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# "STEM EDUCATION" – ON THE THRESHOLD OF THE FUTURE

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**Abstract:** This article provides a comprehensive analysis of the theoretical foundations, historical development, global implementation, and current status of the STEM (Science, Technology, Engineering, Mathematics) education approach—one of the key directions in modern education. In particular, it highlights the advantages of STEM education for the younger generation, such as the development of critical thinking, creativity, problem-solving skills, and technological literacy, based on international experience. The article presents real-life examples of implementing STEM programs at the "Barkamol Avlod" Children's School in Karshi district, showcasing students' involvement in innovative projects. In conclusion, practical recommendations are offered to enhance teacher qualifications, strengthen methodological frameworks, and integrate international practices. From both scientific and practical perspectives, this article is proposed as a methodological resource for further development of STEM education in Uzbekistan.

**Keywords:** STEM education, STEAM approach, critical thinking, technological literacy, innovative education, Barkamol Avlod school, global educational experience, education in Uzbekistan, educational reforms, problem-solving skills.

**Аннотация:**В данной статье представлен всесторонний анализ теоретических основ, исторического формирования, глобального внедрения и текущего состояния STEM-образования (наука, технологии, инженерия, математика), являющегося одним из ключевых направлений современного образования. В частности, на основе международного опыта освещаются преимущества STEM-обучения для подрастающего поколения, включая развитие критического мышления, креативности, навыков решения проблем и технологической грамотности. В статье приведены реальные примеры внедрения STEM-программ на базе детской школы «Баркамол авлод» Каршинского района, отражающие участие учащихся в инновационных проектах. В заключение предложены практические рекомендации по повышению квалификации педагогов, укреплению методической базы и интеграции международного опыта. С научной и практической точек зрения статья может служить методическим ресурсом для дальнейшего развития STEM-образования в Узбекистане.

**Ключевые слова:** STEM-образование, STEAM-подход, критическое мышление, технологическая грамотность, инновационное обучение, школа «Баркамол авлод», мировой образовательный опыт, образование в Узбекистане, образовательные реформы, навыки решения проблем.

**Introduction.** President of the Republic of Uzbekistan, **Shavkat Mirziyoyev**, has rightfully stated: "The foundation of development, the force that makes a nation powerful and great, is science, education, and upbringing." He also emphasized: "We are a nation that has always revered teachers like our own fathers, valuing them as beacons of enlightenment." Furthermore, he noted: "If teaching methodology in schools does not change, neither will the quality, content, nor atmosphere of education." These words are increasingly proving to be true in today's reality.

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**STEM education**—an acronym for Science, Technology, Engineering, and Mathematics—is an interdisciplinary approach that integrates these subjects in a cohesive manner. Its primary objective is to equip students with the skills necessary for 21st-century professions, such as innovative thinking, critical analysis, problem-solving, and creativity.

The STEM approach first emerged in the **United States during the 1990s**, and the term was officially introduced by the **National Science Foundation (NSF)** in 2001. Before that, it was known as "SMET." The revision of the acronym reflected a need to emphasize the interconnectivity among the four disciplines and to present them as a unified educational system.

For instance, the **2005 report** titled "Rising Above the Gathering Storm" highlighted the significance of STEM subjects in ensuring national security and economic stability, stating: "A nation that outsources its science and engineering future risks losing its economic leadership." This report laid the groundwork for numerous government programs, including the **"Educate to Innovate"** initiative launched by President Barack Obama in 2010.

Today, the STEM approach has become an integral part of national education strategies not only in the United States but also in the **European Union, South Korea, Singapore, Japan, and Australia**. In **Singapore**, for example, students begin practical training in robotics and coding as early as age ten. In **Japan**, the Super Science High School project offers selected schools specialized, research-focused STEM curricula that encourage students to conduct scientific investigations.

STEM education is especially crucial in the era of industrial digital transformation. Emerging fields such as **artificial intelligence, automation, and robotics** require a new generation of specialists with interdisciplinary and wide-ranging knowledge. As a result, STEM has come to be regarded as a cornerstone of modern education.

**The Global Importance of STEM Education -** In the 21st century, education systems around the world are being reconsidered in light of economic competitiveness, innovative development, and technological progress. Within this context, **STEM education** has emerged as a global strategic priority. Many advanced nations are integrating this approach at the national level. The main reason for this lies in the recognition that scientific and technological literacy is a cornerstone of modern societal progress.

