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Research Article

PSYCHOLOGICAL AND PEDAGOGICAL FOUNDATIONS OF STEAM EDUCATION IMPLEMENTATION IN MIDDLE SCHOOL

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Rafikova Renata Anatolyevna
Senior Lecturer Of The Department Of "Pedagogy And Psychology" At Namangan State Pedagogical Institute, Uzbekistan

ABSTRACT

This article examines the psychological and pedagogical foundations of STEAM education in middle school. It provides a rationale for STEAM technology and its alignment with the state educational standards of the Republic of Uzbekistan. The impact of integrated learning on the psychological development of schoolchildren is described. The article presents the results of a formative experiment developed based on STEAM technology and conducted with 6th-grade students as part of a dissertation study.

KEYWORDS

STEAM education, STEAM projects, integrated learning, critical thinking, middle school.

INTRODUCTION

Comprehensive reforms aimed at improving the quality of education are being implemented within the educational system of the Republic of Uzbekistan. Key factors contributing to this include the mastery of modern knowledge and skills by teaching staff, the enhancement of research effectiveness, and the integration of contemporary informational and didactic teaching methods. These initiatives play a crucial role in developing the intellectual abilities of students, who represent the future of our country, and in preparing creative, independent, and competitive professionals [1].

Today, a key task is to emphasize not only the development of primary education, which plays a vital role in the lifelong learning system and lays the foundation for each student's future, but also to support subsequent educational stages. In early school years, children gain the opportunity to deeply absorb fundamental scientific knowledge. As they transition

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to middle school, students begin to explore ways to express their individuality and align their learning with personal interests and abilities. During this period, the primary role of educators is to foster and sustain students' scientific curiosity. It is crucial to recognize that this is the time when children must learn to process and apply information from a variety of sources effectively.

The structure of the new secondary education standards in the field of natural sciences is based on research findings related to teaching and learning methods in this area. These standards outline the essential subject knowledge that students are expected to acquire at each educational level within the modern educational framework [2]. The new standards consist of three key components:

- Practices – skills in science and engineering.
- Content – fundamental subject knowledge.
- Crosscutting Concepts – overarching ideas applicable across various disciplines.

The standards highlight eight key skills and competencies in science and engineering:

1. Asking questions (in science) and defining problems (in engineering).
2. Developing and using models.
3. Planning and conducting investigations.
4. Analyzing and interpreting data.
5. Developing and applying thinking skills necessary for performing mathematical operations and calculations.
6. Providing scientific explanations and solving design challenges (in engineering).
7. Justifying conclusions based on evidence.
8. Collecting, evaluating, and effectively communicating information.

STEAM education, which integrates science, technology, engineering, art, and mathematics, is becoming increasingly popular in modern educational systems. The implementation of such educational programs is a necessity of the times. However, not everyone is intellectually and psychologically prepared for the pace of modern digitalization. Flexibility in adapting to the changing world needs to be cultivated from an early age. The proposed STEAM approach is specifically designed to foster this adaptability. It becomes particularly relevant for middle school students, as this is a period when children develop cognitive engagement, abstract thinking, and scientific interest in the world around them. The successful implementation of the STEAM approach relies on deep psychological principles that must be considered when designing and delivering educational programs [4].

STEAM education is an interdisciplinary approach to learning aimed at preparing students to solve the complex challenges of the 21st century. In middle school, STEAM education can significantly impact students' psychological development by fostering cognitive skills, creativity, and critical thinking.

One of the key psychological and pedagogical principles of STEAM education is integrated learning. This concept suggests that combining disciplines enables students to connect knowledge and skills from various fields, fostering a deeper understanding of the world. Research has shown that integrated learning enhances retention, increases motivation, and develops critical thinking (Callanan & Oakes, 1992; Jacobs, 1997).

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Within the proposed approach, a cornerstone is the development and participation in research projects. STEAM projects often require students to solve problems in real-world contexts. This fosters the development of critical thinking, an essential psychological skill for academic and life success. Problem-solving helps students analyze information, evaluate evidence, and draw well-founded conclusions (Halpern, 2003).

It is worth noting that STEAM education emphasizes creativity and innovation. The artistic and engineering components of STEAM projects encourage students to generate unique ideas, find novel solutions, and develop creative abilities. Research has shown that creative thinking is associated with improved academic performance and career success (Sternberg & Lubart, 1995).

Educators (Deci & Ryan, 2000) highlight another crucial aspect of development: fostering self-motivation and curiosity. The integrated and interdisciplinary nature of STEAM projects engages students and encourages them to explore subjects more deeply. Research has shown that students motivated by an intrinsic desire to learn achieve higher academic performance and maintain a more positive attitude toward education. Given the shift in adolescents' primary focus from learning to peer interaction, these aspects of STEAM education can also help sustain students' academic motivation.

