

TEACHING THE SUBJECT “GENETICS” IN THE SYSTEM OF HIGHER  
EDUCATION BASED ON THE STEM EDUCATION APPROACH*Mirzoyeva M.A.*Assistant of the Department of Medical Biology at the Bukhara State Medical  
Institute named after Abu Ali ibn SinoORCID <https://orcid.org/0009-0006-9474-6146>**Abstract**

*This article analyzes the theoretical and practical aspects of teaching the subject Genetics in higher education institutions based on the STEM (Science, Technology, Engineering, Mathematics) education approach. The role of STEM education in the genetics teaching process, opportunities for interdisciplinary integration, and the application of modern pedagogical and digital technologies are examined. Particular attention is given to project-based and problem-based learning methods, virtual laboratories, bioinformatics tools, and mathematical modeling as effective means of developing students' research competencies. The results of the study substantiate that the STEM-based approach in teaching genetics contributes to the development of students' independent thinking, practical skills, and professional readiness.*

**Keywords:** *genetics, STEM education, higher education, interdisciplinary integration, innovative education, project-based learning, problem-based learning, bioinformatics, virtual laboratory, competency-based approach.*

## INTRODUCTION

In the education system of the twenty-first century, innovative approaches have become an important factor in improving the effectiveness of teaching and in developing students' creative thinking and research abilities. One of such modern approaches is the STEM education system, which is based on the integrated teaching of science, technology, engineering, and mathematics.

Moreover, the relevance of STEM education in the modern educational process is reinforced by the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 424 dated July 6, 2021, “On Measures for the Introduction of STEM Education.”

The main objective of the STEM education system is not only to provide students with theoretical knowledge but also to equip them with practical skills, innovative thinking, and scientific analytical abilities. Through problem-solving,

modeling, and project-based activities, students achieve a deeper understanding of knowledge.

Genetics is one of the fastest-developing fields among natural sciences and has significant practical importance. It requires not only biological knowledge but also skills related to technology, computational methods, and modeling. Therefore, introducing the STEM approach into the teaching of genetics is considered an important task for developing students' scientific thinking, research skills, and creativity.

#### *Purpose of the study*

The purpose of this study is to determine the effectiveness of teaching genetics based on the STEM education system and to develop innovative methodological recommendations grounded in this approach.

#### *Objectives of the study*

1. To examine methods of implementing the STEM concept in teaching genetics;
2. To analyze the effectiveness of virtual and animation-based educational tools;
3. To assess students' levels of knowledge, skills, and scientific interest;
4. To compare the outcomes of STEM-based instruction with traditional teaching methods.

#### METHODOLOGY

The research was conducted among second- and third-year biology students of Bukhara State Pedagogical Institute and Karshi State University. A total of 82 students participated in the study. Of these, 41 students were assigned to the experimental group (taught using the STEM-based approach), while 41 students formed the control group (taught using traditional methods).

#### *Content of the experiment*

The topics *Human Genetics*, *Molecular Foundations of Heredity*, and *Solving Genetic Problems* were selected. During instruction, virtual laboratories, animation software, 3D models, genetic coding simulations, and interactive problem-based tasks were actively used.

#### *Teaching process*

Classes were organized using PowerPoint animations and the **GenetikaLab** software. Students were divided into groups, and each group was assigned a specific genetic problem (e.g., blood groups, inheritance of hemophilia, sex-linked traits).

Groups presented their research results using infographics. Students modeled genetic processes using software tools such as **DNA Replication Simulation** and **Punnett Square Builder**.

