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THE ROLE AND PROSPECTS OF DIGITAL EDUCATION TECHNOLOGIES IN TEACHING BIOCHEMISTRY IN HIGHER MEDICAL EDUCATION INSTITUTIONS

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Abstract
This article analyzes the future role of electronic manuals based on artificial intelligence (AI), virtual and augmented reality (VR/AR) technologies in teaching biochemistry. Such adaptive platforms make it possible to create individual learning trajectories tailored to each student's level of knowledge. As a result, digital tools significantly increase students' activity, independent learning skills, and the effectiveness of mastering the subject. The widespread implementation of these technologies in medical higher education institutions and their continuous updating are evaluated as an important condition for training modern, competent physician-researchers.

Keywords: biochemistry education, artificial intelligence, VR/AR technologies, electronic manual, DNA, medical education**.**

Introduction

In the first quarter of the 21st century, the rapid development of information and communication technologies formed fundamentally new approaches in the field of education. In the process of training personnel in medical education, particularly in the field of biochemistry, simulation technologies and digital platforms occupy an important place [1]. In modern medical education, the necessity of integrating students' theoretical knowledge with practical skills is increasing, which requires the introduction of innovative educational tools. Through virtual laboratories, 3D modeling technologies, interactive simulators, and distance learning platforms, students have the opportunity to study complex biochemical processes in a safe environment. According to the World Health Organization's 2023 data, simulation centers operate in more than 78% of higher medical education institutions in developed countries [2]. In particular, due to the fact that the subject of biochemistry includes complex molecular structures, metabolic pathways, and enzymatic reactions, 3D visualization and interactive simulation tools facilitate understanding for students and serve to reinforce knowledge.

Literature Review

Digital Education Platforms and Their Capabilities

Learning Management Systems (LMS) occupy an important place in medical education. In an analytical article published in the Kosin Medical Journal (2023), the impact and benefits of the Moodle platform in medical education were studied [3]. The effectiveness of LMS systems in biochemistry education has been specifically studied. In a study published in the journal

Bioinformation (2023), the use of an LMS platform in teaching biochemistry to first-year MBBS students at the Sri Devaraj Urs Medical College in India was evaluated [4]. Of the 150 students, 99 responded to the questionnaire, 70.7% of them considered the LMS platform effective, 67.74% noted its ease of use, and 52.8% expressed satisfaction with the assessment system. The overall acceptance indicators of the students were positive, with academic flexibility and self-learning opportunities being particularly noted. Internet connection problems were indicated as the main difficulty. (Table 1.)

Comparative analysis of digital education platforms

Table 1

Platform	Type	Main functions	Users (million)	Application in medical education
Moodle	LMS	Course management, assessment, forum	400+	Widespread, 70% of higher education institutions
Canvas	LMS	Integration, analytics, mobile app	30+	Higher education institutions in the USA and Europe
HEMIS	LMS/ERP	Education management, monitoring	1.5	Higher education institutions of Uzbekistan
Coursera	MOOC	Online courses, certificates	130+	Additional education
Labster	Virtual lab	Virtual laboratory simulations	5+	Biochemistry, microbiology

Source: Compiled based on official websites of platforms and scientific research

Experience in Applying Digital Education Technologies in Uzbekistan

In the Republic of Uzbekistan, significant achievements have been made in recent years in the direction of digitalizing medical education. High-technology simulation centers have been established at the Tashkent Medical Academy, which make it possible to train medical students, surgeons, and doctors using modern technologies [5]. With the help of GIZ (German Society for International Cooperation), high-fidelity simulators introduced since 2019 have brought medical education to a new level. Using the simulated patient model named "Leonardo", students gained the opportunity to practice surgical procedures such as appendectomy, emergency situations, and patient diagnostics in a safe environment.

Research by local scientists also confirms the effectiveness of digital education technologies. In the study by L.A. Shigakova and D.R. Inogamova (2023), the use of virtual programs and didactic tools in teaching biology at medical higher education institutions was analyzed [6]. The researchers note that virtual laboratories and simulations allow students to conduct experiments in a virtual environment, which ensures safety, reduces costs for material resources, and expands practical learning opportunities. Didactic tools, including animations, 3D models, interactive graphics, and multimedia presentations, help visualize abstract concepts and simplify complex processes.

The prospects for modernizing medical education in Uzbekistan are wide. In a study published on the scientific portal Scientists.uz (2025), the issue of developing the digital competence of future doctors in creating electronic educational resources was examined [7]. According to a 2024 survey by the European Association for Medical Education, although 80% of students regularly use electronic educational resources, only 35% have received systematic training in

their creation. According to the 2024 Digital Health Index, the development of electronic educational resources is included in the curriculum of more than 70% of medical schools in high-income countries, while in low- and middle-income regions this figure is only 22%. In Uzbekistan, work in this direction is being carried out intensively. (Table 2)

Indicators of education effectiveness based on AI (by country)

Table 2.

