The Use of Virtual Reality in Biology Education

Sultan ÇIKRIK

Gazi University

Musa DİKMENLİ

Necmettin Erbakan University

Introduction

In the modern era, educational technology advancements have significantly transformed how knowledge is delivered and acquired. Digital learning tools, which utilize technology to create interactive and engaging experiences, have become increasingly prevalent across all levels of education. Among these tools, simulation-based learning has emerged as a powerful approach, enabling students to engage with realistic scenarios in controlled environments. Simulations allow exploring complex scientific processes, historical reconstructions, or intricate systems that might otherwise be inaccessible. One of the most promising emerging technologies in this context is virtual reality. Virtual reality combines the strengths of simulations with the interactivity of digital learning tools, offering learners an immersive and lifelike experience. In fields requiring deeper engagement, such as biology education, virtual reality stands out for its ability to facilitate understanding of abstract concepts and complex systems. By allowing students to explore microscopic worlds, interact with biological processes, and realistically visualize ecosystems, virtual reality can revolutionize traditional teaching methods and create more dynamic and impactful learning experiences.

Computer technology has become an integral part of nearly every aspect of life. Advances in science and technology have elevated the importance of information, paving the way for the emergence of the information society. In this context, humans have developed various methods for processing and presenting information via computers, introducing new concepts to the literature. One such concept is virtual reality, often described as a technology enabling the “reconstruction of reality” (Kayabaşı, 2005). Virtual reality is a computer-based technology that enables the creation of simulated environments. Unlike traditional user interfaces that provide only 1D or 2D experiences, virtual reality immerses individuals in a comprehensive 3D representation of the subject. Instead of merely viewing a screen, users can engage with and interact within 3D environments, making virtual reality a more engaging and intuitive technology for many applications (Bardi, 2019).

Virtual reality is a technology through which individuals can be immersed in an artificial environment, which may consist of either a completely imaginary universe or a reproduction of the real world. The experience is typically visual and auditory, with the possibility of incorporating haptic elements in certain applications (Elmqaddem, 2019). Virtual reality software represents one of the most advanced forms of computer-based animation and modeling technologies and is widely recognized as a system applicable for educational purposes. It provides a dynamic digital environment that enables the transfer of three-dimensional models to a computer platform, allowing users to interact with these environments. Typically, users integrate into the virtual environment through specialized equipment, such as electronic gloves, screen-equipped glasses, and wearable devices. These tools continuously relay information to the computer program, including the user’s head orientation and hand movements, facilitating a seamless interaction between the user and the virtual space. Moreover, users can manipulate objects within the virtual environment using devices like joysticks or mice, mimicking interactions found in physical reality. This technology offers diverse experiences, such as driving a race car, skiing, piloting a jet, exploring satellites, or sailing on the ocean, all within a virtual setting (Akpınar, 1999).

The Historical Development of Virtual Reality

Virtual reality has its roots in the mid-20th century, evolving from early attempts to create immersive and interactive experiences using technology. The journey of virtual reality development can be traced through several key milestones that have shaped its growth and applications. The initial ideas of creating simulated environments began with Morton Heilig's Sensorama in the 1950s, a machine designed to provide a multi-sensory cinematic experience. It combined visuals, sound, smell, and vibration, laying the groundwork for immersion in an artificial environment. In the 1960s, Ivan Sutherland introduced the "Sword of Damocles," the first head-mounted display (HMD) system. Although primitive by today's standards, it marked a significant step towards developing modern VR headsets. Daniel Vickers developed the first virtual reality headset in the 1970s at the University of Utah. This device featured two screens, enabling users to observe and interact with a virtual scene by simply turning their heads. A few years later, in 1982, the development of a new interface, the DataGlove, marked a significant advancement in VR technology. The DataGlove was designed to measure hand and finger movements, transmitting this information to the computer and enhancing user interaction within virtual environments. The 1980s and 1990s witnessed the commercialization of VR technologies. Jaron Lanier, often regarded as the pioneer of virtual reality, coined the term "virtual reality" in the 1980s and founded VPL Research, one of the first companies to produce VR equipment, including gloves and headsets. During this time, virtual reality was primarily used in specialized fields such as aviation, military training, and medical simulations, as these applications benefited from immersive training environments. With advancements in computing power and graphical processing in the 2000s, virtual reality technology began to reach broader audiences. Companies like Oculus (acquired by Facebook) and HTC introduced consumer-grade virtual reality headsets in the 2010s, such as the Oculus Rift and HTC Vive, making virtual reality more accessible for gaming, education, and other industries. Innovations in motion tracking, wireless connectivity, and high-resolution displays further supported these developments. In recent years, virtual reality has expanded beyond entertainment and training to include applications in education, healthcare, architecture, and scientific research. With the integration of artificial intelligence (AI) and augmented reality (AR), virtual reality continues to evolve, offering increasingly sophisticated and interactive experiences. The historical development of virtual reality demonstrates a trajectory of innovation driven by the desire to replicate and enhance real-world experiences in digital environments. As technology advances, its potential applications across diverse fields remain a promising area for exploration and growth (Fuchs, 2006; Bown, White, & Boopalan, 2017; VRS, 2020; Akinola, Agbonifo, & Sarumi, 2020).

