



International Conference on Education, Psychology and Humanities

Hosted Online from Moscow, Russia

Date: 28th June, 2026

Website: <https://econferencia.com>

EVALUATION OF THE EFFECTIVENESS OF A BIOCHEMISTRY TEACHING METHODOLOGY BASED ON ARTIFICIAL INTELLIGENCE AND VR TECHNOLOGIES THROUGH EXPERIMENTAL TESTING

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Abstract

This article evaluates the effectiveness of a methodology for teaching **Biochemistry** in higher education institutions based on Artificial Intelligence (AI) and Virtual Reality (VR) technologies through pedagogical experimental work. During the research, an instructional methodology based on the use of AI tools, 3D visualizations, and VR technologies was developed and tested in experimental and control groups. The obtained results showed a significant improvement in students' theoretical knowledge, practical skills, independent thinking, and learning motivation. The results of the statistical analysis confirmed the positive impact of the developed methodology on improving educational effectiveness.

Keywords: biochemistry education, artificial intelligence, virtual reality, VR technologies, pedagogical experiment, educational effectiveness, digital education, innovative pedagogical technologies.

Introduction:

Today, the digital transformation of the higher education system, the wide implementation of innovative pedagogical technologies into the educational



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process, and the development of students' professional competencies are considered among the most urgent tasks. In particular, the effective use of modern information and communication technologies in teaching subjects such as biochemistry, which have complex theoretical and practical content, is recognized as an important factor in improving the quality of education.

Artificial Intelligence technologies make it possible to individualize the educational process, model complex biochemical processes, and provide rapid analysis and feedback, while Virtual Reality technologies enable the interactive visualization of molecular structures, metabolic processes, and laboratory activities. The integration of these technologies creates new pedagogical opportunities for increasing students' interest in the subject, enhancing the depth of knowledge acquisition, and developing practical competencies.

From this perspective, the purpose of this study is to determine the effectiveness of a methodology for teaching biochemistry in higher education institutions based on Artificial Intelligence and Virtual Reality technologies through pedagogical experimental work and to statistically evaluate its impact on educational outcomes. The research findings substantiate the practical significance of the developed methodology for improving the quality of biochemistry education and enhancing students' professional training.

Results of the pedagogical experiment: At the first stage of the experimental study, we organized and conducted special master-class sessions for instructors teaching in the experimental groups. Let us consider the formative stage of the training, in which the research methods and findings were applied. Preparation for this stage involved selecting the control and experimental groups in the chosen medical higher education institutions, identifying the groups for determining the results of the experimental work, and selecting the faculty members who would



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teach these groups. To ensure an objective evaluation of the results in both the control and experimental groups, equal conditions and comparable academic directions were maintained throughout the experimental study. The control assignments administered to the groups were identical in terms of both quantity and level of difficulty. The only difference was that the control groups were taught using traditional teaching methods, whereas the experimental groups were instructed using the methods and instructional tools proposed in this study.

To evaluate the central tendency of students' knowledge levels, the arithmetic mean was calculated for each testing stage. The arithmetic mean was determined using the following formula:

$$\bar{x} = (\sum x_i) / n, \quad \text{where } i = 1, 2, \dots, n$$

where:

- $\bar{x}$ — the arithmetic mean (average value);
- x_i — the score obtained by the i -th student;
- n — the total number of students;

Table 1. Average Scores of the Experimental and Control Groups

Test Stage	Experimental Group (n = 157)	Control Group (n = 118)	Difference	Difference (%)
Pre-test	58.49	57.94	0.55	0.95%
First progress test	68.22	61.45	6.77	11.02%
Second progress test	76.06	64.22	11.84	18.44%
Post-test	83.97	67.76	16.21	23.92%

As shown in **Table 1** and **Figure 1**, the difference between the experimental and control groups at the **pre-test** stage was only **0.55 points**, confirming that the initial knowledge levels of students in both groups were nearly identical. This



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provided the necessary basis for ensuring the objectivity and reliability of the pedagogical experiment.

During the experimental study, the average score of the experimental group increased progressively from **58.49** in the pre-test to **83.97** in the post-test, representing an increase of **25.48 points (43.6%)**. In contrast, the average score of the control group increased from **57.94** to **67.76**, corresponding to an improvement of only **9.82 points (16.9%)**.

