of their ideas.

In contrast, the control group followed the conventional learning path with teacher-centered lectures, textbook exercises, and minimal practical application. This division allowed for a clear comparison between STEAM-based education and traditional methods.

2.2. Assessment Tools and Procedures

To evaluate students' development, the research employed pre-tests and post-tests to measure theoretical understanding and technical competencies before and after the intervention. Additionally, students' performance in practical projects was assessed, focusing on their ability to apply theoretical knowledge creatively and construct functional models.

Teachers conducted observations and interviews to gather qualitative data on student engagement, collaboration, problem-solving strategies, and motivation during the project-based activities. These methods ensured a holistic evaluation of both cognitive and practical learning outcomes.

2.3. Assessment Tools and Procedures

Students' physical and technical abilities were categorized into three competency levels—High, Medium, and Low—based on their performance in both theoretical and practical tasks. The specific assessment criteria are presented in **Table 2**.

Table 2. Assessment criteria for physical and technical abilities.

No	Assessment levels	Assessment Criteria
1.	High level	(i) The student's physical-technical abilities are highly developed, as expressed in the following ways: (ii) Theoretical knowledge: Demonstrates a deep understanding of complex concepts and principles in physics and technology and can analyze them logically. (iii) Practical skills: Independently conducts complex experiments and projects and is capable of creating creative and innovative developments. (iv) Problem-solving ability: Effectively analyzes complex problems and finds unique solutions. (v) Creativity level: Presents original ideas and innovations, serving as an example for other students.
2.	Medium level	(i) At this level, the student can develop their physical-technical abilities to a certain extent independently, which is reflected in the following characteristics: (ii) Theoretical knowledge: Understands fundamental principles in physics and technology and can explain them in their own words. (iii) Practical skills: Can independently perform basic laboratory experiments and participate in creating small technical projects or models. (iv) Problem-solving ability: Can independently solve moderately difficult problems and requires assistance for more complex ones. (v) Creativity level: Proposes unique solutions for simple tasks and experiments with innovative approaches.
3.	Low level	(i) The student's physical-technical abilities are at a basic level, characterized by the following attributes: (ii) Theoretical knowledge: Has a superficial understanding of technical and physical fundamentals and struggles with using terminology. (iii) Practical skills: Faces difficulties in independently completing practical tasks and primarily relies on the teacher's guidance. (iv) Problem-solving ability: Needs assistance in solving simple problems and is unable to solve complex ones. (v) Creativity level: Struggles to propose innovative ideas and solutions, mainly replicating existing examples.

2.4. Data Analysis

For the quantitative analysis, the pre-test and post-test scores of the experimental and control groups were compared using statistical tests, particularly the t-test, to determine the significance of the observed differences. A significance level of $p < 0.05$ was set to validate the results.

For the qualitative analysis, data from interviews and classroom observations were analyzed to identify changes in student motivation, collaboration, creativity, and overall engagement with the learning material.

3. RESULTS AND DISCUSSION

This section presents the findings of the study on the development of students' physical and technical abilities through the STEAM-based learning approach. The results are divided into six main sub-sections, combining both quantitative and qualitative data to provide a comprehensive analysis of the educational intervention.

3.1. Improvement of Theoretical Knowledge and Technical Skills

The implementation of the STEAM-based learning model led to a significant improvement in students' theoretical knowledge and technical skills. Before the intervention, both the experimental and control groups demonstrated similar levels of understanding. The experimental group had an average pre-test score of 65%, while the control group achieved 64%. This indicated that both groups started from an equivalent baseline in terms of physics and technical knowledge.

After the STEAM learning intervention, the post-test results showed substantial improvement in the experimental group. Students in this group reached an average post-test score of 74.02%, reflecting a 9.02% increase in learning outcomes. Conversely, the control group, which followed traditional instruction, only showed a marginal improvement of 1.09%, resulting in a final average of 65.09%.

This result confirms that the STEAM approach not only improves students' understanding of theoretical concepts but also enhances their ability to apply knowledge in technical and problem-solving contexts. The direct comparison of test results between the experimental and control groups is illustrated in **Figure 1**.