Virtual Reality Devices and Tools

The effective use of virtual reality technology relies on a combination of advanced hardware and software components. These tools work together to create immersive and interactive experiences that enhance the user's engagement with the virtual environment. Hardware components, such as headsets, motion sensors, and haptic devices, provide the physical infrastructure necessary for virtual reality interaction, while software elements, including virtual reality platforms, simulations, and 3D modeling tools, ensure the functionality and adaptability of the virtual space. Understanding the roles of hardware and software is essential for comprehending the full potential of virtual reality in various fields, including education, healthcare, and entertainment.

The following sections provide an overview of the key hardware devices and software tools that enable the effective use of virtual reality technology (Onyesolu & Eze, 2011; Onyesolu, Ezeani & Okonkwo, 2012; Brown & Green, 2016; Ballo, 2018).

Hardware

- **VR Headsets:** These are the primary devices for virtual reality experiences, allowing users to see and interact with the virtual world (e.g., Oculus Rift, HTC Vive, PlayStation VR).
- **Control Devices:** Tools such as joysticks, gloves, controllers, or motion detection devices enable users to interact with the virtual environment.
- **Sensors and Cameras:** Devices that track and translate user movements into the VR environment.
- **Haptic Feedback Devices:** Equipment such as gloves, jackets, or other tools that provide tactile feedback to users.
- **Computers or Console Systems:** High-performance computers or gaming consoles are required to operate VR devices effectively.

Software

- **VR Platforms and Applications:** Software, games, or educational programs that manage the VR experience.
- **Simulation and Modeling Software:** Specialized VR applications for educational, scientific, or industrial purposes.
- **Virtual Environment Creation Tools:** 3D modeling software or tools to design virtual scenes and environments.

Engaging with virtual reality is made possible through specialized equipment, primarily a virtual reality headset. These headsets typically feature a stereoscopic 3D display system positioned in front of the user's eyes. Some advanced models are equipped with sensors capable of detecting head movements, enabling head tracking. This functionality allows users to look around within the virtual environment. The visuals are recalculated in real time to align with the direction of the user's head or gaze, ensuring a seamless and immersive experience (Elmqaddem, 2019).

The Role and Impact of Virtual Reality in Enhancing the Learning Process

Virtual reality technologies, increasingly utilized in education, provide novel learning experiences and continuously evolve through updated versions (Bülbül & Ersöz, 2022). Virtual reality has the potential to enhance, motivate, and stimulate students' understanding of specific concepts and phenomena. It is particularly beneficial for addressing topics and conducting challenging or impractical experiments to implement in traditional instructional settings. By enabling hands-on activities and fostering individualized learning experiences within a virtual environment, virtual reality offers a valuable tool for comprehending abstract scientific concepts that might otherwise remain difficult to grasp (Shim et al., 2003).

Virtual reality has been demonstrated to be an effective tool for teaching, particularly in disciplines such as Science, Technology, Engineering, and Mathematics (STEM). These fields often require higher levels of learner engagement, which VR facilitates through immersive, whole-body interactions integrated with environmental components for experiments. This approach can potentially enhance students' interactions with the subject matter and improve their conceptual understanding (Alrababah & Shorman, 2021).

