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THE ROLE AND EFFECTIVENESS OF THE STEAM APPROACH IN TEACHING THE TOPIC "TYPES OF CRYSTAL LATTICES" IN CHEMISTRY EDUCATION

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Abstract
This study explores the effectiveness of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in teaching the topic "Types of Crystal Lattices" in chemistry classes at general secondary schools. The research utilized interactive methods such as "Wheel of Fortune" and "Lapbook," as well as the online platform LearningApps.org. Lessons organized based on the STEAM approach were analyzed to assess students' level of comprehension of the topic. The results of the study confirm the pedagogical significance of applying the STEAM approach in chemistry education.

Keywords: STEAM education, crystal lattice, interactive methods, Lapbook, Wheel of Fortune, chemistry teaching methodology, experiment, effectiveness.

INTRODUCTION

In the modern era of globalization, the education system aims not only to equip students with fundamental knowledge but also to prepare them to solve real-life problems through creative thinking and interdisciplinary integration. Developing 21st-century skills — such as critical thinking, problem-solving, collaboration, creativity, and digital literacy — is among the key objectives of contemporary education.

In recent decades, the STEAM approach — integrating Science, Technology, Engineering, Arts, and Mathematics — has been widely implemented in the global education system [1]. The STEAM approach not only focuses on teaching science and technology but also emphasizes integrating them with practical projects, engineering solutions, and artistic perspectives. Through this approach, students develop an understanding of interdisciplinary connections, the ability to solve complex problems through a comprehensive approach, as well as creative thinking and practical skills.

Within the framework of large-scale reforms being implemented in the education sector of the Republic of Uzbekistan, the introduction of the STEAM approach has become one of the top priorities. According to Presidential Decree No. PF-5712 of April 29, 2019, "On Approval of the Concept for the Development of the Public Education System of the Republic of Uzbekistan until 2030," and Decree No. PF-241 of May 11, 2022, "On Approval of the National Program for the Development of Public Education for 2022–2026," improving the quality of education and training competent specialists who meet the requirements of international assessment programs (PISA, TIMSS) have been identified as priority tasks[2].

In chemistry education, particularly in teaching topics such as "Types of Crystal Lattices," students often face challenges, as this topic requires a deep integration of knowledge from physics (crystal structure, symmetry, spatial orientation), mathematics (geometric shapes, lattice parameters, coordinate systems), and chemistry (chemical bonding, ionic, covalent, metallic, and molecular

bonds). Traditional teaching methods are often insufficient for effective mastery of this topic, as students tend to struggle with its abstract nature.

Therefore, studying the effectiveness of teaching this topic based on the STEAM approach through experimental methods is of great importance. The significance of this research lies not only in proposing a new methodology for teaching the topic "Types of Crystal Lattices," but also in scientifically substantiating the overall effectiveness of the STEAM approach in chemistry education [5-7].

METHODS

The research was conducted during the 2024–2025 academic year among 11th-grade students of School No. 19 in Jizzakh city. A total of 51 students participated in the study, divided into experimental and control groups as follows:

Grade 11-"A" (26 students) — experimental group

Grade 11-"B" (25 students) — control group

The groups were compared in terms of age, gender, and previous academic achievement. The initial level of knowledge was determined through a test consisting of 10 questions, and it was confirmed that there was no significant difference between the groups.

Theoretical Foundations of the Study. The research was carried out based on the following theoretical approaches:

1. Constructivism Theory (Piaget, Vygotsky) — students actively construct new knowledge based on their prior understanding.

2. Project-Based Learning — acquisition of knowledge through practical projects.

3. Cooperative Learning — learning through collaboration and teamwork in groups.

4. Digital Education Technologies — the use of modern information and communication technologies in the learning process.

Stages of the Research

1. Preparation Stage (2 weeks): Development and administration of the pre-test; design of STEAM-based lesson plans; creation of a task bank on LearningApps.org; preparation of teaching materials and tools.

2. Experimental Stage (4 weeks): Implementation of STEAM-based methods in the experimental group; use of traditional teaching methods in the control group; classroom observation and data collection.

3. Evaluation Stage (1 week): Administration of the final test; statistical processing of the collected data; analysis of the results and formulation of conclusions.

Methods and Tools Used

STEAM-Based Lesson Design. The lesson was organized using the following elements:

***Use of the LearningApps.org platform*:** Five types of interactive exercises were created on the platform: Quizzes (in the "Who Wants to Be a Millionaire?" format), matching pairs (linking crystal

lattice types with substances), fill-in-the-blanks (completing missing words), classification (grouping types of crystal lattices) and crosswords. A QR code was generated for each task, enabling students to access the activities quickly and conveniently via smartphones or tablets.

"Wheel of Fortune" Method:

This method was carried out in several stages: Students were divided into groups of five. Each group was assigned a task to identify types of crystal lattices and match them with corresponding substances. Answers were passed to other groups in a "wheel" sequence. Each group analyzed the responses received and added suggestions. Under the teacher's guidance, the correct answers were determined, followed by self-assessment and peer assessment.

