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Pedagogical Effectiveness of Interdisciplinary Integration in English Language Teaching Based on the Steam Approach

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ABSTRACT: This research article is dedicated to examining the pedagogical effectiveness of interdisciplinary integration in teaching English through the STEAM (Science, Technology, Engineering, Arts, Mathematics) approach. The study analyzes the essence of STEAM, methods for teaching English via interdisciplinary integration, interactive approaches, and their role in developing students' communication skills, critical thinking, and creative abilities. Research findings from both Uzbek and international scholars provide scientific evidence supporting the pedagogical efficiency of the STEAM approach.

Introduction.

In today's context of global competition, the education system is required not only to impart knowledge but also to develop students' complex skills — including communication, problem-solving, creative thinking, and critical thinking. In this regard, the STEAM (Science, Technology, Engineering, Arts, Mathematics) approach has become a priority direction in modern education. The STEAM approach enables students to solve real-world problems based on interdisciplinary connections. With globalization and the rise of the digital economy, the demands on the education system have fundamentally changed. Today, students are expected not only to acquire linguistic knowledge but also to develop “21st-century skills” (the 4Cs: Critical thinking, Creativity, Collaboration, Communication). Teaching English through the STEAM approach is not merely about learning grammatical rules; it is a contemporary pedagogical strategy that emphasizes learning the language through specific disciplines and creative projects. Determining the pedagogical effectiveness of STEAM in English language instruction has thus become a current scientific and practical necessity. The STEAM approach transforms English lessons from passive learning into active, contextually meaningful activities.

Purpose of the Study. The aim of this study is to provide a scientific justification of the pedagogical effectiveness of interdisciplinary integration in teaching English based on the STEAM approach.

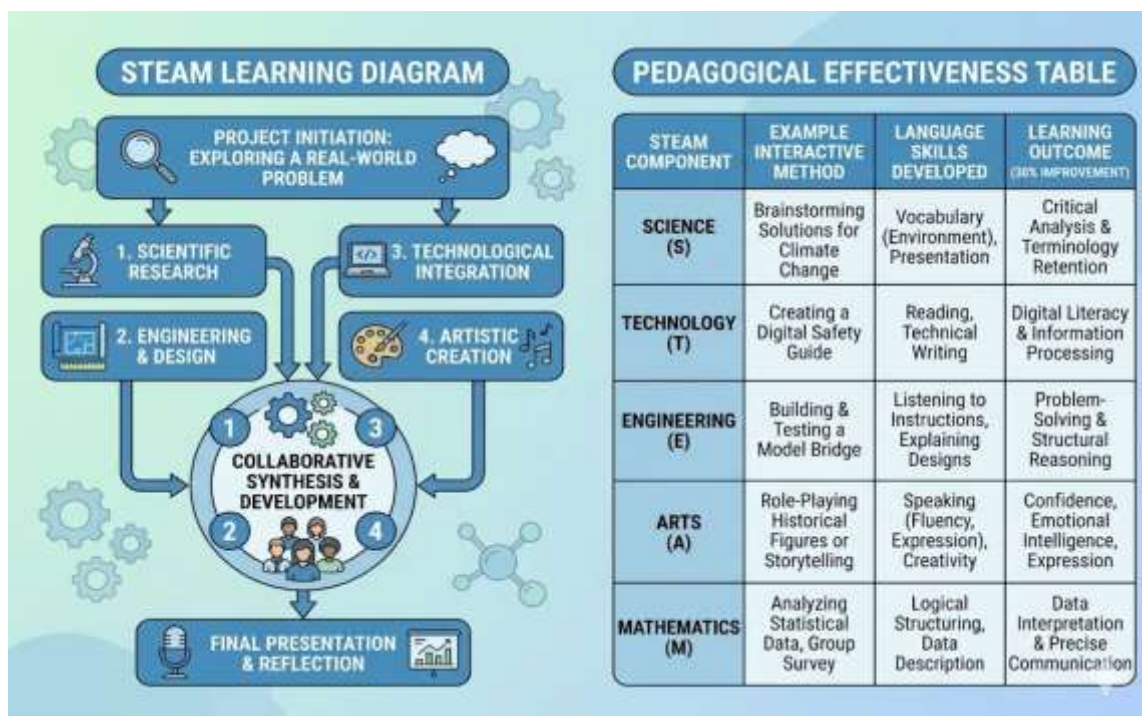


Figure 1. The Conceptual Framework of STEAM Integration and Pedagogical Efficiency in Language Education

The STEAM approach is a methodology that integrates different subjects (Physics, Mathematics, Technology, and Arts) to provide students with knowledge through the resolution of complex problems. Based on scientific and practical foundations, it helps develop students' high-level critical thinking, innovative decision-making, and teamwork skills. The pedagogical principles of STEAM have been scientifically substantiated by several scholars. For instance, according to Howard Gardner's theory of multiple intelligences, each student possesses various types of intelligence, which can be developed through an interdisciplinary approach [5]. Jerome Bruner emphasizes that learning is most effective when students actively discover knowledge themselves [12].

