Immersive Technologies in Education

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Immersive technologies refer to virtual reality (VR), augmented reality (AR), mixed reality (MR), and other technologies and platforms that assist with simulations and visualizations. They are transforming education by creating engaging, interactive, and realistic learning experiences. They are used for a variety of purposes, including skills training simulations, virtual field trips, empathy development, perspective-taking, and visualizing complex ideas. These technologies allow students to explore simulated environments, interact with digital content, and apply knowledge in practical scenarios, enhancing both understanding and retention. Immersive education is an innovative approach to teaching and learning that leverages immersive technologies to create engaging and interactive educational experiences. This paper examines the uses of immersive technologies in education.

KEYWORDS: virtual reality (VR), augmented reality (AR), mixed reality (MR), extended reality (XR), assisted reality (aR), immersive technologies, education, training, immersive education.

INTRODUCTION

Education is the foundation for a thriving society, and the transfer of knowledge has been a top priority for civilizations since the very beginning. It is increasingly being involved with technological resources in order to meet the needs of emerging generations, consequently changing the way people teach and learn. Educators over the years have constantly searched for ways to make knowledge transfer more easily and more effectively. We have come a long way from traditional classroom learning, wherein a teacher, lecturer, or trainer stands in front of the class. This teaching method is gradually becoming a thing of the past as the world becomes more and more technologically driven day after day. Gone are the days when a simple chalkboard would suffice for instruction in the classroom. Today, various methods and tools are used in the educational system as educators use all sorts of breakthrough technology as primary mediums of instruction. Immersive tech has emerged as a tool that helps improve the learning process. It helps the students to study their content and increases student engagement in studies [1].

Human beings are visual creatures. Both hearing and seeing are central to our sense of space. As we have been spending an increasing amount of time in front of computers, the need for exploring more of the role of virtual environments needs to be increased as well. The requirement of obtaining more comfortable and inexpensive living standards makes the incorporation of immersive tech into our life unavoidable.

Webster's Dictionary 1989 edition defines virtual as "being in essence or effect, but not in fact" and reality as "the state or quality of being real. Something that exists independently of ideas concerning it. Something that constitutes a real or actual thing as distinguished from something that is merely apparent" [2]. Immersive technologies are a group of emerging technologies that all share a common aim: to create an experience for users that mediates their perception of their physical environment. Organizations in a diversity of sectors have adapted them for uses ranging from healthcare treatment to workplace training.

WHAT ARE IMMERSIVE TECHNOLOGIES?

Immersive technology is any technology that extends reality or creates a new reality by leveraging the 360 space. Virtual reality (VR), augmented reality (AR), mixed reality (MR), extended reality (XR), and assisted reality (aR) are the most popular, principal types of immersive technologies. Therefore, we will consider only five types of digital realities leading to different types of immersive technologies.

1. *VIRTUAL REALITY:* VR, as implied by its name, involves the use of a specialized headset to simulate an environment in which the user is fully immersed. Virtual reality (VR) is XR at its most extreme. It completely immerses the user in a digital world, often using a computer-generated environment with scenes and objects that appear to be real. The term "virtual reality" essentially means "near-reality." Virtual reality is the key technology for experiencing sensations of sight, hearing, and touch of the past, present, and future. VR is a fully immersive technology where users wear a head-mounted display and experience a simulated world of imagery and sounds. The terms, "virtual reality" and "cyberspace" are often used interchangeably. A cyberspace may be regarded as a networked virtual reality. A person using virtual reality can look around an artificial world, move around it, and interact with virtual features or items. This effect is commonly created by virtual reality headsets [3]. Virtual reality technology includes multiple components divided into two main groups: hardware and software components. The most common hardwire is the head-mounted displays (HMDs), which is used in combination with tracking systems. A head-mounted display is shown in Figure 1 [4].

