Learning with virtual reality (VR) and augmented reality (AR)

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Abstract (150 words)
Over the past few decades, there has been an increasing in the application of Virtual Reality (VR) and Augmented Reality (AR) in educational contexts worldwide. Their immersive and interactive nature provides a range of unique opportunities for teachers and students to explore their surrounding environment in a collective and participatory manner.
Within the scope of the "STRONG: Resilient Skills and Teachers Focused on the Next Generations" project, identifying successful teaching and learning strategies using digital technologies has been a priority. To achieve this goal, a survey of national and international initiatives was conducted, which utilized digital technologies not only to enhance the acquisition of disciplinary knowledge but also to promote the recognition and utilization of cross-cutting competencies.
Among the selected cases, this paper highlights the usage and benefits of Virtual Reality and Augmented Reality technologies, as well as their application in a university context.

Keywords: Virtual Reality, Augmented Reality, STRONG project, Education.

Introduction

The effort to apply Virtual Reality (VR) and Augmented Reality (AR) in an educational context has been intensifying worldwide. The immersive and interactive nature of these technologies provides a range of differentiated opportunities that allow teachers and students to explore their surrounding environment collectively and actively.

Within the scope of the "STRONG - Skills and Resilient Teachers Focused on the Next Generations" project, promoted by the Polytechnic Institute of Tomar, the identification of best practices in teaching and learning with digital technologies was a priority. To achieve this objective, a survey of national and international initiatives that utilized digital technologies was conducted, aiming not only to enhance the acquisition of disciplinary content but also to promote the recognition and mobilization of cross-cutting skills. The selected cases presented in this document represent examples of creative integration of technology in pedagogical practices, all of which involve the mobilization of a set of transversal competencies that complement the technical and scientific knowledge acquired throughout academic training.

This study analyses the application of Virtual Reality and Augmented Reality in a university context through web-based applications such as *Giza 3D*, *Virtual Speech*, and *MoleculARweb*. These applications undoubtedly expand and diversify the range of educational activities. It is important to note that these tools are made available to the academic community. Their interactive potential requires a paradigm shift, and the role of teachers is crucial in facilitating two-way communication, cooperation, engagement, and student participation.

Despite the widespread use of these technologies in various sectors of society (entertainment, gaming, healthcare, industry, specialized training, among others), their impact on education is still highly dependent on the digital proficiency levels of educators. Therefore, it is important to promote sustainable and systematic training initiatives that encourage continuous professional development and the enhancement of technological skills, in order to overcome some of the barriers that hinder the effective use of these types of tools in education.

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The paper presents a brief theoretical contextualization of Virtual Reality and Augmented Reality technologies, followed by the case studies – *GIZA 3D*, *VirtualSpeech* and *MoleculARweb*.

Method

As previously stated, within the framework of the STRONG project, a set of pedagogical practices that integrated digital technologies to enhance the teaching and learning process were examined. This research was conducted across scientific databases and websites of European higher education institutions, based on four keywords: digital educational resources, virtual reality, augmented reality and higher education. The analysis period encompassed publications between 2011 and 2021, excluding papers that did not focus on the application of digital technologies in higher education. Among the selected studies, particular attention was given to those that employed Virtual Reality and Augmented Reality.

Virtual Reality

According to Velev and Zlateva (2017), Virtual Reality can be defined as "immersive multimedia or computer-simulated reality, replicating an environment that simulates a physical presence in places in the real world or an imagined world, allowing the user to interact in that world" (p. 33).

The term VR, coined by Lanier in the 1980s (Bryson, 2013), has acquired different meanings and applications over the years, but the idea of immersion and interaction finds consensus in the specialized literature (Manetta & Blade, 1995; Bryson, 1996; Velev & Zlateva, 2017).

In an academic context, the integration of virtual reality environments has encouraged students to discover and explore complex content while developing technical skills, creative thinking, and problem-solving abilities. It is also important to mention the dimension of experiential learning, inseparable from these more immersive and interactive technologies. In fact, the use of VR offers to the academic community the opportunity to access practical knowledge directly without leaving the classroom. In this regard, Velev and Zlateva (2017) reinforce that the introduction of VR in education has the potential to provide activities that, not being possible to replicate in reality, can take place in virtual environments.