The main features of virtual reality technology used in education can be defined as follows (Nikolou et al., 1997; Camp et al., 1998; Çavaş, Çavaş & Can, 2004):

- **Interactivity:** Virtual reality provides an interaction-oriented learning experience by allowing users to actively engage in the learning process.
- **Scale:** Virtual reality enables users to modify their physical dimensions, facilitating exploration and interaction within macro and micro worlds. This allows students to access learning opportunities that would otherwise be impossible, even with tools like a real microscope. For instance, virtual environments can simulate shrinking down to the size of a cell organelle, enabling detailed exploration within its structure. This feature aids in concretizing abstract biological concepts and deepening the learning experience.
- **Focusing Attention**: Virtual reality helps students fully concentrate on learning, enhancing their focus and increasing motivation.
- **Narrative Flexibility:** Virtual reality enables the flexible presentation of instructional content across different contexts and scenarios, adapting to diverse educational needs.
- **Experiential Learning:** Virtual reality allows students to experience abstract concepts tangibly, allowing them to learn by doing and experiencing.
- **Appealing to the Senses:** By engaging multiple senses, such as sight, hearing, and touch, virtual reality enriches the learning process, making it more multidimensional and immersive.

Strengths and Limitations of Virtual Reality Use in Education

Virtual reality offers several advantages over traditional learning techniques. With the increasing prevalence of computers in education, students' growing familiarity with technology has facilitated the development and adoption of more virtual reality-based learning tools. Research suggests that students often exhibit positive attitudes toward learning with virtual reality, particularly regarding enjoyment, realism, and the ease of understanding complex biological concepts. Through virtual reality, students can navigate and interact within virtual environments, manipulating learning objects to understand the subject matter better. Additionally, the immersive nature of virtual reality experiences can potentially enhance students' motivation and engagement in the learning process (Salis & Pantelidis, 1997).

Virtual reality enhances motivation, presents concepts more realistically, and provides opportunities for individuals with disabilities- who may not have previously had access to experimental and learning environments- to participate in these settings actively. It also allows students to learn at their own pace, facilitating a more effective learning process. Additionally, virtual reality offers students a broader time frame for learning than the constrained durations typically available in traditional classroom environments. By requiring mutual interaction, it engages students actively, fosters creativity, and supports the development of digital skills (Çavaş, Çavaş & Can, 2004).

While virtual reality systems offer significant advantages in learning environments, they also have limitations. One such limitation is the need to pre-program the desired knowledge into the system before it can be utilized effectively. Additionally, using VR may influence students' attitudes negatively, potentially leading to a lack of seriousness, responsibility, or attention to detail. Moreover, at the advanced stages of training, there remains a necessity for hands-on experience with actual equipment to ensure that learners gain practical skills and familiarity with real-world applications (Pearson & Kudzai, 2015; Potkonjak et al., 2016).

The Use of Virtual Reality in Biology Education

Most biological structures and phenomena are highly interrelated and inherently complex. Due to their abstract nature, many biological concepts present significant challenges for teaching and learning (Eidson & Simmons, 1998; Barack et al., 1999; Buclley, 2000). Humans perceive reality through their senses, which process diverse information from their surroundings (Amory et al., 1999). Consequently, visualization plays a crucial role in teaching and learning. Approximately fifty percent of the human nervous system is involved in vision, and visualization techniques aim to optimize this capacity (Pang, 1995). While the human senses are powerful tools for perceiving the environment, they are also inherently limited. For instance, the human eye has a restricted range of vision and cannot detect all sound waves. Similarly, the ability to perceive and comprehend scientific phenomena at the atomic or molecular level is constrained (Karr & Brady, 2000).