2. *AUGMENTED REALITY:* The term "augment" is defined as "to make something greater by adding to it" by the Oxford Dictionary. Augmented reality (AR) is a technology that combines real-world environments with computer-generated generated information such as images, text, videos, animations, and sound. It can record and analyze the environment in real-time. In augmented reality, the user typically experiences the real world through a device such as a smartphone, tablet, smart glasses, or head-mounted display. For example, AR allows consumers to visualize a product in more detail before they purchase it. This feature enhances consumer interaction and helps them never to repurchase the wrong item. The key objective of AR is to bring computer-generated objects into the real world and allows the user only to see

them. In other words, we use AR to track the position and orientation of the user's head to enhance/augment their perception of the world. Augmented reality falls into two categories: 2D information overlays and 3D presentations, like those used with games [5].

3. *MIXED REALITY:* Augmented reality and virtual reality often go hand in hand in many applications, constituting what is known as mixed reality or hybrid reality. Mixed reality (MR) is a term used to describe the merging of a real-world environment and a computer-generated one. Physical and virtual objects may co-exist in mixed reality environments and interact in real time. This is an extension of AR that allows real and virtual elements to interact in an environment. MR liberates us from screen-bound experiences by offering instinctual interactions with data in our living spaces and with our friends. Online explorers, in hundreds of millions around the world, have experienced mixed reality through their handheld devices [6].

4. *ASSISTED REALITY:* Like mixed reality, assisted reality (aR) is an extension of augmented reality, with a few notable differences to both. One of these differences is that aR is primarily hands-free through the wearing of a headset, whereas AR usually requires the holding of a device such as a mobile phone. While MR is a digital-first, real-world second reality, aR is a real-world first system. It combines software and a head-mounted display. It is best experienced using smart glasses or other wearable technology.

5. *EXTENDED REALITY:* The term "extended reality" (XR) has recently gained favor as an umbrella term that encompasses all of AR, VR, and MR. The primary user inputs for XR devices are described as follows. Voice interfaces are now ubiquitous thanks to mobile devices and standalone smart speakers. Many XR devices enable user control with handheld controllers, which have capabilities beyond button press inputs. Both voice-driven interfaces and human-computer interactions have been developed specifically for XR devices, including gaze and gesture controls [7]. Extended reality (XR) is the overarching term used to describe employing technology to blend real life and the digital world. It includes all the machine-human interfaces beyond the physical realm (reality) such as augmented reality (AR), mixed reality (MR), assisted reality (aR), and virtual reality (VR). Figure 2 shows the XR spectrum [8].

IMMERSIVE TECHNOLOGIES IN EDUCATION

Immersive technology is a broad umbrella term for interactive technologies like virtual reality (VR), augmented reality (AR), and mixed reality (MR). For many people, immersive technologies are most associated with gaming and immersive virtual worlds, sometimes referred to as "the metaverse." Researchers have been exploring the potential of immersive technologies as an educational tool since at least the 1990s. The use of immersive technologies in education has rapidly increased beyond early applications in entertainment and gaming. In fact, healthcare and education currently lead other industries in directing investment in immersive technologies. AR/VR devices and applications have only recently become affordable and user-friendly enough for these solutions to actually be implemented in classrooms. Despite their differences, immersive technologies often share many hardware and software elements such as cameras, motion sensors, visual display devices and rendering engines.

Immersive education refers to a pedagogical approach that incorporates immersive technologies, such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and 360-degree video, to enhance the learning process. It immerses learners in virtual or augmented environments that engage multiple senses, including sight, sound, and sometimes touch. It aims to provide learners with realistic and sensory-rich environments that stimulate their senses and encourage active participation and exploration. It promotes experiential learning, where learners acquire knowledge through direct experience and hands-on activities.