In terms of scope, the use of this technology encompasses a wide range of areas, such as Architecture, Civil Engineering, Chemistry, Medicine, Biology, Physics, Astronomy, Media, Sports, Fashion, Entertainment and Telecommunications (Velev & Zlateva, 2017). The provision of various realistic training scenarios, in preparation for a profession and/or to reduce potential risks and hazards, is also one of the benefits of implementing VR in education.

Augmented Reality

Augmented Reality (AR), as defined by Wellner et al. (1993), refers to "a system that enhances the real world by superimposing computer-generated information on top of it" (p. 30). Azuma et al. (2001) further complement this idea by stating that the primary objective of AR systems should be "to enhance the user's perception of and interaction with the real world through supplementing the real world with 3D virtual objects that appear to coexist in the same space as the real world." (p. 1).

The digital evolution, along with the ubiquity of technological devices, has led to the proliferation of AR in the field of education. Similar to Virtual Reality (VR), there has been a significant increase in interest and research on educational activities that utilize AR technology, particularly in the disciplines of Chemistry, Biology, Mathematics, Physics, and Astronomy (Lee, 2012).

Regarding the effects of integrating AR into the teaching and learning process, various literature reviews suggest higher levels of student engagement and gains in curriculum-based learning (Bacca-Acosta et al., 2014). It also leads to increased motivation, interaction, and learner satisfaction (Saltan & Arslan, 2017), the possibility of exploring and visualizing items in three dimensional format (Wu et al., 2013), and the ability to integrate digital and physical objects in immersive hybrid learning environments that stimulate creative thinking, problem-solving skills, communication, and teamwork (Dunleavy et al., 2009).

Giza 3D project

Giza 3D, a component of the "Giza Project" developed by Harvard University, refers to a virtual environment that relies on immersive reconstructions of three-dimensional models sourced from the project's online digital repository. Within an academic context, it has fostered knowledge acquisition and in-depth exploration of the Giza Pyramids, offering an interactive virtual setting that includes virtual tours (Giza Project, 2023). This enables access to and understanding of realities that would otherwise remain inaccessible.

The 3D visualization, due to its immersive nature, has become the current format for teaching and research purposes. This research approach is the result of a thorough analysis of available excavation data from the early 20th century, complemented by recent photographs of the site (Der Manuelian, 2013). Presented below is an example of a restored model of the Tomb of Queen Meresankh III, which allows real-time exploration of this space (Figure 1) and provides access to additional information about specific elements within the model (Figure 2). Additional information about the statues depicted in the model and their significance is also highlighted. Regardless of the sequence of "clicks" the archaeological information provided by the website guides users through a narrative that will lead them to a deeper investigation of the main research theme. This aspect is particularly useful in an academic context as the dynamism provided by real-time navigation generates higher levels of engagement and participation from students (Der Manuelian, 2013).

Figure 1. Virtual tour of the Tomb of Queen Meresankh III.
Source: Giza 3D (2023). Retrieved from http://giza.fas.harvard.edu/giza3d/?mode=matterport&m=d42fuVA21To. Accessed in June, 2023.

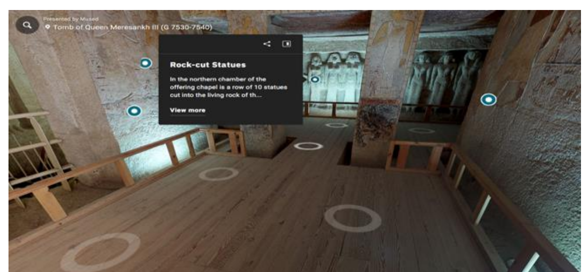

Figure 2. Virtual tour of the Tomb of Queen Meresankh III, featuring addicional information about the rock-carved statues.
Source: Giza 3D (2023). Retrieved from http://giza.fas.harvard.edu/giza3d/?mode=matterport&m=d42fuVA21To. Accessed in June, 2023.