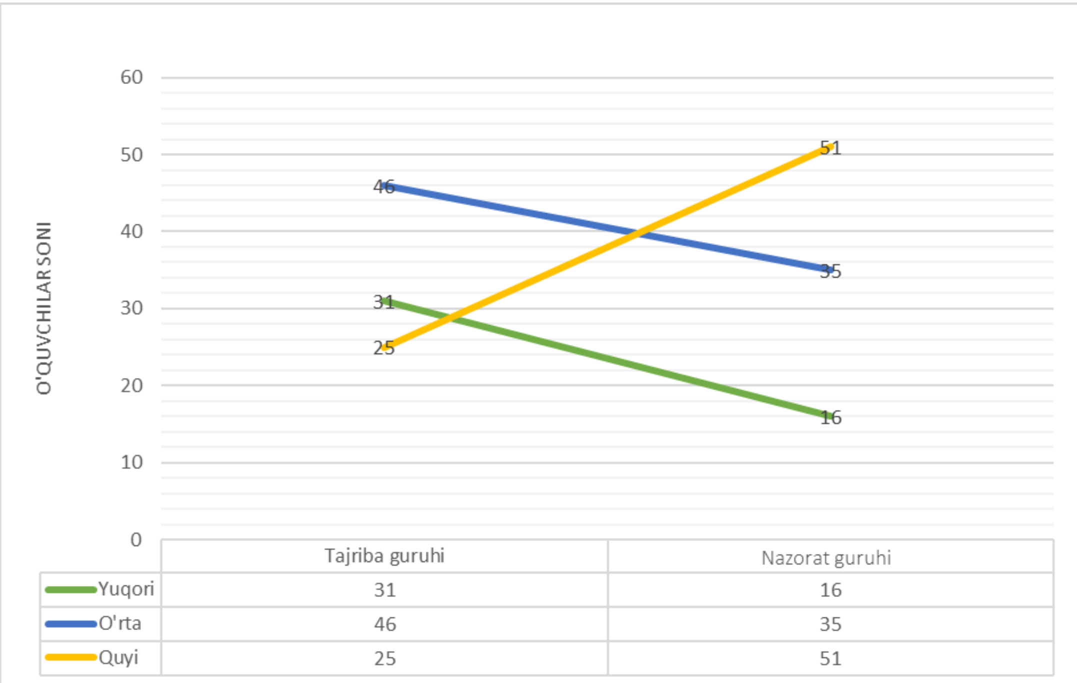

Figure 1. Comparison of pre-test and post-test scores.

3.2. Performance in Project-Based Learning Activities

In addition to test scores, students' practical competencies were assessed through their performance in project-based learning activities. Students in the experimental group were tasked with designing and constructing physical models or devices that represented the principles they learned in class. These projects included building simple electric generators, mechanical lifting devices, and hydraulic systems using recyclable and low-cost materials.

Approximately 80% of the students in the experimental group successfully completed these projects with minimal guidance. They demonstrated the ability to transfer theoretical knowledge into practical applications, solve engineering-related problems, and innovate with limited resources. This experience helped students to develop creative thinking, technical reasoning, and teamwork skills. In contrast, students in the control group did not participate in hands-on projects, resulting in less development of practical competencies.

3.3. Observation and Student Engagement

Observations conducted throughout the learning process indicated a higher level of engagement and active learning behavior among students in the experimental group compared to those in the control group. Students in the STEAM group actively participated in group discussions, posed questions, and worked collaboratively to find solutions to technical problems.

They took ownership of their learning by sharing responsibilities, brainstorming ideas, and constructing prototypes. This collaborative environment fostered critical thinking and problem-solving abilities. Meanwhile, the control group mostly followed passive learning patterns, relying heavily on teacher instruction and focusing on textbook exercises. This difference highlights the advantage of project-based STEAM learning in promoting student-centered education.

3.4. Student Feedback and Perception

Interviews with students revealed that the STEAM approach had a positive impact on their learning motivation and perceptions of physics and technology. Many students reported that, prior to the intervention, they perceived physics as an abstract and difficult subject. However, after engaging in STEAM-based projects, they found the subject more relatable, practical, and enjoyable.

Students emphasized that working on real-life problems through creative projects made the lessons meaningful. They also noted improvements in their communication skills, as they had to present their projects, explain the scientific concepts involved, and collaborate effectively within their teams. Sample student responses included:

(i) *"We now understand why physics is important because we can see how it works through our projects."*
(ii) *"Building and testing models made learning fun and helped us remember the lessons better."*
(iii) *"Working in teams helped us learn to communicate, share ideas, and solve problems together."*

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(v) "Building and testing models made learning fun and helped us remember the lessons better."

(vi) "Working in teams helped us learn to communicate, share ideas, and solve problems together."

3.5. Statistical Analysis of Learning Outcomes

To validate the differences in learning outcomes between the experimental and control groups, a paired sample t-test was conducted. The statistical analysis showed that the improvement in the experimental group was statistically significant at $p < 0.05$. This result confirms that the STEAM-based project learning method had a measurable and meaningful impact on students' academic performance and technical skills development. The control group's slight improvement, on the other hand, was not statistically significant, suggesting that traditional instruction did not produce notable changes in learning outcomes.

4. CONCLUSION

This study concludes that the STEAM-based learning approach effectively enhances students' physical and technical abilities. The experimental group, which engaged in project-based STEAM activities, showed a significant improvement in both theoretical knowledge and practical skills, with a 9.02% increase in test scores compared to only 1.09% in the control group.

The STEAM method fostered not only cognitive development but also creativity, collaboration, and real-world problem-solving abilities. Statistical analysis confirmed the effectiveness of this approach at a $p < 0.05$ significance level.

Overall, STEAM-oriented project-based learning is a superior strategy for developing interdisciplinary competencies in secondary education. It is recommended for broader implementation to prepare students for future technological and scientific challenges.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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