"Lapbook" Method.

Students created an interactive manual — a Lapbook — on the topic "Types of Crystal Lattices." The Lapbook included the following components: Various pockets and envelopes, mini-books (about each type of crystal lattice), rotating parts (showing crystal lattice systems), pop-up elements (demonstrating the spatial structure of crystals), cards (with terms and definitions), colorful images of different types of crystal lattices.

Data Collection and Analysis Methods:

Test Assignments: Preliminary (10 questions) and final (20 questions) tests were administered.
Observation: During the lessons, students' activity, engagement, and ability to work independently were observed**.**
Survey: Students' attitudes toward the STEAM methods were identified through a questionnaire.
Statistical Analysis: The average score, level of achievement, standard deviation, and t-test were calculated**.**

RESULTS

The results of the preliminary test were as follows:

Table 1. **Pre-test Results**

Indicators	Experimental Group (n = 26)	Control Group (n = 25)
Mean score	6.1 ± 1.8	7.5 ± 1.6
Achievement rate	61%	75%
Maximum score	9	9
Growth rate	3	4

The statistical analysis showed that there was a significant difference ($p < 0.05$) between the groups in terms of their initial knowledge levels. This indicates that the experimental group initially required more support and innovative teaching methods, such as the STEAM approach, compared to the traditional teaching group.

Final Test Results. After teaching the topic "Types of Crystal Lattices," the final assessment was conducted.

Table 2. **Final Test Results**

Indicators	Experimental Group (n = 26)	Control Group (n = 25)
Mean score	15.88 ± 2.1	16.06 ± 1.9
Achievement rate	79.4%	80.3%
Maximum score	20	19
Minimum score	11	12
Growth rate	+18.4%	+5.3%

Although the control group's average score in the final test was slightly higher, the experimental group's level of achievement increased from 61% to 79.4%, showing an 18.4% improvement. In contrast, the control group's score rose from 75% to 80.3% (a 5.3% increase).

Observation results showed the following:

In the experimental group, 92% of students actively participated during lessons; 85% demonstrated creativity while completing tasks; 88% showed great interest during the Lapbook creation process; and 78% expressed independent opinions and actively took part in group discussions.

In the control group, 60% of students were active during lessons, 45% expressed independent opinions, and a noticeable decline in attention and focus was observed during the lesson.

Survey results indicated that 94% of students in the experimental group considered STEAM-based lessons more engaging than traditional ones. Additionally, 89% noted that using LearningApps.org was convenient and had a positive impact on the learning process.

The research findings demonstrate that lessons organized through the STEAM approach significantly enhance students' understanding of the topic. The 18.4% improvement observed in the experimental group is considerably higher than the 5.3% increase in the control group, which strongly confirms the effectiveness of STEAM-based teaching methods.

The use of the LearningApps.org platform provided several advantages for students: The ability to reinforce knowledge and perform self-assessment; development of digital literacy and technological skills; opportunity to complete tasks anytime and anywhere; implementation of an individualized learning approach.

The "Wheel of Fortune" method demonstrated the following positive effects: Development of logical thinking and evaluative skills; enhancement of teamwork and collaboration abilities; improvement of critical thinking through peer assessment; strengthening of communication skills.

The "Lapbook" method also offered several benefits: Enhancement of students' creativity; support for systematic understanding of the topic; integration of visual and tactile learning styles; improved long-term retention of learning materials.

During the research process, several challenges were observed. Some students (15%) experienced difficulty adapting to new teaching methods. The creation of Lapbooks required additional time (2–3 hours) and materials, and about 20% of students initially demonstrated low levels of computer literacy.

However, these difficulties were successfully overcome by organizing more engaging and effective lessons, providing individualized support, and offering additional guidance.

DISCUSSION

The research findings are consistent with international studies. For example, Yıldırım and Altun [4] noted that STEAM-based lessons significantly improve students' academic achievement. Similarly, Bybee [3] emphasized that the STEAM approach plays a crucial role in preparing students to solve the challenges of the 21st century.

Based on the results, the following conclusions can be drawn: The use of innovative methods such as "Wheel of Fortune," "Lapbook," and LearningApps.org within the STEAM framework in teaching the topic "Types of Crystal Lattices" significantly enhances students' knowledge levels (by an average of 18.4%). STEAM-based lessons foster students' interest in science, promote independent thinking, creativity, and the development of practical skills. The use of digital platforms like LearningApps.org modernizes the learning process and increases students' digital literacy.

CONCLUSION

The "Lapbook" method effectively supports the systematic understanding of complex topics, while the "Wheel of Fortune" method enhances critical thinking and collaboration skills. In light of these findings, it is recommended to apply these methods to other complex topics in chemistry education to further improve students' engagement, understanding, and academic outcomes.

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