Although the implications of virtual reality in biology have been explored in a limited number of studies, a comprehensive understanding of its potential applications is yet to be fully developed. As a discipline, biology heavily relies on experimentation as a cornerstone of effective learning. However, understanding complex concepts and processes often presents challenges when relying solely on traditional educational methods. Integrating virtual reality into biology education offers a promising solution by simulating realistic environments, which enhance immersion and interaction, ultimately facilitating a deeper understanding of biological phenomena (Alrababah & Shorman, 2021). To further demonstrate the potential of virtual reality in biology education, the following examples illustrate how this technology can be effectively applied to enhance the teaching and learning of diverse biological concepts.

Virtual Cell: The cell is a complex, multidimensional environment where time and location are critical factors in determining when and where cellular events occur. Capturing this multidimensional environment on a two-dimensional printed page, a blackboard, or a web page is highly challenging. Virtual Cell is a project NDSU (North Dakota State University) developed. It provides a three-dimensional environment where students can learn about the functions and structures of a cell. The Virtual Cell includes subcellular components such as the nucleus, endoplasmic reticulum, Golgi apparatus, mitochondria, chloroplasts, and vacuoles (McClean, Slator & White, 1999).

Virtual Biology Laboratories: Virtual laboratories include a variety of objects such as microscopes, centrifuges, whole organisms, or single cells, along with pre-programmed specific actions. Students interact with these objects to achieve specific objectives, such as examining the properties of cells, separating cellular components, or measuring enzyme activities. Using creative representations of these objects and their behaviors allows students to engage in limitless experimentation within the virtual world (Subramanian & Marsic, 2001).

Virtual Molecular Biology Teaching: Teaching molecular biology, particularly at the secondary school level, faces significant challenges due to student disengagement and inadequate resources. This often results in confusion and frustration among students. Visualization plays a critical role in learning molecular biology; however, traditional classroom tools like diagrams and models fall short of representing the complexity of cellular and molecular dynamics as described in modern biology curricula. In this context, virtual reality technologies offer the ability to visualize DNA, proteins, and cellular structures in three-dimensional space, making it easier for students to grasp these concepts. An experimental study demonstrated that such virtual visualization activities significantly improved molecular biology achievement, particularly among male students. Focus group interviews revealed that these technologies reduced reliance on rote memorization, clarified complex concepts, and increased student interest and engagement. In conclusion, the findings of this study recommend integrating technology-supported learning environments into the teaching of molecular biology (Tan & Waugh, 2013).

Three-dimensional animated models based on virtual reality have various applications, including representations of the human eye and ear, cell membranes, peptide models, and actin-myosin structures (Amon & Valencic, 2000; Rourk, 2000). At the University of Chicago, Karr and Brady (2000) designed a fertilized Drosophila egg for university students and used virtual reality to present the behavior of a single sperm within a Drosophila egg. Shim et al. (2003) designed an environment based on three-dimensional virtual reality technology to teach the structure and functions of the eye. In the study, primary school students explored the structure and functions of the eye within the virtual environment. The results showed that students' interest in the subject increased, and they could better understand scientific concepts and phenomena.

In their study, Mikropoulos et al. (2003) designed a virtual environment based on plant cells and photosynthesis and made it available for experienced in-service teachers. In this virtual plant cell, users begin by navigating through the plant tissue outside the cell. Within the cell, intracellular structures are visible, and users can freely explore, observe, and study how the organelles are organized in the three-dimensional space of the cell and how they work together for the cell to function. The organelles' functions and adaptations to environmental changes can also be studied. In a study conducted with 37 teachers, the researchers examined teachers' attitudes toward the virtual environment and its impact on learning. According to the results of this study, 81% of the teachers believe that virtual reality is a valuable and effective learning tool in biology, and virtual reality provides an engaging, motivating, creative, and safe learning environment.

In a study, researchers investigated secondary school students' experiences using a mobile virtual reality application to explore the environmental impact of large-scale developments on nature reserves. The study involved 64 students from southeast England who participated in a geography field trip to their local nature reserve. During the trip, students used Google Expeditions (GEs), a smartphone-based VR application, to compare the physical field trip location with its virtual reality version. Google Expeditions provides over 700 guided virtual field trips, including locations such as the Queen Elizabeth Olympic Park, the Grand Canyon, and Antarctica, using 360-degree photospheres. Through VR and the GE app, students gained awareness of environmental issues caused by large-scale developments, acquired knowledge about their impact on ecosystems, and proposed actions for environmental protection. Following the field trip, students wrote letters to the Chiltern Society, a voluntary organization dedicated to preserving the Chilterns' landscape, discussing the implications of large-scale development plans near their local nature reserve (Tudor et al., 2018).

