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## A Brief Analysis of the Educational Implications of Virtual Reality

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**Citation:** Nucera S. (2024). A Brief Analysis of the Educational Implications of Virtual Reality. *Preliminary Reports and Negative Results in Life Science and Humanities* 1(1). <https://doi.org/10.13129/3035-062X/pmr-4222>

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### Abstract

The continuous advancements of the technological system have allowed for the creation of interactive environments, thus creating optimal conditions for a culture of sharing and interaction among individuals and contexts. The application of computers in various environments and professional contexts has resulted in technological evolution and growth, which has led to the development of ecologically adaptable and integrated technologies (Nucera et al., 2018). Specifically, in this work, we will seek to determine and describe virtual reality in terms of a “transformative technology” with significant implications within structured educational contexts. The central focus of this work will revolve around how knowledge dissemination is undergoing a profound restructuring, demonstrating that Weiser’s insight regarding the increasingly blurred boundary between bodies and technologies is becoming more tangible.

**Keywords:** Virtual Reality, Education, Disabilities

### Introduction

Scientific research defines virtual reality as a completely synthetic environment (Gandedkar, 2021). It is interesting to note that, although these technologies are relatively recent, the concept of an “immersive environment” dates back almost a hundred years. In 1929, Edward Link created the Link Trainer, a flight simulator for pilot training. Sensorama appears to have been the first technology for virtual reality, built in 1957 by Morton Heilig, incorporating stereoscopic screens, stereo speakers, and a partially mobile chair (Rheingold 1991). Subsequently, Ivan Sutherland, a pioneer in computer graphics, developed a virtual reality device known as the “Sword of Damocles,” which, despite being bulky and ergonomically limited, marked a significant step in the development of this technology.

Over the years, advancements in both hardware and software, along with cost reductions, have led to a broader adoption of VR, particularly in recreational, educational, and training settings.

The landscape of virtual reality devices has undergone incredible transformations in many sectors such as gaming (e.g., Zyda, 2005; Pallavicini et al., 2019), educational contexts (e.g. Hu-Au, Lee, 2017; Chavez, Bayona, 2018; Nucera, 2022; Rojas-Sánchez et al., 2023), military applications (e.g. Pallavicini et al., 2026; Ahir et al., 2020), surgical simulations (e.g. Lungu et al., 2021), orthopedic rehabilitation (e.g. Ehioghae et al., 2024), cognitive rehabilitation (e.g., Maggio et al., 2019; Huang et al., 2024), psychiatric and psychological rehabilitation (e.g. Valmaggia et al., 2016; Carl et al., 2019; Park et al., 2019; Porrás-García, 2020), and physical education (e.g. Kiefer et al., 2017).



## **Virtual Reality in Educational Environments**

In the following pages, we will focus on some applications in the educational and training fields of virtual reality technologies, exploring how these can enrich and facilitate cultural experiences and provide engaging storytelling and user experiences, allowing users to delve into learning in a deeper and more engaging manner. As highlighted by various authors, virtual reality provides significant enhancements to the learning process by replacing existing learning environments with engaging and immersive virtual environments that stimulate students' creative thinking and imagination (Chen et al., 2016). Virtual reality can be defined as a medium with tremendous potential that can transport individuals to different places and fully immerse them in unimaginable modes of interaction and communication. While previously inaccessible to average consumers due to high costs, recent technological advancements have made virtual reality more accessible, revolutionizing the market significantly, akin to the introduction of television, the internet, and smartphones. Virtual reality devices used in various fields offer greater comfort, albeit not without potential side effects. Particularly in the field of education, virtual reality has benefited from a series of highly intriguing experiments that we will try to analyze without claiming to be exhaustive.

### **VR within structured educational environment**

As highlighted by Golos et al. (2022) "A "structured educational environment" was defined when most activities were included in the curriculum, with a time frame, and children were required to participate in all activities. A "semi-structured educational environment" was defined when some of the activities were included in the curriculum, the time frame had flexibility, and children were required to participate in some activities but could choose 2–3 personal preferences. A "fluid educational environment" was defined when a few of the activities were included in the curriculum, with a lot of flexibility in the time frame, and children were required to participate in a minority of the activities but could choose four or more different preferences".

### **VR in chemistry courses**

In this section, we will analyze a series of studies that have highlighted how VR can be very helpful in courses where the visual-spatial experience is predominant. As noted by Reeves et al. (2021), over the past twenty years, there has been a growing interest in understanding the potential of virtual reality laboratories. The same authors examined student learning in a chemistry course using virtual reality. It is interesting to note that this study reveals qualitatively different learning experiences. Some students found that virtual reality hindered their learning; others linked learning to prior knowledge, while others recognized the positive aspects of virtual reality. The fourth group perceived virtual reality as a tool that removed barriers to learning. This study's analysis concludes that, despite its early stages, VR experimentation in chemistry courses should aim to create virtual environments based on student needs rather than emulating physical lab learning models. Maksimenko et al. (2021) conducted another study in a chemistry course using the MEL Chemistry VR application and came to a different conclusion. On one hand, the teaching of chemistry (traditionally understood) is often considered complex and abstract, requiring a deep understanding of the concepts and chemical reactions. The opportunity to manipulate atoms and experiment with chemical reactions in a three-dimensional environment could become a valid tool to make learning more engaging, interactive, and effective. The study revealed that out of the 43 students involved, 27 achieved better scores in the



tests administered after the virtual reality experience, 12 obtained the same score, and 4 obtained a lower score, with an average improvement rate of 20.3%. The study demonstrated that most students improved their understanding of atomic structure. Edwards et al. (2019) conducted a more complex experiment by utilizing gloves to simulate a tactile experience. The authors point out that only Molecular Rift, among these virtual reality systems, can directly simulate with hands without the need for additional hardware (Norrby et al., 2015, cited in Edwards et al., 2019). The results of this study show that 45 participants rated the system for multisensory learning with very encouraging views regarding the level of engagement and motivation, as well as the overall adequacy of the virtual experience for learning chemistry.