The application of STEAM education requires students to develop high cognitive flexibility and adaptability. Students must be able to switch between disciplines and apply different approaches to problem-solving. This cognitive flexibility enables them to cope with uncertainty and find solutions across various contexts (Miyake & Friedman, 2012).

As part of the dissertation research, a formative experiment was conducted to apply STEAM technologies in Natural Science lessons for 6th-grade students across three regions of the Republic of Uzbekistan. The "Animation" module from the aforementioned technology was selected for the experiment. Scenarios were developed based on the themes outlined in the Natural Science textbook. The experiment was carried out in three stages.The first stage was diagnostic, during which the students' academic performance and knowledge retention in the subject were assessed. The second stage involved the implementation of the formative experiment itself. In the third stage, data were collected on the impact of project-based activities on students' performance in Natural Science.

The general data on the participants involved in the study are presented in Table 1.

Andijan		Kokand		Namangan		Total
CG	EG	CG	EG	CG	EG	
54	58	55	58	55	57	**337**

Table 1. Distribution of Experiment Participants by City

To obtain more reliable results, the participants were divided into Experimental (173) and Control groups (164). For the first, diagnostic stage, tests were developed based on the topics presented in the 6th-grade Natural Science textbook. The results were categorized into four groups: high, good, satisfactory, and unsatisfactory. The following results were obtained at this stage (Table 2):

	Andijan		Kokand		Namangan	
	CG	EG	CG	EG	CG	EG
High	11	9	7	12	8	11
Good	11	16	13	17	18	15
Satisfactory	19	21	13	18	12	18
Unsatisfactory	13	11	22	11	17	13
Total	**54**	**58**	**55**	**58**	**55**	**57**

Table 2. Pre-Experiment Test Results.

At the second stage, scenarios were developed for a future animated video using the stop-motion method. The scenarios were dedicated to the following topics:

- Topic 9: Study of the phenomenon of diffusion [3; 23]
- Topic 11: Density of matter [3; 27] (page 27)
- Topic 19: Study of plant systematics [3; 43]

For editing the photos, the frame-by-frame animation software Adobe Animate was used. The online version of Adobe Animate is regarded as a classic and popular tool for creating animations. It also offers a free trial version.

The work with students was conducted as extracurricular activities in Natural Science, once a week, in the form of project-based learning. Preparations for the videos, including decorations and characters, were made in advance. Under the guidance of the researcher, students independently crafted, glued, and molded the elements. Creating the characters required the students to study their structure, shape, size, and functioning in greater detail. Next, the scenes were captured frame by frame, demanding focus and precision from the students. In the final stage, a large number of photographs had to be compiled into a single video. This project reflected their mastery of technical tools and their ability to work with the Adobe Animate software.

At the third stage, we conducted a follow-up test. The following results were obtained (Table 3):

	Andijan		Kokand		Namangan	
	CG	EG	CG	EG	CG	EG
High	11	16	8	17	12	14
Good	12	19	11	20	12	21
Satisfactory	22	15	14	13	17	15
Unsatisfactory	10	8	22	8	14	7
Total	**54**	**58**	**55**	**58**	**55**	**57**

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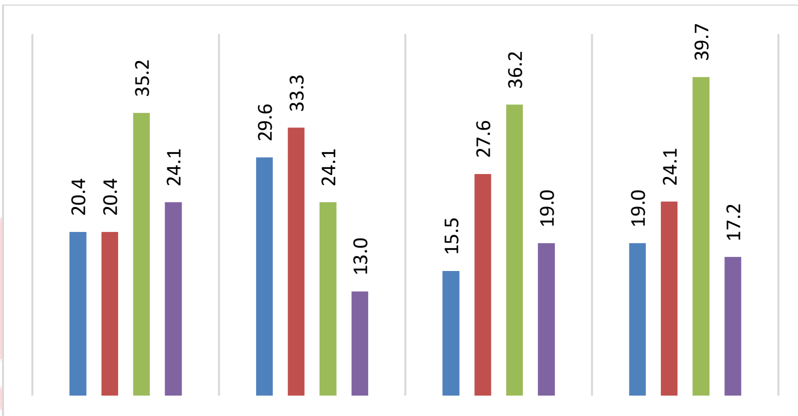
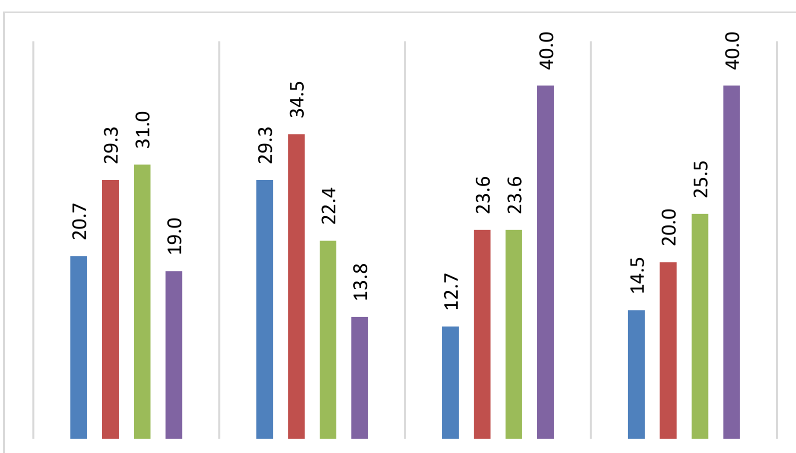
Table 3. Post-Experiment Test Results.

