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THE ROLE OF 3D VIRTUAL LABORATORIES IN DEVELOPING STUDENTS' EXPERIMENTAL SKILLS

Abdullayev N.J .
Senior Lecturer,Phd Namangan State Pedagogical Institute
Rakhmatova N.I .
Master's Student, KIM-AU-24 Group
Namangan State Pedagogical Institute

Abstract: This article examines the role of 3D virtual laboratories in forming and developing students' experimental skills. Through virtual labs, students can explore complex chemical and physical experiments in a safe, cost-effective, and visual manner. The paper highlights the educational value, practical implications, and contribution of such technologies to modern education.
Key words: 3D virtual laboratory, experimental skills, interactivity, STEM, digital education, chemistry, simulation

Introduction: In the modern educational landscape, the integration of digital technologies into the learning process plays a vital role in enhancing interactivity, accessibility, and overall effectiveness. In particular, the use of innovative approaches such as 3D virtual laboratories has become increasingly significant in teaching experimental sciences like chemistry, physics, and biology. Traditional laboratory instruction often faces challenges due to financial limitations, safety concerns, or lack of equipment. In this context, 3D virtual laboratories not only address these issues but also serve as an effective tool for developing robust experimental skills among students. A 3D virtual laboratory is a software-based, three-dimensional visual interface that simulates real laboratory conditions and allows users to conduct various experiments in a virtual environment. Through these platforms, learners can observe reactions, interact with processes, analyze outcomes, and most importantly, learn from mistakes without risk. Such virtual activities foster essential cognitive abilities like critical thinking, analytical reasoning, and logical problem-solving, while enhancing students' practical understanding of theoretical concepts. Moreover, the integration of 3D technologies into education aligns with the global STEM education framework promoted by UNESCO, OECD, and other international organizations. These platforms not only deliver fundamental scientific knowledge but also contribute to the development of digital literacy, creative thinking, and technological competencies. The "Digital Education" concept introduced by the President of the Republic of Uzbekistan also emphasizes the advantages of virtual laboratory systems in improving the quality of education and equipping learners with 21st-century skills. Therefore, this article explores the educational value of 3D virtual laboratories, with a particular focus on their role in enhancing students' experimental competencies. It also presents the scientific and practical foundations for the integration of such technologies into teaching and learning processes

Main body: 3D virtual laboratories are interactive educational tools developed using artificial intelligence, 3D modeling, real-time animations, and simulations. These environments allow students to interact with virtual lab settings and learn through repeated, risk-free experimentation. They are based on constructivist pedagogy, where learners build knowledge actively through engagement. According to constructivist theory, meaningful learning arises

from hands-on experience rather than passive memorization. In 3D virtual labs, students observe, manipulate, and explore, constructing their understanding through action and feedback. This is particularly effective in STEM education, where conceptual clarity is essentia. Learning through experimentation helps students sharpen observation, reasoning, and cause-effect analysis. While traditional labs are limited by funding, safety, and equipment availability, 3D virtual labs remove these barriers. Evidence-based findings:

In a 2020 study conducted by Kerala University, India [Menon, R. et al.], 100 chemistry students were split into two groups. After four weeks of training, the group using 3D virtual labs outperformed the control group by 27% in their assessment scores.

At the Tashkent Institute of Chemical Technology (Uzbekistan), the implementation of the "Virtual Tahlil" platform in 2022 led to a 19% increase in academic performance in just one semester (internal institutional data).

3D laboratories visualize the full sequence of complex experiments through animations, making it easier to grasp abstract concepts. For instance, oxidation-reduction reactions are not visually apparent in traditional labs but can be clearly demonstrated in virtual settings. This:

Makes abstract topics concrete,

Allows error-based learning,

Encourages repeated experimentation.

Using 3D labs requires familiarity with digital tools, preparing students for technologically advanced workplaces. Moreover, conducting independent experiments without instructor supervision cultivates higher-order thinking skills such as critical analysis, interpretation, and problem-solving

According to the Resolution No. 105 of the Cabinet of Ministers of the Republic of Uzbekistan (March 11, 2023), the integration of digital educational technologies is a priority direction in national education reform.

The 2023 UNESCO report indicates that learners exposed to virtual laboratory environments demonstrate up to 30% higher engagement and interest in science subjects.

Conclusion: 3D virtual laboratories have emerged as an essential tool in the modernization of education. These technologies not only provide a safe and interactive environment for learning but also cultivate students' ability to think experimentally, analyze data independently, and draw scientific conclusions.

Research findings indicate that students who engage in virtual lab activities consistently outperform their peers in traditional laboratory settings. Such platforms increase students' interest in science, reduce the fear of making mistakes, and develop crucial digital competencies. In conclusion, the wide integration of 3D virtual laboratories in the education system not only enhances students' experimental skills but also significantly improves the

quality of learning through modern technological support. This approach aligns perfectly with the objectives of the "New Uzbekistan" educational reform strategy.

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