The **United States** is considered one of the leading countries in this regard. The **Federal STEM Education Strategic Plan**, introduced by the U.S. government in 2018, highlights the need to implement STEM approaches at all levels of education, encourage students to address real-life problems, and enhance the qualifications of teachers (U.S. Department of Education, 2018, p. 9, total 46 pages). According to official statistics, by 2022 more than **10 million students** in the U.S. were enrolled in STEM-related fields of study.

In **South Korea**, STEM education has been gradually introduced starting from the preschool level. As part of the **"Creative Korea"** initiative, "Science Gifted Schools" have been established in each province, offering students lessons in **robotics, artificial intelligence, and coding**. As a result of this program, Korean students aged 15–16 consistently rank high in **PISA international assessments**.

The **Singaporean education system** has become a global model for the integration of STEM approaches. Since 2013, the **"STEM Applied Learning Programme"** has been implemented, allowing students to apply theoretical knowledge to real-life projects in schools. As Tan et al. (2019) observe: "STEM education in Singapore is not just about academic excelence, but about preparing students to be problem-solvers in an uncertain world."

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**Japan**, through its **"Super Science High School (SSH)"** initiative, has focused on engaging students in scientific research activities. Over a five-year period, SSH schools have participated in more than **1,000 international science competitions**, winning over **300 awards**, showcasing Japan's strong commitment to nurturing young scientists.

Within the **European Union**, the **"Horizon Europe"** program is aimed at supporting innovation and research in STEM fields. Between **2021 and 2027**, a budget of **€95.5 billion** has been allocated, with a significant portion dedicated to STEM-based projects, reflecting the EU's strategic investment in future-oriented education and research.

The Current State of the STEM Approach in Uzbekistan's Education System. In recent years, a number of reforms and initiatives have been implemented in Uzbekistan to introduce the STEM (Science, Technology, Engineering, Mathematics) approach into the national education system. This section provides a detailed overview of the role of STEM in the national curriculum, as well as ongoing projects and reforms.

The Role of STEM Elements in the National Curriculum. **On** September 23, 2020**, a revised version of the Law "On Education" was adopted, outlining essential steps toward reforming the national education system. Based on this law, the** National Curriculum Framework (NCF) **was developed, encompassing educational plans, subject syllabi, teaching methodologies, and assessment systems.**

One of the main goals of the NCF is to equip students with 21st-century skills, and in this process, the integration of the STEM approach plays a crucial role.

Ongoing Projects and Reforms. 1. Implementation of STEAM Education

Alongside STEM, Uzbekistan is also adopting the STEAM model, which incorporates the Arts into science and technology education. This model focuses on developing students' creative thinking. According to recent studies, STEAM education serves as an effective bridge between students' personal development and their interaction with the real world.

2. Integration of STEAM Technologies in Early Childhood Education. **The** STEAM approach **is also being introduced in the** preschool education system**. For example, through the** EDU LINK information system**, digital technologies are being implemented in preschool institutions to support early exposure to STEAM-related concepts.**

3. Enhancing Teacher Qualifications.

Under the **Fulbright program** supported by the **American Councils**, efforts are being made to improve curricula and syllabi in STEM subjects, introduce school-based STEM teaching methodologies, and develop **methodological guides** for Uzbek educators. These initiatives aim to provide teachers with modern pedagogical tools and enhance their competence in delivering integrated STEM lessons.

## Advantages of the STEM Approach for the Younger Generation

STEM (Science, Technology, Engineering, Mathematics) education plays a critical role in developing essential skills necessary for the younger generation to succeed in modern society. This approach fosters critical thinking, creativity, problem-solving abilities, and technological literacy.

**Critical Thinking and Problem Solving.** STEM education helps students analyze complex problems and find effective solutions. According to the National Math and Science Initiative, STEM programs encourage independent and creative thinking, enabling students to comprehend and apply advanced concepts.

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**Creativity.** STEM education gives students the opportunity to apply creative approaches in solving open-ended problems. The India STEM Foundation notes that designing prototypes and writing code expands learners' creativity and supports the development of innovative thinking.

