FORMATION OF STUDENTS' CRITICAL AND CREATIVE THINKING SKILLS THROUGH STEAM TECHNOLOGIES

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Annotation. The article examines the theoretical and pedagogical foundations of STEAM (Science, Technology, Engineering, Arts, and Mathematics) technology within the modern educational paradigm. It provides a scientific analysis of the role of interdisciplinary integration in developing students' critical thinking, creativity, and engineering skills. The content of the STEAM components is detailed, and their connection to the constructivism theory of J. Piaget and L.S. Vygotsky is substantiated. The research focuses on the formation of a new type of intellectual personality capable of applying theoretical knowledge to solve practical and innovative engineering tasks.

Keywords: STEAM education, interdisciplinary integration, transdisciplinary approach, constructivism theory, engineering thinking, design thinking, creativity, methodology of scientific cognition.

Introduction

In the modern educational paradigm, STEAM technology (Science, Technology, Engineering, Arts, Mathematics) is a transdisciplinary approach that unites academic disciplines within a single paradigm, rather than in an isolated state. Its main goal is not only the development of students' cognitive abilities, but also the formation of a new type of intellectual personality that directs theoretical knowledge to solving practical, engineering and creative tasks. STEAM is a modern approach to learning based on interdisciplinary integration in education, which aims to develop students' critical thinking, creativity, research, and problem solving skills by combining the fields of Science, Technology, Engineering, Arts, and Mathematics.

The depth of the content of STEAM components and their scientific description in the context of the article are determined as follows:

*S- Science : This component forms the methodology of scientific cognition for students. It allows you to objectively understand the laws of the environment by observing natural phenomena, conducting empirical research, hypothesizing and testing them in practice.

* T- Technology : not only the use of modern tools and digital resources, but also their programming and optimization as an effective mechanism for solving a specific problem. This section lays the foundation for digital literacy and algorithmic thinking.

*E- Engineering : Through design and engineering, students acquire design thinking skills. Engineering is the connecting link that transforms scientific laws and technological capabilities into a real material or digital model.

* A- Art : The "art" component in STEAM attaches humanitarian and aesthetic importance to technological solutions. He ensures that technical projects are human-centered, developing creativity, visual communication, and empathy. This component stimulates divergent thinking (the search for multiple solutions to the same problem).

* M- Mathematics: It is considered as the logical basis of all components. He justifies the viability and effectiveness of projects through data analysis, mathematical modeling, computational accuracy, and abstract thinking.

The main purpose of this model is to develop integrated thinking, creativity, research and technological skills, and not just provide students with knowledge.

Results and discussion. Below is a detailed scientific and methodological explanation of the pedagogical foundations of the STEAM approach. Let's delve into the pedagogical foundations of the STEAM approach.

1. The theory of constructivism (J. Piaget, L. S. Vygotsky). The main idea of this theory is that education is a process based on the active activity and experience of the student. The student independently "constructs" new information, linking it with previous knowledge. In STEAM lessons, the student does not receive ready-made knowledge, experiments independently, studies the problem and makes discoveries. The individual trajectory of thinking and cognitive activity of each student are taken into account. For example: a student and a group invent a tool that uses solar energy. In this process, they combine science, mathematics, art, and technology in their personal practice.

2. Theory of interdisciplinary integration. The main idea of this theory is that the content of education should be organized not only within the framework of a discipline, but also in a combination of several disciplines. Modern problems are solved not only within the framework of one discipline, an integrated approach is needed.

STEAM is a prime example of an interdisciplinary approach. Students simultaneously use various subject knowledge (for example, physics and art) to solve the problem. For example:

A student in the Eco-City project:

- studies climate in geography,
- creates a mock-up from engineering,
- suggests a design from art,
- calculates in mathematics,
- simulates using devices from the technology.

3. Theory of active and exploratory learning. The main idea of this theory is that the student's search activity and research skills cause a deep assimilation of knowledge. He is a teacher-facilitator (guide), student – researcher, experimenter. Students study, analyze, build, and evaluate themselves. This approach develops life skills and scientific literacy. Let's give an example:

In the project "assembling a water treatment device ", the student:

- examines the problem,
- offers a solution,
- creates a prototype,
- conducts tests and provides results.

4. Creative thinking and design thinking. The main idea of this theory-the development of a creative and innovative approach-is important for a person of the 21st century. Design thinking consists of 5 stages of the process from empathy to problem solving: empathy → discovery → idea → prototype → testing. In STEAM lessons, the student acts with creative freedom. Making a "mistake" is considered a means of gaining knowledge, it is a normal practice. For example: in the School of the Future project, a student introduces a new learning model: he performs creative work on the design, structure, digital tools and aesthetics of the school.

5. Humanistic pedagogy (K. Rogers, A. Maslow). The main idea of this theory is that each student is a unique person. It is necessary to create conditions for the disclosure of his abilities, freedom and choice. Internal motivation, self-awareness, and evaluation are important. When learning STEAM, a student can make a choice according to their interests, and offer their own idea. The student is responsible for his work, sets goals, evaluates himself. For example: during STEAM week, students freely choose their projects: one creates an energy–efficient house, and the other simulates the 3D layout of the city.

Materials and methods: Summarizing the pedagogical foundations of the STEAM approach, we have prepared the table below.