Bennett & Saunders (2019) assessed the educational impact of virtual reality on student learning and engagement in a sophomore-level cell biology course at Otterbein University. The study involved three stages: first, students explored the cell and its environment within the human body using virtual reality; second, they participated in a team-based activity to match images of cell components from the virtual reality application with their corresponding names; and finally, they completed a voluntary survey to provide feedback on the virtual reality experience and the related activity. Survey results showed that most students enjoyed the virtual reality experience and felt it positively influenced their education. The findings suggest that VR can be supportive in enhancing learning across various undergraduate courses.

In their research, Arslan, Kofoğlu, and Dargut (2020) examined techniques to improve learning performance in fields such as biology, anatomy, physiology, and experimental animals and analyzed the process of developing a specific mobile application using the Unity3D platform. The study focused on using virtual and augmented reality applications to enable students to practice in realistic conditions and gain knowledge and skills relevant to their professional fields. The study results suggest that disseminating virtual laboratories and augmented reality applications developed through needs analysis, lesson or course content design, and scenario writing can help overcome challenges in providing materials for students and address ethical debates surrounding using experimental animals.

Conclusion

Today, societal development is often linked to advancements in science and technology, with education as the cornerstone of this progress. Innovations in educational technologies profoundly impact learning processes, reshaping traditional approaches to teaching and learning. While virtual reality technology has not yet been widely adopted within education systems, it allows individuals to engage in artificially created environments that simulate real experiences. This capability enables students to benefit significantly from immersive and interactive learning experiences. Research indicates that virtual reality technology enhances students' learning processes by fostering interaction with virtual environments, maximizing learning effectiveness. As a technology poised to become a fundamental component of educational environments in the future, virtual reality holds the potential to be effectively utilized across various fields of education and training. In these virtually constructed settings, students can actively engage in their learning processes through hands-on, experiential activities.

Integrating virtual reality into biology education can significantly enhance student engagement and understanding. While there are some logistical and financial challenges, the positive feedback from students indicates a bright future for virtual reality in education as long as these obstacles are managed effectively (Toman & Hubálovská, 2024).

Recommendations

For virtual reality to be more widely utilized in education, developing content that aligns with the biology curriculum and fulfills pedagogical objectives is essential. Collaboration between teachers and subject matter experts is crucial in this process. Encouraging the development of virtual reality applications tailored to biology topics is particularly important. For instance, applications that allow detailed exploration of cell structures, recreate natural ecosystems in digital environments, or provide an in-depth examination of human anatomy can aid students in concretizing abstract concepts. Additionally, virtual reality can enable students to interactively and visually study genetic processes, such as DNA replication or protein synthesis. It can also simulate the behavior of microscopic organisms, such as bacteria and viruses, under various conditions, providing insight into microbiology concepts. Students could virtually experience processes like photosynthesis, respiration, or nutrient cycles in plants, enhancing their understanding of these essential biological mechanisms. Furthermore, VR can facilitate the exploration of evolutionary processes by simulating the progression of species over time or illustrating how environmental changes affect biodiversity. Transferring laboratory experiments to virtual reality environments-especially simulations of costly or hazardous experiments-can provide students with valuable hands-on experiences in a safe and risk-free setting.

To ensure the effective use of virtual reality in education, in-service training programs should be implemented, incorporating practical, hands-on activities to enhance teacher competency. One significant barrier to the widespread adoption of this technology is the high cost of virtual reality tools and equipment. To address this issue, more accessible and cost-effective solutions need to be developed. Additionally, further scientific research is essential to evaluate the impact of virtual reality on teaching and learning processes. Such studies will provide valuable insights into the effectiveness and limitations of virtual reality, guiding its integration into educational practices.

References

Akinola, Y. M., Agbonifo, O. C., & Sarumi, O. A. (2020). Virtual reality as a tool for learning: The past, present and the prospect. *Journal of Applied Learning and Teaching*, *3*(2), 51-58.