The STEAM methodology allows students to simultaneously learn multiple fields of knowledge and understand the interconnections between them. Interdisciplinary integration refers to the approach of connecting several subjects and providing knowledge through complex tasks. In English language teaching, this method is implemented as follows: students create scientific projects in English (for example, analyzing a mathematical problem or explaining a natural phenomenon in English). This process strengthens both their language skills and their understanding of interdisciplinary connections. By expressing foundational subject knowledge in English, students gain not only language proficiency but also a deeper understanding of scientific concepts.

The STEAM approach presents content in English through videos, diagrams, and digital models, which enhances both students' verbal and analytical thinking skills. According to the cognitive development theory of Jean Piaget, students consolidate knowledge more effectively through interactive activities [11]. Interactive methods play a crucial role in the effectiveness of the STEAM approach, as they increase student engagement and encourage the practical application of language in real-life contexts.



Figure 2. Structural-Logical Model of an Interactive Lesson Process

Types of Interactive Methods:

Group Work — students work together in small groups to complete tasks.

Debate — develops skills in defending one's opinion and engaging with opposing viewpoints.

Brainstorming — encourages creative thinking.

Cluster Method — teaches a topic by classifying it graphically.

Role Playing — simulates real-life situations.

For the STEAM approach to be effective, pedagogical conditions are crucial. The teacher must have a deep knowledge of modern educational technologies, as STEAM requires a carefully planned didactic system. In an open environment for expressing opinions, students actively participate in discussions and confidently articulate their thoughts. Collaboration between teacher and students is essential, and Bruner's principle of dialogue-based learning plays a significant role in this process [8]. The STEAM approach helps students develop the following skills: they consistently express their ideas in English during lessons, provide arguments, and actively participate in discussions. Solving interactive problems enhances analytical thinking. John Hattie's research on active learning methods highlights the importance of such approaches [6]. STEAM frequently includes creative tasks, encouraging students to develop innovative solutions. The STEAM approach organizes the educational process in an interactive, context-based, and practical manner. In English language teaching, this is expressed through the following methodological principles: Students work with real-life situations, such as analyzing ecological, technological, or social issues in English, which enhances their critical thinking and deep understanding of the subject. Students create interdisciplinary projects in English. For example, they may interpret graphs in mathematical statistics or describe biological processes in English. This process develops both verbal and logical skills. The STEAM approach transforms students from passive listeners into active participants. Through group work, role-playing, and debates, students learn to justify their ideas, ask questions, and solve problems. Richard E. Mayer recommends combining visual, auditory, and interactive methods through multimodal teaching, which increases the effectiveness of teaching English via interdisciplinary integration [9].

Teaching English through the STEAM approach results in the following positive changes in students:

- **Increased verbal activity** — students freely express their thoughts in English during lessons.

- **Enhanced critical thinking** — problem-solving activities and debates develop students' analytical skills.
- **Fostered creativity** — projects and brainstorming exercises encourage innovative thinking.
- **Strengthened teamwork skills** — group activities improve collaboration, problem-solving, and communication abilities.
- **Improved independent learning skills** — the STEAM approach allows students to assess their work and draw conclusions independently.

In recent years, the STEAM approach has been widely implemented in schools in Uzbekistan. For example, in some schools in Tashkent, interdisciplinary projects in English integrate subjects such as Biology and Computer Science. As a result, students strengthen not only their language skills but also their scientific knowledge. In the United States and European countries, STEAM has become a standard part of education. For instance, in schools in California and Finland, interdisciplinary integration is widely practiced through project work and laboratory sessions conducted in English. This significantly develops students' communicative, critical thinking, and creative skills [6, 7].

Digital platforms, virtual laboratories, and interactive software further enhance the effectiveness of the STEAM approach.

Virtual Classes and Online Projects – students collaborate remotely, maintaining teamwork even at a distance.

Interactive Presentations – students gain a deeper understanding of topics through graphics, diagrams, and multimodal content.

Debates and Forums – students are able to justify their own ideas and analyze the viewpoints of others. According to the educational theories of **Jean Piaget** and **Lev Vygotsky**, students acquire knowledge more effectively in interactive and multimodal learning environments [7, 11]. This table systematizes the **cognitive and communication competencies** that develop in students through the mastery of STEAM subjects.

Table1

STEAM Component	Cognitive Focus	Communicative Competence	Competence Learning Outcome (30% Improvement)
SCIENCE (S)	Critical Analysis	Reading, Data Visuals	Digital Literacy & Information Processing
TECHNOLOGY (T)	Information Processing	Listing, Explaining	Structural Reasoning & Design thinking
ENGINEERING (E)	Problem-Solving	Listing, Explaining	Structural Reasoning & Design thinking
ARTS (A)	Creativity, Expression	Speaking (Fluency), Emotion	Confidence, Expression, & Interaction
MATHEMATICS (M)	Data Interpretation	Logical Structuring	Data Description & Precise Communication

The STEAM approach demonstrates maximal effectiveness in teaching English when combined with interactive methods. This integration is manifested in the following areas: Group Work and Project-Based Learning – Students carry out interdisciplinary projects in small groups. For example, preparing an ecological project in English combines knowledge of biology and chemistry. This process enhances students' verbal activity and critical thinking skills.