Augmented reality (AR) and virtual reality (VR), positioned at different points along the virtuality continuum, offer distinct advantages in education. AR/VR solutions can enhance classroom experiences and expand opportunities at all levels of learning. Immersive environments allow students and instructors to interact face to face and in real time, regardless of where they might be physically located. These immersive experiences can place students in scenarios that would otherwise be impossible. Educators can use these resources to enhance classroom learning in subjects such as natural sciences and US history.

APPLICATIONS OF IMMERSIVE TECHNOLOGIES IN EDUCATION

Although still in its early stages, there are many promising applications of immersive technology already in use in K-12, higher education, and teacher training. Applications range from STEM education and technical training to arts and humanities. Common areas of application of immersive technology in education include the following [9,10]:

➢ *Immersive Learning:* Immersive learning is a learning approach that simulates real-world scenarios in a safe and engaging environment, enabling learners to practice and master tasks with hands-on experience. It is an innovative approach to education leveraging cutting-edge, immersive technology to create engaging and interactive learning experiences. This technology simulates real-world environments and scenarios, allowing students to learn in both the physical and virtual worlds while eliminating distractions. Coupled with artificial intelligence (AI), immersive learning tools can adjust lesson plans and adapt to students' needs when necessary. Immersive learning has the potential to revolutionize education and workforce training. It can enhance traditional classroom education by enabling students to explore historical events, scientific phenomena, and complex concepts in a more engaging and interactive manner. Immersive learning is transforming training and education by promoting active engagement over traditional passive methods. Figure 3 depicts immersive learning experience [11].

➢ *K-12 Education:* Due to the unique capabilities of these technologies, immersive solutions are gaining popularity among K-12 educators and administrators. AR/VR solutions can either enhance, partially replace, or fully substitute for traditional classroom learning. They can provide K-12 educators with interactive and engaging tools for classroom learning. These include libraries of immersive content, experiences for specific subjects or learning objectives, and tools for students with learning disabilities. Immersive technologies allow students to passively participate in remote learning experiences and engage with instructors and peers in real time using shared virtual elements. Immersive learning can also supplement career and technical education.

➢ *Higher Education:* Immersive technologies are equally valuable in more advanced learning environments. College and university educators across disciplines are implementing immersive technologies in their courses. Higher education solutions combine the learning advantages of immersive experiences with AR/VR's capacity to reduce barriers found in physical space. In higher education, AR/VR can help learners grasp abstract concepts and gain hands-on experience in

low-risk virtual settings. This can enhance STEM courses, medical simulations, arts and humanities materials, and technical education. Some academic institutions have introduced dedicated spaces (such as dedicated labs) that allow students and faculty to access AR/VR devices and develop their own content. For example, Colorado State University launched an Immersive Reality Training Lab in 2019 to accommodate up to 100 students for simultaneous immersive learning experiences. One well-established use of AR/VR in higher education is immersive simulations. Virtual simulations offer relatively low-cost alternatives to more traditional in-person scenarios while maintaining a level of immersion that makes participants feel like they are "really there." Beyond medical education, virtual simulations can also facilitate soft-skills training, such as negotiation and communication skills. Figure 4 shows the use of immersive tech in higher education [12].

➤ *STEM Education:* The integration of STEM education in learning curricula promotes a deeper comprehension of scientific and technological concepts, crucial for fostering 21st-century skills in students. Although the STEM approach has gained prominence in science education, it still requires proper teacher readiness for successful implementation. Immersive experiences can be particularly beneficial in STEM education because they offer hands-on experiences that would be either logistically difficult or physically impossible in the real world. A growing number of STEM faculty and educational technology experts are developing creative ways to teach complex and often abstract concepts using AR/VR tools. Figure 5 shows the use of immersive technologies in STEM education [13].

➤ *Medical Education:* Immersive technology is a growing field in medical education. Medical education requires significant hands-on, in-person learning to prepare students for everything from interacting with patients to completing complex procedures. Medical and healthcare educators are increasingly turning to AR/VR solutions to provide low-cost, low-risk, and often more interactive alternatives to traditional approaches in this field. Medical students can view and manipulate anatomical models in real time using MR headsets [14]. AR/VR technologies can help students develop critical soft skills that will better equip them for success in the future. Figure 6 shows a typical use of immersive tech in medical education [10].