Akpınar, Y. (1999). *Bilgisayar destekli öğretim ve uygulamalar*. Anı Yayıncılık.

Alrababah, Z., & Shorman, S. (2021). Review of effects of the virtual reality in education. In *The big data-driven digital economy: Artificial and computational intelligence* (pp. 445-459). Springer International Publishing.

Amon, T., & Valencic, V. (2000). VRML: Enhanced learning in biology and medicine. Future *Generation Computer Systems*, *17*:1-6.

Amory, A., Naicker, K., Vincent, J., & Adams, C. (1999). The use of computer games as an educational tool: ıdentification of appropriate game types and game elements. *British Journal of Educational Technology*, *30*: 311-321.

Arslan, R., Kofoğlu, M., & Dargut, C. (2020). Development of augmented reality application for biology education. *Journal of Turkish Science Education*, *17*(1), 62-72.

Ballo, P. (2018). Hardware and software for ar/vr development. *Augmented and virtual reality in libraries*, 45-55.

Barack, J., Sheva, B., & Gorodetsky, M. (1999). As 'process' as ıt can get: students' understanding of biological processes. *International Journal of Science Education*, *21*: 1281-1292.

Bardi, J. (2019). Virtual reality defined & use cases | 3D Cloud by Marxent. 3D Cloud by Marxent. Retrieved May 17, 2023, from https://www.marxentlabs.com/what-is-virtual-reality/

Bennett, J. A., & Saunders, C. P. (2019). A virtual tour of the cell: Impact of virtual reality on student learning and engagement in the STEM classroom. *Journal of microbiology & biology education*, *20*(2), 10-1128.

Bown, J., White, E., & Boopalan, A. (2017). Looking for the ultimate display: A brief history of virtual reality. In *Boundaries of self and reality online (pp. 239-259). Academic Press.*

Brown, A., & Green, T. (2016). Virtual reality: Low-cost tools and resources for the classroom. *TechTrends*, *60*, 517-519.

Bucldey, B. C. (2000). Interactive multimedia and model-based learning in biology. *International Journal of Science Education*, *22*: 895-935.

Bülbül, H., & Ersöz, B. (2022). Eğitimde yapay zekâ sanal gerçeklik ve sanal evren (Metaverse). Yapay zekâ ve büyük veri kitap serisi (4. Baskı, s. 149-183) içinde. Nobel Akademik Yayıncılık.

Camp, J. J., Cameron, B. M., Blezek, D., & Robb, R. A. (1998). Virtual reality in medicine and biology. *Future Generation Computer Systems*, *14*(1-2), 91-108.

Çavaş, B., Çavaş, P. H., & Can, B. T. (2004). Egitimde sanal gerceklik. *TOJET: The Turkish Online Journal of Educational Technology*, *3*(4), 110-116.

Eidson, S., & Simmons, P. E. (1998). Microcomputer simulation graphic and alphanumeric modes: examining students' process skills and conceptual understanding. *The Journal of Computers in Mathematics and Science Teaching*, *17*: 21-61.

Elmqaddem, N. (2019). Augmented reality and virtual reality in education. Myth or reality?. *International journal of emerging technologies in learning*, *14*(3), 234-242.

Fuchs, P. (2006). *Le traité de la réalité virtuelle (Vol. 2). Presses des MINES.*

Kayabaşı, Y. (2005). Sanal gerceklik ve egitim amacli kullanilmasi. *TOJET: The Turkish Online Journal of Educational Technology*, *4*(3), 151-158.

Karr, T. L., & Brady, R. (2000). Virtual biology in the CAVE. *Trends in Genetics*, *16*(5), 231-232.

McClean, P. E., Slator, B. M., & White, A. R. (1999). The virtual cell: An interactive, virtual environment for cell biology. In *EdMedia+ Innovate Learning* (pp. 1442-1443). Association for the Advancement of Computing in Education (AACE).

Mikropoulos, T. A., Katsikis, A., Nikolou, E., & Tsakalis, P. (2003). Virtual environments in biology teaching. *Journal of Biological Education*, *37*(4), 176-181.

