дозволить створювати персоналізовані навчальні траєкторії для кожного учня. Завдяки таким технологіям освіта стає більш адаптивною, гнучкою та орієнтованою на індивідуальні потреби учнів, що сприяє підвищенню якості навчального процесу та глибшому засвоєнню знань.

Таким чином, використання доповненої та віртуальної реальності у викладанні біології відкриває нові горизонти для освіти, забезпечуючи інтерактивний, візуально насичений та експериментально орієнтований підхід до навчання. Це дозволяє не лише підвищити рівень засвоєння матеріалу, а й сприяти розвитку критичного мислення, творчих здібностей та дослідницьких навичок учнів, що є основними складовими сучасної науки та освіти.

Список використаних джерел

1. Bockholt, N. VR, AR, MR and what does immersion actually mean? Cross-media, Global, Media & Entertainment, Technology, Industry Perspectives. 2017. С. 207–210.
2. Monaha, T. Virtual Reality for Collaborative E-learning. Computers & Education. 2008. Т. 50, № 4. С. 1339–1353.
3. Thakral, S. Virtual Reality and M-Learning. S. Thakral, P. Manhas, C. Kumar. International Journal of Electronic Engineering Research. 2010. Т. 2, № 5. С. 659–661.
4. Кривонос, М. П. Використання елементів дистанційного навчання у процесі вивчення сучасних інформаційних технологій студентами-філологами. О. М. Кривонос, М. П. Кривонос. Інтернаука. 2016. № 7. С. 48–55.
5. Мінгальова, Ю. Засоби ІКТ в шкільному курсі навчального предмету «Географія». Актуальні питання сучасної інформатики: матеріали доп. VII Всеукр. наук.-практ. конф. з міжнар. участю «Сучасні інформаційні технології в освіті та науці», (17–18 листоп. 2022 р.). Житомир, 2023. Вип. Х. С. 118–122.

INTEGRATION OF VIRTUAL LABORATORIES AND VR/AR TECHNOLOGIES INTO STEM EDUCATION

Kukharchuk M., Olendr T. M.

The rapid development of technology requires new approaches to education, especially in the field of natural sciences and mathematics. Traditional methods are not always sufficient to explain the complex processes taking place at the microscopic level. The use of virtual laboratories and virtual (VR) and augmented reality (AR) technologies in science and mathematics education opens new horizons for improving learning quality. These innovative approaches enable students to immerse themselves in interactive environments where they can conduct experiments, explore complex concepts, and develop practical skills

without the physical limitations of traditional laboratories. At the same time, this promotes STEM education, which emphasizes research activities and an interdisciplinary approach to learning.

One of the leading platforms providing virtual laboratories is PhET Interactive Simulations. This free resource, developed by the University of Colorado Boulder, offers interactive simulations in physics, chemistry, biology, and mathematics. Learners can interact with models, change parameters, and observe results in real time, facilitating a deeper understanding of scientific principles. For example, the «Atomic Models» simulation allows students to explore atomic structures and the influence of various factors on their behaviour [1].

Another important platform isLabster, which provides access to virtual laboratories in various scientific fields, including biology, chemistry, and physics. Labster offers realistic 3D simulations where students can conduct experiments, solve scientific problems, and receive immediate feedback. Education institutions in Ukraine have gained free access to Labster's materials through collaboration with the Ministry of Education and Science. It enables the integration of these resources into the learning process [2].

VR and AR technologies are also widely used in education. Using VR headsets, students can immerse themselves in three-dimensional environments where they, for example, explore the molecular structure of DNA or take a virtual journey through the internal organs of a person [3]. AR technologies, in turn, overlay digital objects onto the real world. AR_Book is a mobile application for school students that usesaugmented reality technology. This can be applied to to the study of anatomy, whenstudents see 3D models of organs overlaid on their textbooks.

There are many virtual laboratories and online platforms that can be effectively used in education. For example, Go-Lab is a free web platform that offers a wide range of laboratory simulations in natural sciences. Mozaik Education provides access to interactive 3D scenes and educational videos that help study various subjects. With the support of VR and AR technologies, students can interact with learning materials in a more visual way. For a better understanding of physical processes, My Physics Lab is used, which includes simulations of mechanical systems, oscillations, and other phenomena that aid in mastering fundamental physics concepts.

The use of virtual laboratories and VR/AR technologies in science and mathematics education has a number of significant advantages that positively impact the quality of the learning process. One of the key

benefits is the iraccessibility, as they allow experiments to be conducted regardless of the availability of expensive equipment or laboratory environment [4]. This is particularly important for educational institutions that have limited financial resources.

Another key advantage is safety. Chemistry or physics experiments can involve potential risks. Virtual laboratories let avoid dangerous situations since all reactions, interactions, and experiments take place in a digital environment [5]. This is especially important for disciplines such as organic chemistry, electricity, or biological research.

The integration of VR and AR technologies into STEM education not only enhances the visualization of complex processes and phenomena but also stimulates the development of research skills among learners. Using an interactive laboratory format, students learn to analyze experiment results, formulate hypotheses, and find scientific justifications for their conclusions. This helps in shaping the competencies needed for modern scientists, engineers, or technologists.

Thus, the introduction of virtual laboratories and VR/AR technologies into the educational process not only expands access to quality education but also makes learning safer, more engaging, and more effective.

References

1. Wieman, C. E., & Perkins, K. K. PhET: Interactive Simulations for Teaching and Learning Physics. *The Physics Teacher*, 2005, 44(1), pp. 18-23.
2. Christensen, D., & Engel, G. Labster Virtual Labs: A New Frontier in Science Education. *Journal of Educational Technology Systems*, 2019, 48(2), pp. 244-252.
3. Mental.ua. Virtual Reality in Education: How VR and AR Technologies Are Changing Learning. – 2023. URL: https://mental.ua/virtualna-realnist-v-osviti-yak-tekhnolohii-vr-i-ar-zminiuiut-navchannia/
4. Petrenko L. M. Organizational Methods of Distance Learning in Vocational (Vocational-Technical) Education Institutions. *Information Technologies in Education*, 2018, Issue 50, pp. 30-35. URL: https://www.irbis-nbuv.gov.ua
5. Tikhonova A. Ye. Formation of Key Competencies in Natural Sciences through Information and Communication Technologies. *Cherkasy University*, 2021. URL: https://cusu.edu.ua

ВИКОРИСТАННЯ ЕФЕКТИВНИХ МЕТОДІВ НАВЧАННЯ ДЛЯ РОЗВИТКУ ПРИРОДНИЧИХ КОМПЕТЕНТНОСТЕЙ

Линда Л., Мельник В. Й.

Згідно нового Державного стандарту базової освіти в приорітеті освітнього процесу є компетентнісний підхід [3, 5]. Відповідно до «Рекомендацій Європейського Парламенту та Ради Європи щодо формуванняк лючових компетентностей освіти впродовж життя»