Country/Region	Research year	Main results	Effectiveness indicator
USA	2024-2025	AI usage increased from 24% to 77%	91% of students benefited from AI
China	2024	Blueink AI assistant was introduced	Engagement increased significantly
India	2024	Survey of 356 students conducted	65.5% understand ML/DL
Saudi Arabia	2024	586 students participated in the research	ChatGPT was evaluated positively
Germaniy	2022-2023	TüKITZMed project	Competencies were identified
Indonesia	2022	271 students virtual laboratory	Academic performance improved
Uzbekistan	2024-2025	5 pilot projects in medicine	Diagnosis time accelerated by 80%

Comparative Analysis and Prospects

The analysis of the conducted literature shows that the introduction of AI technologies in medical education worldwide is continuing at an active pace, and this process is characterized by a number of general trends and national characteristics. The use of AI technologies in medical education has demonstrated significant growth since 2018, and especially entered a new stage with the release of ChatGPT in November 2022 [8].

Based on the analysis of 30 scientific sources, the following conclusions can be drawn: first, AI technologies are opening up wide opportunities in biochemistry education – tools such as AlphaFold have fundamentally changed the study of protein structure, ChatGPT and other chatbots are creating an interactive learning environment, and virtual laboratories are providing safe and effective practical training; second, the introduction of AI technologies comes with a number of challenges – ethical issues, data privacy, reliability of AI results, and the risk of students over-relying on AI; third, equipping medical students with AI competencies is a pressing task of today, and national standards and curricula are being developed in this regard.

Methodology and Practical Application

Results

An electronic textbook designed for a virtual educational environment in the subject of "Biochemistry" is a digital educational complex created on the basis of mutual optimization of

3D and VR (virtual reality) technologies, interactive multimedia tools, and software-technical solutions (C++, iSpring Suite, AutoCAD, 3DMax, HTML5, CSS3). This textbook demonstrates the spatial structure of biochemical processes, changes at the molecular level, and metabolic pathways in a lively, interactive, and visual manner within a virtual reality environment. Tests, simulations, and a feedback system implemented through software tools (C++, iSpring Suite) allow assessing the student's level of independent learning in real time. Three-dimensional models of biomolecules, enzyme-substrate complexes, and cell organelles created with the help of AutoCAD and 3DMax, through a flexible web interface based on HTML5 and CSS3, ensure convenient use on any device (computer, tablet, mobile phone). Unlike traditional text-based textbooks, such an electronic textbook is a highly effective tool for developing students' spatial imagination, cognitive activity, and practical skills in teaching complex subjects such as biochemistry. (figure 1)

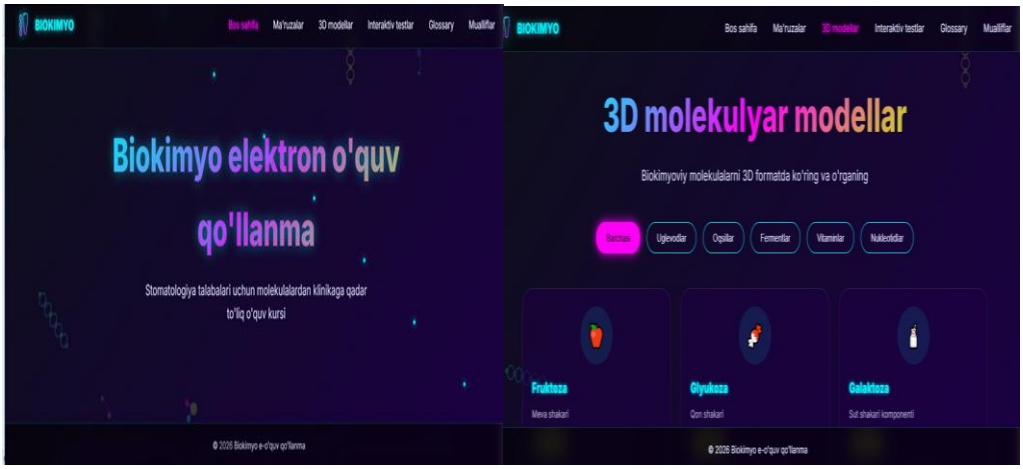

Figure 1. Interactive biochemistry study guide.