**Technological Literacy.** STEM education empowers students with the skills to understand and efficiently use modern technologies. Research from the University of Iowa highlights that incorporating technology into STEM lessons makes learning interactive and engaging, thereby enhancing students' critical thinking and creative skills.

## Implementation of STEM Programs in "Barkamol Avlod" Children's Schools

To increase the scientific and technical potential of the youth, Uzbekistan has undertaken a series of practical measures to implement STEM programs in "Barkamol Avlod" children's schools. In particular, the school in Karshi district has launched several innovative projects aimed at cultivating student interest in technology and engineering.

**Practical Examples and Student Activities.** On March 28, 2024, a competition using the "STEM Engineering" toolkit was held at the Karshi district "Barkamol Avlod" school, where students constructed car models within 15 minutes. The event aimed to develop students' practical skills and interest in engineering.

Additionally, during the national Navruz celebration held at the Karshi Amphitheater on March 20, 2024, students from the same school participated by showcasing their creative works, contributing to both cultural enrichment and the demonstration of creative potential.

**Innovative Projects.** According to a resolution issued by the Ministry of Preschool and School Education of the Republic of Uzbekistan in October 2023, 100 "Barkamol Avlod" schools across the country are set to establish STEAM education laboratories. These labs are designed to further enhance students' scientific and technical knowledge and practical competencies.

## Conclusion and Recommendations: Ways to Further Develop STEM Education

The findings discussed above show that STEM education plays a vital role not only in mastering modern technologies but also in fostering critical thinking, problem-solving, and creative abilities among the younger generation. Although Uzbekistan has launched major educational reforms in this area, further development requires a more systemic approach and targeted initiatives.

**1. Establishing a Systemic Approach.** To ensure the sustainable development of STEM education, a unified methodological base, a national curriculum, and structured teaching materials must be developed. Countries like South Korea and Singapore serve as exemplary models, where STEM subjects are consistently and comprehensively integrated across all educational levels (Tan et al., 2019, p. 128).

**2. Improving Teacher Qualifications.** To implement the STEM approach effectively, educators need to possess adequate knowledge and skills. Therefore, there is a need for nationwide training programs that focus on using modern laboratories, applying interactive teaching methods, and fostering hands-on learning. While pilot training sessions have been conducted with the support of UNICEF and the Fulbright Program in 2023, scaling these efforts remains a priority (unicef.org).

**3. Integrating International Experience.** Advanced nations such as the U.S., Japan, Germany, and Singapore have deeply embedded the STEM approach in their education systems. These countries incorporate real-life projects, start-up workshops, and problem-based learning to provide students with practical, life-connected knowledge. Uzbekistan should similarly collaborate with international educational platforms, invite foreign specialists, and train students for global science competitions.

**Summary of Recommendations:**

- Develop specialized textbooks and manuals on STEM.
- Improve technological infrastructure in schools.
- Encourage student participation in scientific projects.

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- Promote the STEAM approach with art integration.
- Equip laboratories through local and international grants.

## Research Methodology

**Analytical Method.** This article provides a thorough analysis of the essence of STEM education, its global significance, and its current implementation in Uzbekistan, drawing from various academic sources. Comparative studies of Singapore and the U.S. were used to assess how such experiences can be adapted to the Uzbek context.

**Comparative Method.** The article includes a comparative analysis between Uzbekistan's education system and those of countries like Singapore, the U.S., Japan, and South Korea to identify strengths, weaknesses, and applicable best practices.

**Descriptive Method.** Key concepts, historical development, and components of the STEM approach are presented in a simplified and accessible manner, making the article suitable for a wider audience.

**Empirical Method.** Real-life events, initiatives, and projects from the "Barkamol Avlod" school in Karshi district were analyzed using data from official sources and educational news platforms.

**Outcomes of the Article.** A comprehensive analysis of the scientific foundations of STEM education was provided, including its interdisciplinary structure and relevance to modern educational trends.

1. The current state of STEM integration in Uzbekistan's national curriculum and education reforms was critically evaluated.
2. The positive impact of STEM education on youth development—such as fostering critical thinking, creativity, and technological skills—was demonstrated through practical examples.
3. Recommendations were developed based on international best practices, with strategies tailored to the Uzbek educational context, including teacher training, resource development, and infrastructure support.

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