### **VR in architecture courses**

Architecture or construction engineering courses are also ideal for experimenting with virtual reality technologies. A study by Bashabsheh et al. (2019) demonstrated how VR serves as an important tool in transitioning from a teacher-centered educational model to a student-centered one, adding an element of fun or edutainment, referring to the fusion of educational elements and playful experiences. Within a modern architecture course, Ibrahim et al. (2021) found that participants in the VR condition, besides expressing mostly positive feedback on the experience, also outperformed students exposed to a traditional teaching model.

### **VR in medicine courses**

Lui et al. (2020) achieved similar results in an experiment involving 34 students in a microbiology course, who demonstrated improved performance compared to peers who did not experience VR. Meng et al. (2024) conducted another very interesting and recent study regarding the application of VR in a microbiology course, testing an educational model combining virtual and real-world experiences (experimental group) against traditional teaching methods (control group). The results highlighted how students in the experimental group performed better in both practical and theoretical tests, with 89% of them rating the experience very positively. The nature of virtual reality technology allows for experiential learning utilizing individual learning styles, as demonstrated in an experiment by Kolla et al. (2020), where students in an anatomy course interacted differently within the virtual environment, showcasing how the versatility of this technology can be extremely beneficial in structuring individual learning methods and timelines.

### **VR, disabilities and inclusion in educational contexts**

Virtual reality can also become an effective tool to promote inclusion. Specifically, although large-scale studies are lacking, the use of VR in individuals with autism can promote the learning of social (Matsentidou, Poullis, 2014; Ip et al., 2018) and emotional (Lorenzo et al., 2016) skills that, if experienced in the real world, could potentially be negative for the individuals. Especially for individuals with autism, a controlled environment could prove valuable and flexible, tailoring to each individual's specific needs. It is clear that, in this case, programs and training sessions are necessary not only for the users but also for the staff assisting individuals with disabilities.



## Conclusions

We have attempted to outline the current state of the art regarding the adoption of VR within structured educational contexts using an updated bibliography, even though the presented text inevitably lacks certain sections related to, for example, music learning through VR or second language acquisition. Contrary to traditional learning and teaching platforms, virtual reality technologies (as well as augmented reality technologies) have sparked the development of immersive platforms and activities in modern education. Despite the positive aspects presented in this paper, this shift forces us to view these advancements as a transitional stage in a paradigmatic research line characterized by unpredictable dynamics. Often, certain aspects, like low media literacy among teachers and students or the uneven distribution of these technologies geographically, can lead to negative outcomes.

In educational settings, virtual reality is revolutionizing the learning experience. By providing interactive and engaging simulations, virtual reality allows students to explore complex concepts, relive historical events, and engage in hands-on learning activities. This technology enhances learning outcomes by promoting active participation, information retention, and a deep understanding of academic content, taking into consideration diverse learning styles and preferences.

Despite the barely concealed optimism that always accompanies the experimentation of new technologies, as previously stated elsewhere (Nucera 2022), it is imperative to persist with VR experimentation within educational contexts. On the other hand, the scientific literature on the topic, despite the excellent results achieved, is almost always cautious, both because more extensive experimentation is necessary and because VR technologies are not free from negative effects. For example, as reported by Reeves et al. (2021), some participants experienced a sense of frustration regarding the lack of training before the VR experience. Other participants stated that the lack of interaction with an instructor was a potential obstacle. On the other hand, participants perceived the sense of isolation positively, as it alleviated pressure on outcomes and reduced competition with other students. Ibrahim et al. (2021) report that some participants experienced a sense of nausea during the VR experience. For a systematic discussion on this topic, refer to Chang et al. (2020). Lui et al. (2020) also noted that the mode of experimentation (standing or sitting) with VR can negatively influence the results, just as previous knowledge does. Chan et al. (2022) talk about hardware power limits, especially those that have to do with operational speed. Their study on the use of VR in a history of architecture class highlights the importance of these limits in achieving a sense of “reality” when projecting geometries, resolutions, and detailed architectural elements.

In conclusion, the rapid spread of virtual reality within educational systems, as confirmed by extensive academic literature, suggests an imminent and necessary shift in educational paradigms. However, it is crucial to keep in mind, as highlighted by Gui (2019), that the main obstacles to the widespread diffusion of technologies (including virtual reality) within educational institutions are the lack of a dedicated research path for the development of specific educational materials and the shortage of shared standards (Qiu et al., 2023).

This swift transformation underscores the need for a systematic and collaborative approach to successfully integrating immersive technologies in the educational field. Addressing the lack of resources and clear guidelines could pose a significant challenge to the complete integration of these technologies into the educational context. Moreover, it is important to consider the significance of



creating a robust corpus of specific educational material that fully exploits its educational potential while trying to mitigate any possible content-related and medium-related side effects.

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