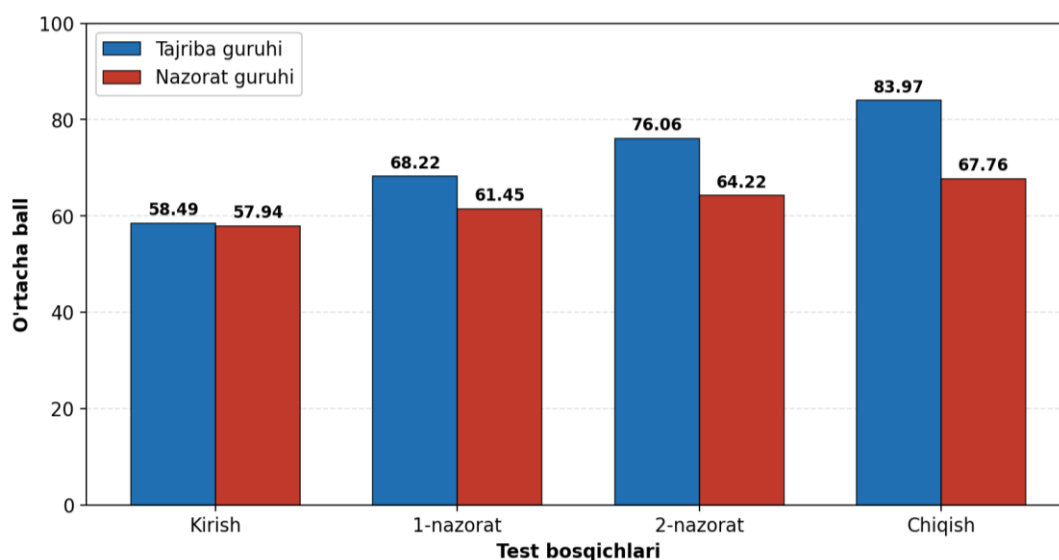


Figure 1. Average Scores of the Experimental and Control Groups

As shown in **Table 1** and **Figure 1**, the difference between the experimental and control groups at the pre-test stage was only **0.55 points**, indicating that the initial knowledge levels of students in both groups were nearly identical. This served as an essential prerequisite for ensuring the objectivity of the experimental study. Throughout the experimental process, the average score of the experimental group increased steadily from **58.49** in the pre-test to **83.97** in the post-test,



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representing an increase of **25.48 points (43.6%)**. In contrast, the average score of the control group increased from **57.94** to **67.76**, corresponding to an increase of only **9.82 points (16.9%)**.

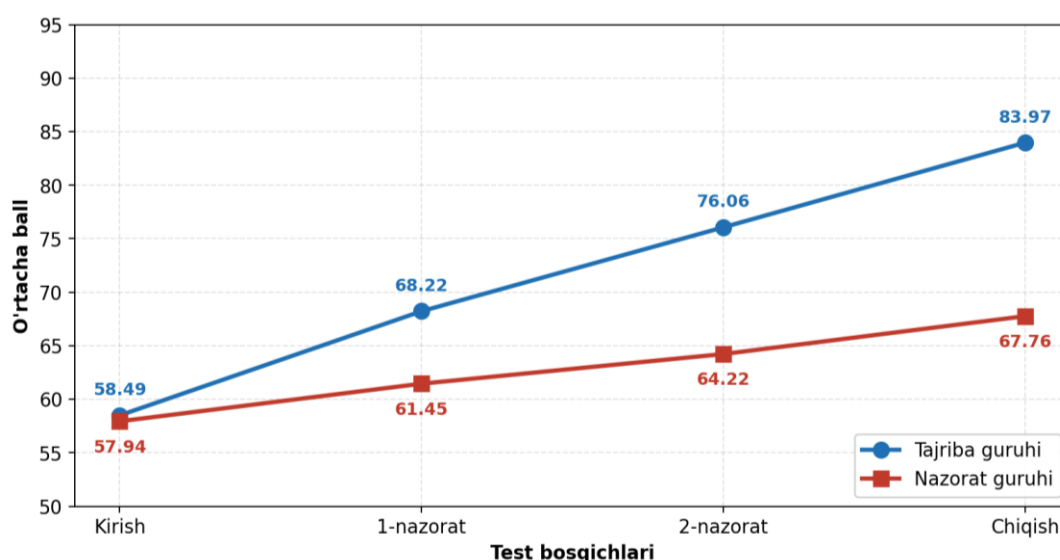


Figure 2. Dynamics of Knowledge Level Improvement

The trend shown in **Figure 2** clearly illustrates a steeper upward trajectory for the experimental group compared with the more gradual increase observed in the control group. By the post-test stage, the difference between the two groups had reached **16.21 points**, providing strong evidence of the effectiveness of the proposed pedagogical methodology.

The results of the pedagogical experiment confirmed the effectiveness of the methodology for teaching biochemistry in higher education institutions based on Artificial Intelligence (AI) and Virtual Reality (VR) technologies. Before the intervention, the difference in the initial knowledge levels between the



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experimental and control groups was only **0.55 points**, indicating that the study was conducted under objective and comparable conditions.

During the experiment, the experimental groups were taught using AI-based educational tools, VR technologies, 3D visualizations, interactive learning tasks, and modern digital teaching methods. As a result, the average knowledge score of the experimental group increased from **58.49** to **83.97**, representing an improvement of **25.48 points (43.6%)**. In contrast, the control group, which received traditional instruction, showed an increase of only **9.82 points (16.9%)**. The **16.21-point** difference observed in the post-test demonstrates the substantial advantage of the proposed methodology over conventional teaching approaches. The findings indicate that the integration of AI and VR technologies enhances students' understanding of complex biochemical processes, facilitates the visualization of abstract theoretical concepts, and positively influences independent learning and learning motivation. Furthermore, the experimental results confirmed that the proposed methodology is an effective pedagogical approach for improving students' professional competencies and the overall quality of biochemistry education.

In conclusion, the findings demonstrate that the developed methodology is suitable for implementation in the teaching of biochemistry at medical higher education institutions. Its integration into the digital learning environment contributes to the development of future healthcare professionals' theoretical knowledge, practical skills, and professional competencies while significantly improving the overall effectiveness of the educational process.



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