The table shows changes in the number of students in each group. Specifically, the number of students from the Experimental group who achieved high scores on the tests increased by an average of four. Additionally, the number of students with unsatisfactory scores decreased. In the Control groups, where the experiment was not conducted, no significant changes were observed. To visualize the results, the scores were represented graphically. For this purpose, we calculated the percentage changes before and after the experiment. Thus, Graph 1 presents the results obtained in the city of Andijan.



Graph 1. Comparative Results Before and After the Experiment.

In the Experimental Group, the percentage of students with high scores increased by 9.2%, while the percentage of those with unsatisfactory results decreased by 11.1%. This may indicate the effectiveness of the methodology used in studying Natural Science. In the Control Group, the percentage change averaged around 3%. Below, Graph 2 presents the results of the participants from the city of Kokand.



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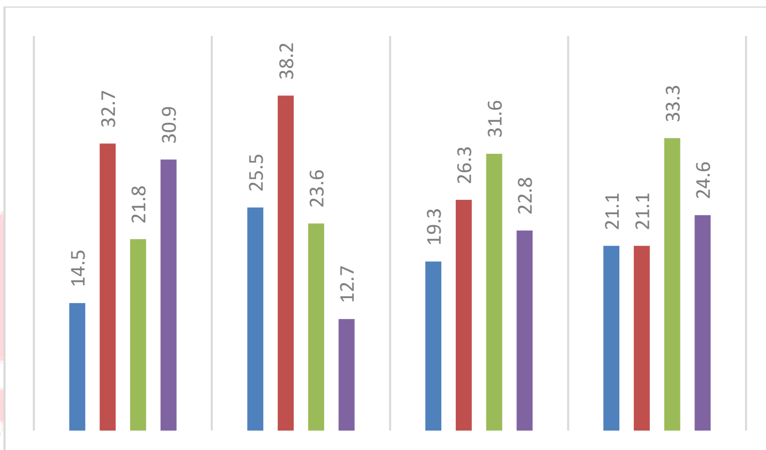
Graph 2. Comparative Results Before and After the Experiment.

This graph shows the dynamics of academic performance changes among 6th-grade students from Kokand. In the Experimental Group (EG), there is a positive trend, with the number of high-achieving students increasing by 7.6%. Meanwhile, in the Control Group (CG), this indicator changed by only 2.2%. The number of students with unsatisfactory responses remained unchanged in the CG, whereas in the EG, the number of such students decreased by 6.2%. These results further confirm the positive impact of the experiment on students' academic performance. Next, we will analyze Graph 3, which presents the results obtained in the city of Namangan..



Graph 2. Comparative Results Before and After the Experiment

The primary indicator of interest is the group with high results. In the Experimental Group (EG), this indicator increased by 11%, while in the Control Group (CG), it rose by only 1.8%. The percentage of students with unsatisfactory results decreased by 18.2%, the most significant improvement compared to other cities. Observations of 6th-grade students in Namangan yielded unexpected results. The most active participants in project-based activities turned out to be students with low grades. They contributed the most ideas for solving various problem tasks and completed creative assignments more quickly (e.g., decorating sets, making characters move, etc.). In our view, the STEAM approach successfully revealed the creative potential of students traditionally considered low-performing.

CONCLUSION

In conclusion, we can say that the psychological principles of STEAM education in middle school play a crucial role in students' development, fostering cognitive skills, creativity, and critical thinking. Integrated learning, problem-solving, a focus on creativity, self-motivation, and cognitive flexibility are key elements that contribute to students' overall growth and prepare them to tackle the complex challenges of the future. Promoting STEAM education in middle school can significantly impact students' academic performance, personal development, and

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future success. The formative experiment we conducted demonstrated the effectiveness of this approach in studying Natural Science. Project-based activities not only enhanced students' understanding and retention of the topics studied but also revealed their creative potential, developed their creative thinking, and increased their motivation to engage with science-related subjects.

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