➤ *Teacher Training:* Technology can play a supporting role, positively changing the way students learn, but it cannot be a replacement for teachers. The teacher is the one who integrates the technology into instruction by encouraging and motivating students to grasp new knowledge in their studies. Teachers, therefore, should reasonably expect that they are provided with training in the effective use of immersive technologies. Children and university students are not the only audiences for education-focused immersive experiences. The same capabilities that make these technologies a valuable tool in K-12 and higher education also position them to help teachers learn and grow. Immersive technology can help teachers understand their own classroom behavior in a low-impact setting—if something goes wrong, or they react inappropriately, they can simply reset the simulation. For example, Teacher's Lens translates the Harvard Implicit Association Test into a VR simulation for teachers. Teacher's Lens aims to address unconscious or implicit biases that may impact how teachers interact with female students and students of color.

➤ *Wearables:* Another interesting immersive trend hitting classrooms are wearable devices. These can co-exist with AR and can provide the hardware alternatives for delivering AR systems. Most young adults have heard of wearable devices and those that actually own one report using it for fitness tracking.

BENEFITS
Immersive education plays a significant role in modern pedagogy, offering many benefits. AR offers various advantages to students. Some of those advantages include enhanced motivation, entertainment, learning outcomes, and memory. This is accomplished by providing students with a learning environment that includes continual feedback, collaboration, personalization, and active engagement. Other benefits include the following [14]:

➤ *Engagement:* Immersive experiences capture learners' attention, making the learning process more effective. Learners are four times more focused during VR training than online training. Immersive education harnesses immersive technologies to create engaging and effective learning experiences. With its potential to enhance engagement, understanding, and retention, immersive education offers a promising path for the future of education. Learners actively engage with the environment, making decisions

and observing the outcomes of their actions. Compared to traditional learning methods, learners engage with VR content at much higher levels. One of the major benefits of virtual and augmented reality in the classroom is that they can block out classroom distractions.

➢ *Retention:* Immersive learning environments capture the attention of trainees, making it easier for them to focus and absorb information. This method is particularly effective for training in high-stress environments, interpersonal communication, and human relations, where practical experience is crucial for understanding and retention. Learners retain information better in VR for several reasons. They feel like it is real life, thereby raising the stakes and telling our brains that this information is critical. Learners are able to repeat training much more frequently.

➢ *Accessibility:* Immersive learning is a fantastic way to make the classroom more accessible. It can make education more accessible to learners with diverse needs and abilities, accommodating various learning styles. Many VR training scenarios can be accessed on multiple devices. It is critical to have this, because real life does not always wait for the ideal conditions.

➢ *Equitable Education:* This refers to young learners achieving a similar level and range of learning outcomes regardless of their social, economic, and academic circumstances. Geographical location and proximity to resources are also important factors in the search for equitable education. Students in rural areas and smaller towns must have the same opportunities, and achieve the same results, as those in the urban areas. Immersive technology is removing barriers to achieving equitable education. The implementation of immersive technology is making it easier for schools to create accessible learning environments and get closer to achieving equitable outcomes for all students.

➢ *Enjoyment:* It is simply more fun to have interactive training. Immersive learning provides accessible and enjoyable training experiences for diverse learners. This increases motivation and improves learning outcomes, making it easier for individuals to grasp concepts, learn new skills, and repeat their training as much as needed.

➢ *Real-World Applications*: High-fidelity simulations closely mimic real-world scenarios to enhance the learning experience. Immersive education provides opportunities for learners to apply theoretical knowledge in practical, real-world scenarios. For example, immersive experiences can replace or complement physical field trips and tours.