Within the scope of this project, a noteworthy anthropology session (Figure 3) took place, in which students from Harvard University (United States of America), in collaboration with Zhejiang University (China), "transported" themselves, in avatar mode, to the pyramids of Egypt, highlighting a cooperative and interactive environment that proved conducive to the learning process.

Figure 3. Anthropology session using VR technology.
Source: TU Delft (2021). *Immersive University education in 2021: best practices collected by the NewMedia Center of TU Delft*. Retrieved from https://www.tudelft.nl/teachingacademy/previous-newsletters/the-educator-october-2021/immersive-university-education-in-2021. Accessed in June, 2023.

In the future, it is anticipated that Digital Giza will be made available through a mobile application, along with immersive interface devices, with the incorporation of AR also being planned in the short to medium term.

Virtual Speech

The use of VR to enhance language learning and/or practice oral presentations and job interviews has shown very positive results. The emergence of VR applications, specifically in a classroom environment, can contribute to supporting students in developing their communication skills while minimizing potential feelings of anxiety and nervousness (Owens & Beidel, 2015; Hinojo-Lucena et al., 2020).

Virtual Speech is a paid mobile VR application that promotes the acquisition and consolidation of a set of transferable skills. It allows users to practice their communication skills in a virtual learning environment, offering various interactive scenarios (Figure 4).

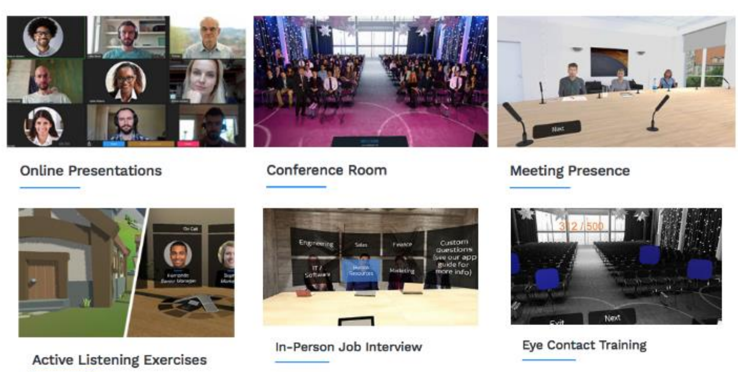

Figure 4. VirtualSpeech training scenarios.
Source: VirtualSpeech. (2023). *Virtual Reality Training*. Retrieved from https://virtualspeech.com/product. Accessed in June, 2023.

This application allows users to upload their own presentations, analyse body language to identify areas for improvement, and engage in collaborative online training in a virtual environment with peers. Another noteworthy aspect is the application´s ability to provide real-time feedback on the user´s performance (Figure 5). In this way, it provides tips (e.g. pacing, eye contact, loudness, among others), enabling educator´s to focus their feedback on aspects more closely related to the curriculum content (VirtualSpeech, 2023).

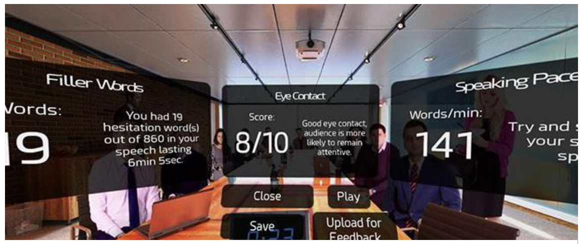

Figure 5. Example of feedback provided by VirtualSpeech platform.
Source: Educraft. (2018). *VirtualSpeech (Language VR)*. Retrieved from https://educraft.tech/language-vr-virtual-speech/. Accessed in June, 2023.

Assuming that feedback contributes to enhancing students' learning process, it is not always provided in an immediate and continuous manner. Recognizing this reality, the University of Maastricht has implemented VirtualSpeech in four out of its six faculties, leading to significant improvements in students' communication and presentation skills (VirtualSpeech, 2023). Furthermore, a study (Alsaffar, 2021) conducted among learners in an academic English program at the university level is worth mentioning. All participants reported that this virtual tool played a crucial role in reducing feelings of nervousness, proving to be a valuable support for practicing presentations and public speaking.