This electronic manual has been developed with the aim of increasing the effectiveness of teaching chemistry and biology subjects, in which three-dimensional (3D) models of molecules are presented interactively. The manual gives students the opportunity to clearly see abstract concepts (for example, the geometric shape of a molecule or orbital structure) and work with them practically.(figure 2)

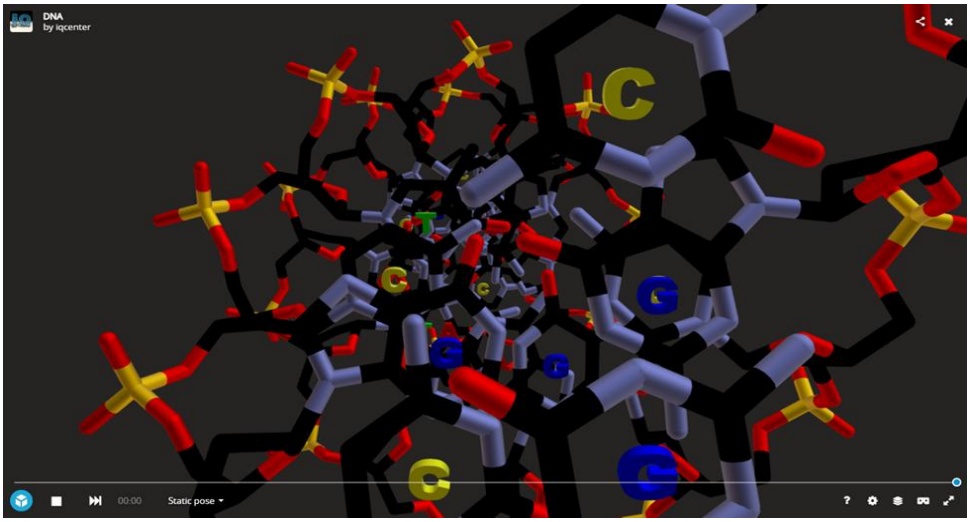

Figure 2. 3D view of DNA.

The electronic manual presents a complete interactive 3D model of the DNA molecule. The model visually and colorfully displays the structure of the double helix, the arrangement of nitrogenous bases, and the principle of complementarity (A–T, G–C). The user can rotate the DNA 360 degrees, zoom in on any desired part, and obtain additional information about the name, structure, and function of each nitrogenous base. These capabilities help students grasp abstract biochemical concepts in a clear, vivid, and practical way.

Conclusion

In the future, AI-based adaptive electronic manuals and platforms enriched with virtual and augmented reality (VR/AR) technologies will be widely implemented in biochemistry education. This will make it possible to create individual learning trajectories tailored to each student's level of knowledge.

Thus, digital technologies, and in particular electronic manuals, significantly increase the effectiveness of teaching biochemistry, as well as students' activity and independent learning skills. The wider application of these tools in medical higher education institutions and their continuous updating are important conditions for training modern, competent physician-researchers.

References

1. World Health Organization. Global strategy on digital health 2020-2025 // WHO Report. – 2023. – P. 112-118.
2. Lateef F. et al. Simulation centers and Simulation-Based education during the time of COVID-19 // J Emerg Trauma Shock. – 2021. – Vol. 14(1). – P. 45-52. DOI: 10.4103/JETS.JETS_185_20
3. Kim J. et al. Do we need Moodle in medical education? A review of its impact and utility // Kosin Medical Journal. – 2023. – Vol. 38(3). – P. 1-14. DOI: 10.7180/kmj.23.126
4. Agarwal S. et al. Efficacy of LMS for teaching biochemistry to medical students in India during the COVID-19 pandemic // Bioinformation. – 2023. – Vol. 19(8). – P. 840-843. DOI: 10.6026/97320630019840
5. GIZ Uzbekistan. Digital simulators improve medical training in Uzbekistan // Healthy Developments. – 2022. – URL: health.bmz.de
6. Shigakova L.A., Inogamova D.R. Virtual dasturlar va didaktik vositalar tibbiyot vuzlarida biologiya fanini o'qitish metodikasi sifatida // Universum: Psixologiya va ta'lim. – 2023. – № 10(112). – B. 17-19.
7. Developing digital competence of future physicians in creating electronic educational resources // Scientists.uz. – 2025. – P. 1-8.
8. Eysenbach G. (2023). The Role of ChatGPT, Generative Language Models, and Artificial Intelligence in Medical Education: A Conversation With ChatGPT and a Call for Papers
9. S.M.Turabdjanov, G.Ixtiyarova, J.Sharopov, A Sharafov Organik kimyo / O'quv qo'llanma.- Ilm-fan nashriyoti., 2024. -304 b.
10. G.Ixtiyarova , N, Eshchanova Biokimyo elektron darslik DGU 54829 2025 y