➢ *Personalization:* Learning styles have been described as how we might learn in different ways and how technology can be designed to accommodate our differences. Immersive technology may be personalized. It may be set up to respond both to the users' personal manipulations and the training instructor to accentuate learning in areas where the student may require more attention and focus. Immersive education can be customized to suit individual learning preferences, pace, and objectives. Like soft skills training, AR/VR can enhance technical education and specialized training by creating a low-risk, low-cost learning environment. Immersive learning gives employees on-the-job training without being on the job.

➢ *Collaboration:* Learners collaborate on immersive projects that require teamwork and creativity. AR fosters team learning by allowing students to work with digital elements in their actual surroundings. This enhances their teamwork and communication abilities.

➢ *Safety:* Sometimes we need to prepare for dangerous situations. Creating these situations for training is not only dangerous for learners, but extremely costly. Immersive learning offers a controlled environment where individuals can safely practice high-risk scenarios without real-world consequences. It creates a safe environment for learners to experiment and make mistakes without real-world consequences. This enhanced safety encourages both risk-taking and exploration, which are critical components of learning.

CHALLENGES

In spite of its many benefits, immersive technologies pose new challenges. Because AR/VR is still a relatively new technology, there is a notable technical learning curve for both students and educators that may discourage adoption. This requires extensive training for educators and learners to use them effectively. Another problem of immersive technologies is there is no common vocabulary or understanding of what these technologies are, how they work, what kinds of data they collect and what kinds of technical components they use. Other challenges include the following [3]:

High Cost: One of the primary challenges is the high cost of implementing and maintaining immersive learning technologies. Although the cost of

immersive solutions is going down, it is still prohibitive for many, particularly districts and institutions with limited resources. Schools that do have the budget for new technology solutions will likely prioritize established, proven technologies such as laptops and tablets over newer devices and applications—such as AR/VR—that carry higher uncertainty and unfamiliarity. The economic resources of parents and of the school itself mean that many students miss out on valuable experiences.

Technical Literacy: Technical literacy presents a challenge for adoption among learners and educators. The skills and attitudes of teaching staff could also hinder widespread use. The Department of Education should offer educators training and resources for using immersive technologies. The department should provide funding for educators to enroll in courses to learn how to create basic immersive content so they can create their own materials to meet specific learning objectives. It should integrate key AR/VR skills into existing digital literacy resources and initiatives for both K-12 and adult learners.

Regulation: Given that immersive technologies may be used in a variety of settings, regulators may find they need to determine how to apply existing regulatory guidance or whether new guidance may be needed to address the risks – be it for medical device regulation, employment law or online safety regulation. Regulators will also need to consider what kinds of users may be affected and the contexts and functions for which these technologies may be deployed.

Risks: The risks of immersive technologies may arise in many ways – from the way these technologies function to social factors such as the dynamics among those developing these technologies. The severity and likelihood of the risks of these technologies will depend on: how they are designed and operated, what purpose they are used for, what contexts they are used in, and what kind of people will be affected. Examples of these risks include algorithms used within immersive technology products that have been found to perpetuate bias and discrimination.

Data Protection: At a technical level, immersive technologies operate through a process of data creation and processing that often involves specialized hardware products that collect a significantly higher volume of data than devices such as smartphones and laptops, including a diversity of sensitive data. This creates significant privacy and data-protection risks that developers must navigate.

CONCLUSION

Immersive tools offer enormous potential to transform the way students of varying ages and disciplines learn. As immersive technologies evolve, their potential to transform how learners interact with digital content and the world around them will only continue to expand. As they become more affordable and accessible, their integration into education and training is expected to become more widespread. By embracing immersive technologies, educators and learners alike can embark on exciting educational journeys that bring learning to life.