MoleculARweb

The "MoleculARweb" website, available for widespread use in eight languages, stands out as a valuable addition for the study and teaching of Chemistry and Biology through AR. In this website, teachers and students can explore, visualize, and manipulate 3D molecule models as if they were tangible, providing a significantly higher impact compared to simple computer graphics or plastic molecular models (Rodríguez et al., 2021). Simply by pointing the camera of a smartphone, tablet, or computer at the marker (Figure 6), users can access molecules as three-dimensional objects (Figure 7).

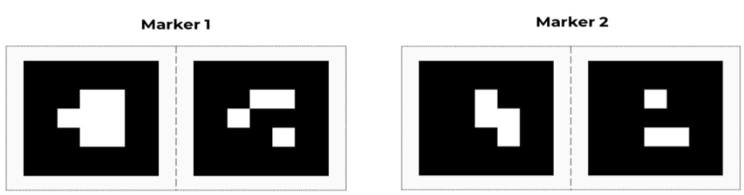

Figure 6. Printable markers.
Source: MolecuARweb (2020). *Markers*. Retrieved from https://molecularweb.epfl.ch. Accessed in June, 2023.

a) b) c)

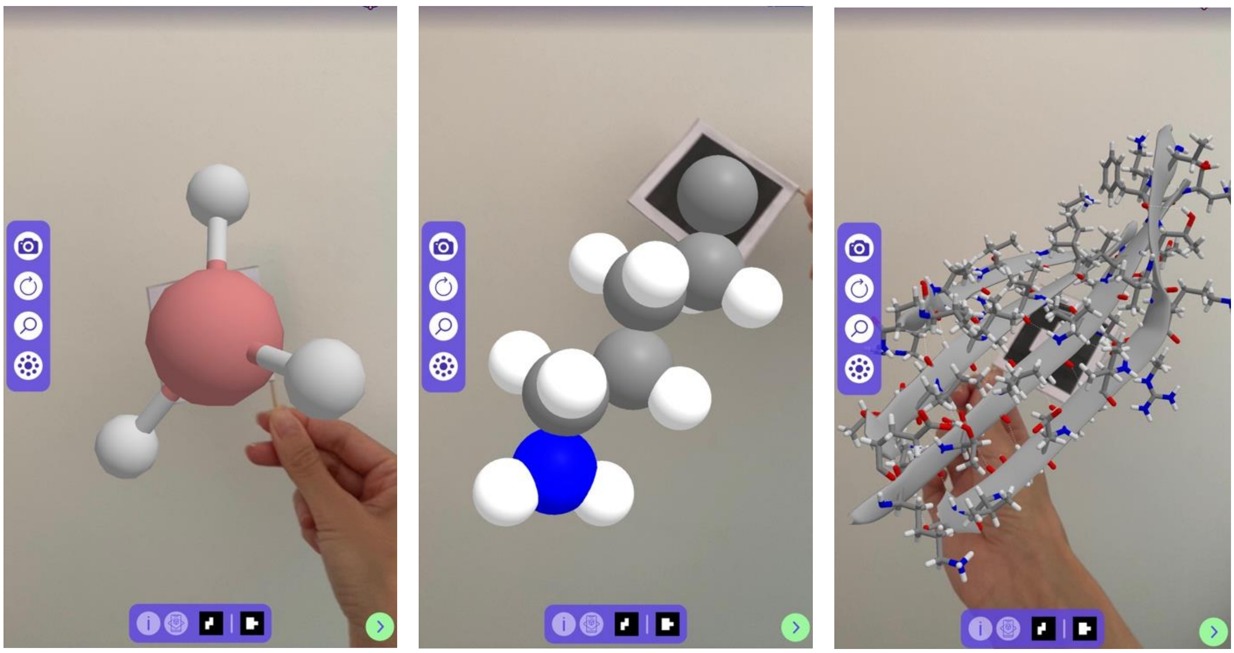

Figure 7. (a) Molecular shapes by VSEPR, displayed on a marker in a smartphone screen. (b) Equilibrium between acidic and basic amino acid side chains, displayed on a marker in a smartphone screen. (c) Protein secondary structures and stabilizing interactions displayed on a marker in a smartphone screen.