Theory	Connection with STEAM
Constructivism	The student creates knowledge on his own experience.
Interdisciplinary integration	The boundary between disciplines is blurring
Research training	Student-researcher, teacher-guide

Creativity and design thinking	Creative problem solving
A humanistic approach	The individual characteristics and the choice of the student are taken into account

STEAM is an innovative educational technology aimed at developing students' critical and creative thinking skills, research culture, creativity, and skills in solving real-life problems that combine science, technology, engineering, art, and mathematics in interdisciplinary relationships.

Through STEAM, students develop the most important "4K" skills of the 21st century.:

1. Critical thinking.
2 . Creativity.
3. Communication — protection and transmission of your idea.
4. Collaboration — working in a group.

The "4K" model in the context of STEAM technologies is a set of soft skills necessary for a modern specialist. The peculiarity of STEAM Education is that here these four skills are developed not separately from each other, but as part of a single process.

Below we will discuss in detail the role of each skill in STEAM design:

1.Critical thinking. It is the ability to filter information, identify cause-and-effect relationships, and make informed decisions. In a scientific experiment or mathematical calculations, the student puts forward hypotheses. If the experiment is not successful, the student may ask, "Why did this happen?"analyzes the issue. The student does not memorize the finished formula, understands where this formula came from and how to test it in practice. This creates a culture of "dealing with errors."

2.Creativity. Creativity is not just drawing, it is an opportunity to find an unconventional, new solution to any problem. When Engineering and art combine, creativity is born. For example, when designing a bridge layout, a student comes up with not only its strength (engineering), but also its shape, aesthetics, and ways to save resources (creativity). The student learns ingenuity by building a complex object in conditions of limited resources (for example, using only paper and glue).

3. Communication. This is the ability to express your thoughts clearly, visualize data, and communicate with an audience. After completing the project, the student must defend their work. He proves the value of his idea using technical drawings, graphs, and digital presentations. The ability to interpret complex technical or

scientific information in simple language is an important step towards leadership. Here the student learns not only to speak, but also to listen.

4. Collaboration. Collaboration is effective interaction with team members, sharing responsibility on the way to achieving a common goal. Any STEAM project is a team effort. One student plays the role of an "engineer" (responsible for the design), another is a "designer" (aesthetics), and the third is an "analyst" (computing and code).The student feels that he considers other people's opinions, resolves conflicts, and that the success of the team depends on the share of each member.

This is the best school for adapting to the future corporate environment.

The 4K skill interaction model

Skills	The main issue on STEAM	Result
Critical thinking	"How does it work and why?"	Objective analysis
Creativity	"How else can I do it?"	An innovative product
Communication	"How do I explain it?"	Implementation of the idea
Collaboration	"How will we do it together?"	Synergy

4K skills on STEAM are not just additional abilities, they are the main product of the learning process. A student may forget the law of physics, but the skills of working in a team and finding a solution to a problem will remain with him for the rest of his life.

STEAM technologies simply transform a student from a "client" into a "Creator." The combination of critical and creative thinking allows students to quickly adapt to uncertainty and find innovative solutions to complex problems.

Critical thinking is an intellectually ordered process of actively and skillfully formulating, applying, analyzing, accumulating, and evaluating information gathered through observation, experience, reflection, reasoning, or communication.

From the point of view of psychology and pedagogy, this is "thinking about thinking." That is, a person must control the quality of his thought process and check its consistency, accuracy and objectivity.

2 . Cognitive skills of critical thinking.

A group of experts led by Peter Facione (1990) identified six main cognitive components of critical thinking. Be sure to focus on this in the article.:

1. Explanation: comprehension and description of the essence, meaning of data and events.
2. Analysis: breaking down ideas and arguments into their component parts, finding connections between them.
3. Evaluation: verification of the reliability of the information source and the logical strength of the argument.
4. Formulate: draw logical conclusions based on the data, predict the consequences.
5. Provide explanations: substantiate the conclusions of your thought in a reasoned manner.
6. Self-regulation: find mistakes in your thinking and correct them (top level).

3. Connection with Bloom's taxonomy. Critical thinking refers to the higher-level thinking skills of Bloom's taxonomy.

Lower level: know, understand, apply.

High level (critical thinking area): analysis, evaluation, accumulation (or creation).

4. It is important to show that the intellectual qualities of a critical thinker - critical thinking is not only a skill, but also a position of personality. recognizing that one's own knowledge is limited and may make mistakes. be skeptical of established stereotypes and not be afraid to explore new ideas. the ability to see a problem from someone else's point of view

5. What is critical thinking for? The distinction between fake information and manipulation during the " post-truth " period . Find errors in complex systems (STEAM, IT, medicine) and make optimal decisions. Passing it through a scientific filter, without blindly believing in the other's idea.

"Critical thinking is not just a skeptical attitude towards information, it is a logically correct and purposeful system of thinking based on evidence. This is the main factor that transforms a student from a passive recipient into an active researcher."

Conclusion. In international educational practice, STEAM learning is considered as an integrative educational model aimed at developing creative thinking, the ability to make engineering decisions and critical thinking of students in a combination of science and technology with art. In the STEAM learning process, students learn to combine theoretical knowledge with practice and solve real-life problems through design, laboratory, and creative tasks. This approach shapes the student as an active researcher and innovator rather than a passive consumer of knowledge.

Developing students' critical and creative thinking skills through STEAM technologies is an important area of education. These technologies foster an active,

inquisitive, and exploratory personality in the student. STEAM teaching methods motivate students: They intellectually encourage the creation of new ideas and direct them to prepare for the future.

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