Education's future is intertwined with technology. Immersive tech is becoming a new future of education technology with virtual classrooms where students globally can learn together. Immersive education represents a significant leap in education and training, offering an active, engaging way to learn. There is growing enthusiasm among students and educators—as well as parents, administrators, and institutions—around using immersive technologies as educational tools. The future of immersive education is bright, with technological advancements and a growing understanding of their educational potential. More information about immersive technologies in education can be found in the books in [15-31].

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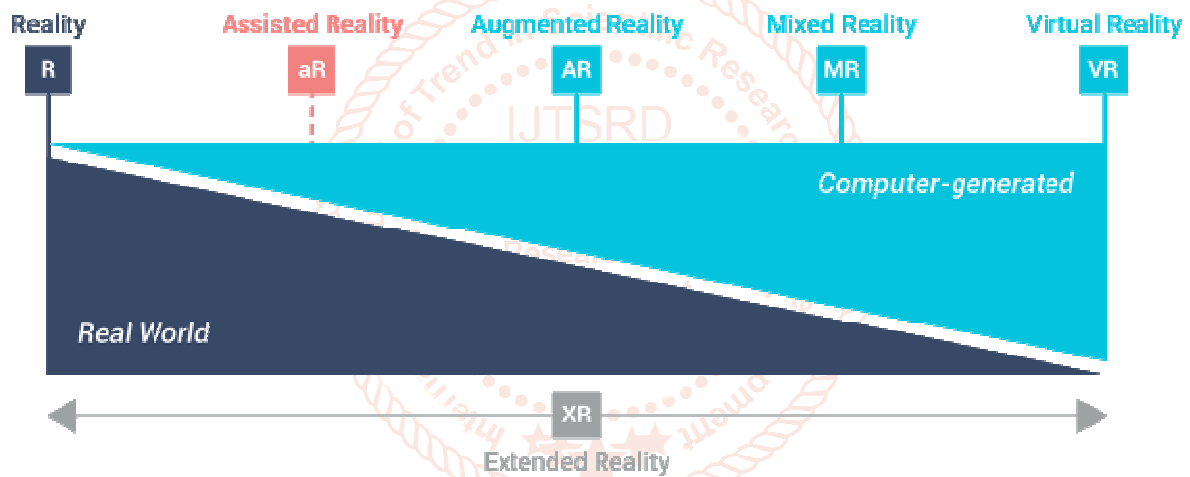
Figure 1 A head-mounted display [4].

Figure 2 The XR spectrum [8].

Figure 3 Immersive learning experience [11].

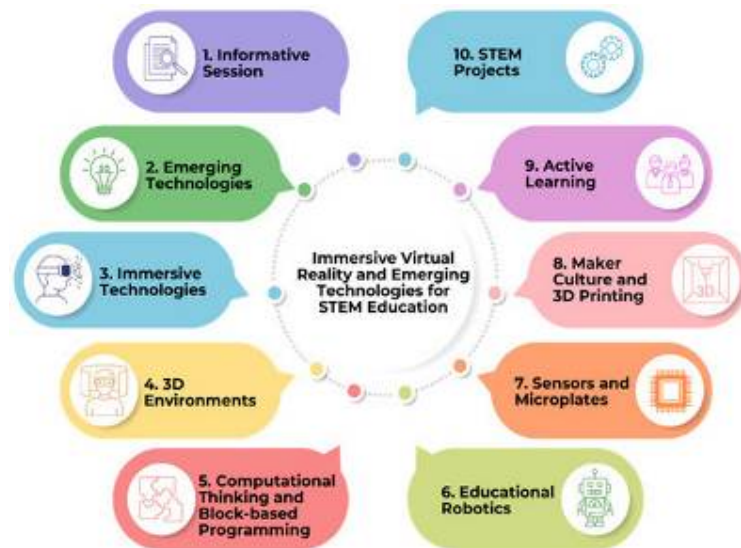**Figure 4 Use of immersive tech in higher education [12].**

Figure 5 Use of immersive technologies in STEM education [13].

Figure 6 A typical use of immersive tech in medical education [10].