Debate Methods – Students discuss problem-based issues in English. For instance, debating “Renewable Energy vs. Fossil Fuels” allows them to express interdisciplinary knowledge logically and practice argumentation skills.

Role Play – By simulating real-life situations, students strengthen their communicative skills. Examples include presenting laboratory results in English or simulating a scientific conference.

Brainstorming – Students generate new ideas, link topics to various subjects, and develop creative thinking.

Cluster Method – By visually representing interdisciplinary integration and analyzing topics graphically, students are trained to think logically.

When these methods are combined, students' motivation for learning and independent study skills increase significantly.

The STEAM approach becomes even more effective in teaching English through digital technologies.

1.Virtual Laboratories – Students conduct experiments in biology, chemistry, or physics online in English, reinforcing interdisciplinary knowledge.

2.Online Platforms and Forums – Students communicate in English on forums, justify their opinions, and learn to listen to others.

3.Multimodal Learning – Richard E. Mayer emphasizes the effectiveness of combining visual, audio, and interactive content [9]. For example, video lessons, infographics, and interactive presentations reinforce interdisciplinary integration.

4.Assessment and Reflection Tools – Students analyze their activities through online tests, evaluation forms, and portfolios, promoting independent learning and critical thinking. Teaching English through STEAM and interdisciplinary integration leads to the following pedagogical outcomes:

5.Enhanced verbal activity and communicative competence – Students express ideas clearly in English, provide arguments, and respond to questions.

6.Development of critical and creative thinking – Debates, problem-solving tasks, and brainstorming activities foster analytical and creative thinking.

7.Strengthened teamwork skills – Group projects and role plays teach students collaboration and joint problem-solving.

8.Improved independent learning ability – Reflection and self-assessment enable students to analyze and improve their knowledge independently.

9.Deeper mastery of knowledge through interdisciplinary integration – For example, explaining physical processes in English or linking mathematical statistics to biological experiments promotes cohesion across subjects. Research by both Uzbek and international scholars shows that teaching English through STEAM and interdisciplinary integration significantly enhances students' knowledge, skills, and social competencies [5, 6, 7, 8].

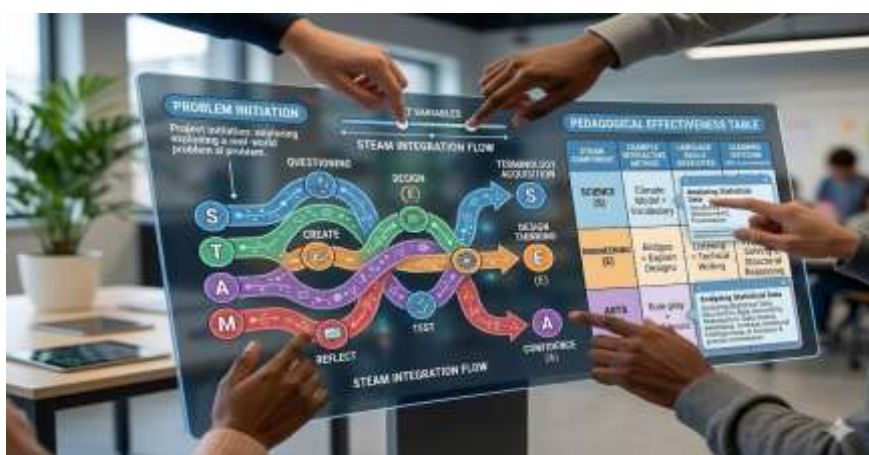


Figure 3. Interactive Visualization of STEAM Integration Flow and Pedagogical Outcomes in a Digital Learning Environment.

CONCLUSION.

The interdisciplinary integration in teaching English based on the STEAM approach significantly enhances pedagogical effectiveness. This approach develops students' verbal activity, critical and creative thinking, teamwork skills, and independent

learning abilities. Interactive methods such as group work, debates, role-playing, the cluster method, and brainstorming facilitate deeper understanding of interdisciplinary topics in English.

By utilizing digital platforms, multimodal materials, and virtual classrooms, students apply knowledge in practice and enhance their independent learning through self-assessment. At the same time, they become socially active, cultivate communication culture, and develop as independent thinkers capable of meeting the demands of modern society. Research by both Uzbek and international scholars indicates that systematic and consistent use of the STEAM approach and interdisciplinary integration methods improves the quality of education, strengthens students' communicative and social competencies, and makes lessons more engaging and effective. Therefore, educators should integrate interactive and interdisciplinary strategies at all stages of the lesson to maximize learning outcomes.

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