Nikolou, E., Mikropoulos, T. A., & Katsikis, A. (1997). Virtual realities in biology teaching. M. Bevan (éd.), *Proceedings VRET, 97*, 59-63.

Onyesolu, M. O., & Eze, F. U. (2011). Understanding virtual reality technology: advances and applications. *Adv. Comput. Sci. Eng*, *1*, 53-70.

Onyesolu, M. O., Ezeani, I., & Okonkwo, O. R. (2012). A survey of some virtual reality tools and resources. *Virtual reality and environments*, *21*, 22-42.

Pang, A. (1995). A Syllabus for Scientific Visualisation. *Scientific Visualisation in Mathematics and Science Teaching*, 261-283.

Pearson, C., & Kudzai, C. (2015). Virtual laboratories a solution for tertiary science education in Botswana. *European Journal of Logistics, Purchasing and Supply Chain Management*, *3*(3), 12-24.

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education*, *95*, 309-327.

Rourk, W. (2000). Virtual biochemistry-a case study. *Future Generation Computer Systems*, *17*(1), 7-14.

Salis, C., & Pantelidis, V. S. (1997). Designing virtual environments for instruction: concepts and considerations. *VR in the Schools*, *2*(4), 1-8.

Shim, K. C., Park, J. S., Kim, H. S., Kim, J. H., Park, Y. C., & Ryu, H. I. (2003). Application of virtual reality technology in biology education. *Journal of Biological Education*, *37*(2), 71-74.

Subramanian, R., & Marsic, I. (2001). VIBE: Virtual biology experiments. In *Proceedings of the 10th International Conference on World Wide Web (pp. 316-325).*

Tan, S., & Waugh, R. (2013). Use of virtual-reality in teaching and learning molecular biology. *3D immersive and interactive learning*, 17-43.

Toman, M., & Hubálovská, M. (2024). Review Study "Virtual Reality in Biology Education". In *International Conference on Technology in Education* (pp. 235-245). Singapore: Springer Nature Singapore.

Tudor, A. D., Minocha, S., Collins, M., & Tilling, S. (2018). Mobile virtual reality for environmental education. *Journal of Virtual Studies*, *9*(2), 25-36.

Virtual Reality Society (VRS). (2020). History of virtual reality. https://www.vrs.org.uk/virtual-reality/history.html.

About the Authors

Assist. Prof. Dr. Sultan ÇIKRIK completed her undergraduate education in 2005 at Selçuk University, Faculty of Education, in the Secondary Science and Mathematics Education program. She earned his master's degree in 2008 from the Institute of Science at Selçuk University and her doctorate in 2015 from the Institute of Education at Gazi University. She currently serves as an Assistant Professor in the Department of Biology Education under the Mathematics and Science Education Division at Gazi University, Gazi Faculty of Education. Her scientific work focuses on innovative approaches in biology education, education in natural sciences, and teacher training. She has participated in various projects, including "Erasmus+ 2023 School Education Accreditation Environmental Project: Biodiversity Awareness Education," "A Comparative Study on Biology Teacher Candidates' Views on Out-of-School Learning Environments," "TÜBİTAK 4004 Climate Change Awareness School."

E-mail: sultanaltunsoy@gazi.edu.tr, **ORCID:** 0000-0002-6821-7922.

Prof. Dr. Musa DİKMENLİ completed his undergraduate education in 1991 at Selçuk University, Faculty of Education, in the Secondary Science and Mathematics Education program. He earned his master's degree in 1996 from the Institute of Science at Selçuk University and his doctorate in 2000 from the same institute. He currently serves as a Professor in the Department of Biology Education under the Mathematics and Science Education Division at Necmettin Erbakan University, Ahmet Keleşoğlu Faculty of Education. His scientific work focuses on innovative approaches in biology education, education in natural sciences, and teacher training. Prof. Dr. Musa DİKMENLİ has numerous research articles, conference papers, and books on biology education. He has also worked in the fields of nature observation and nature photography.

E-mail: mdikmenli@erbakan.edu.tr, **ORCID:** 0000-0001-6501-9034.

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