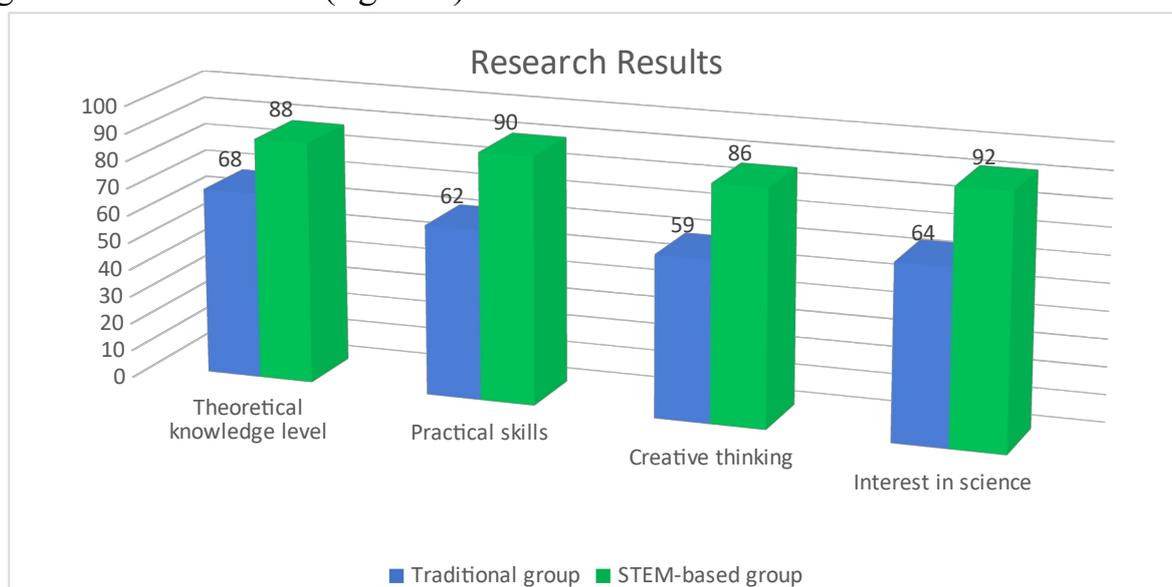
#### *Assessment methods*

Students' performance was evaluated based on the following criteria:

1. Level of theoretical knowledge (assessed through tests);
2. Practical skills (modeling and analysis);
3. Creative and scientific thinking indicators (based on observation and interviews);
4. Students' interest in the subject (assessed through questionnaires).

#### RESULTS

The results of the study showed that students taught using the STEM-based approach demonstrated higher performance indicators compared to those taught using traditional methods (figure 1).



**Figure 1.** Comparative analysis of teaching effectiveness using the STEM education approach

During the research process, the effectiveness of teaching genetics based on the STEM education approach was analyzed. Interdisciplinary integrated lessons, project-based learning, problem-based situations, virtual laboratories, and bioinformatics elements were introduced into the instructional process. The obtained results indicate that the STEM approach has several advantages over traditional teaching methods.

Students taught based on the STEM approach not only gained a deeper understanding of genetic processes but also demonstrated skills in modeling, problem-solving, and research-oriented thinking.

According to interview results, **87% of students** reported that virtual and animation-based methods helped them better understand and retain the subject content.

## DISCUSSION

The findings of the study demonstrate that implementing the STEM education system in teaching genetics yields high effectiveness. Unlike the traditional “lecture–practice” model, this system transforms students into active participants in the learning process.

*The main advantages observed during the research include:*

1. Development of students’ abilities to analyze problems and find solutions;
2. Formation of scientific thinking and research skills;
3. Interdisciplinary integration of biology, mathematics, and information technologies;
4. Increased intrinsic motivation for learning.

International experience shows that STEM education has become a leading platform for training scientific personnel in countries such as the United States, Japan, South Korea, and European nations. In particular, the use of robotic laboratories, simulation models, and big data analysis in genetics and molecular biology education significantly enhances learning outcomes.

In Uzbekistan, programs aimed at implementing STEM education are being carried out within the framework of the “New Generation of Specialists” concept. The results of this study conducted at higher education institutions in Bukhara and Karshi confirm that the STEM system is highly effective not only in natural sciences but also in genetics education.

## CONCLUSION

1. The STEM education system enables the integration of theoretical and practical knowledge in teaching genetics.
2. It promotes the development of students’ research skills, creative thinking, and technological competence.
3. Virtual laboratories, animation software, and modeling methods facilitate deeper mastery of the subject.
4. The study results show that knowledge and interest indicators in the STEM-based group increased by **25–30%**.
5. Teaching genetics based on the STEM approach not only improves the quality of education but also fosters innovative thinking among future specialists in biology, medicine, and education.

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