The website also offers the option of markerless model visualization (Figure 8). Instead, the application overlays the models on a flat surface, allowing users to move around them and explore them from various angles.

a) b)

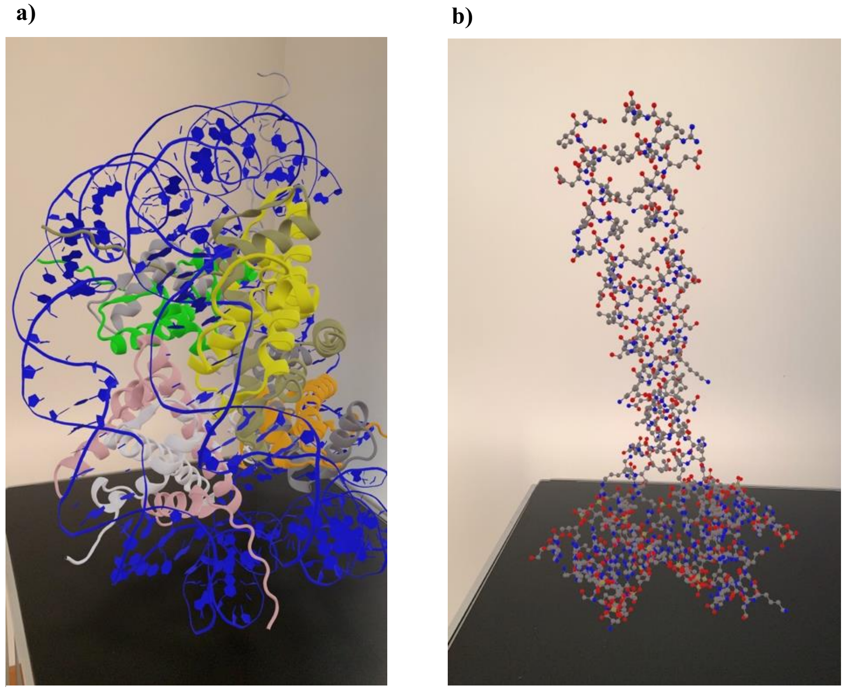

Figure 8. (a) X-ray structure of a nucleosome including the 4 histones and 2 rounds of ssDNA wrapped. (b) Protein-protein and protein-DNA interactions in a B-zip transcription factor.

The main advantage of this web-based application is that it doesn't require specialized equipment, which can be costly, and can be used on commonly available devices.

The website MoleculARweb has been widely used around the world, with a higher usage prevalence in Europe and the United States. According to feedback from the majority of teachers who participated in online evaluation surveys, the application has proven to enhance students' understanding of complex concepts, promote collaborative work, and facilitate peer dialogue (Rodríguez et al., 2021). Furthermore, it can be utilized in online learning environments, in-person classroom settings, or by students independently.

Conclusion

Both Virtual Reality and Augmented Reality have the transformative potential to diversify teaching and learning processes. The justification that the technology is too expensive or difficult to use hardly applies in today's world, as there is a clear trend towards making VR and AR increasingly accessible in the future.

Nevertheless, the reviewed literature also suggests several challenges that somewhat limit the sustainable use of VR and AR. The cost and the need for continuous updates, as reported by Nguyen et al. (2019), ensuring that all students have access to the necessary tools to use these technologies (Biswas et al., 2021), the absence of solid pedagogical strategies for their implementation, and ensuring user-friendly technical interfaces (Akçayır & Akçayır, 2016) are some of the challenges associated with the constraints of using VR and AR.

This paper aimed to present two VR applications - *Giza3D* and *VirtualSpeech* - and one AR application - *MoleculARweb*, explain their modes of operation, and demonstrate their potential applications in the context of higher education. The interactive and immersive dimension achievable through these applications allows the academic community to embrace pedagogical practices that align more closely with the underlying needs of the current digital era.

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