Virtual reality and Augmented Reality in Educational Development in the 21st Century

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ABSTRACT

Education is a foundational element of society that is concerned with sharing and expanding knowledge in the most efficient ways using, of course, new technologies. This makes education a perfect case for testing the technologies of Virtual Reality (VR) and Augmented Reality (AR) solutions, respectively. Moreover, while education is treated with utmost seriousness, it is not without its issues, namely the limited availability of educational services and lack of trained personnel. Besides, there is a huge problem with people who have limited physical abilities or who live in places that are hard to reach. For these reasons, implementing VR/AR tech into the education system has become imperative. With the continuous development of modern information technology and the increasing level of science and technology, virtual reality and augmented reality technologies play a significant role in educational development. This paper focuses on the meanings, forms, key differences, and educational applications of virtual reality and augmented reality technologies.

KEYWORDS: Virtual reality, Augmented reality, Teacher, Educational development, Technology.

Introduction

Over the last few decades, virtual reality (VR) and augmented reality (AR) interfaces have shown the promise to improve teaching and learning by merging the physical and virtual worlds and utilising the benefits of both. More recently, advances in virtual reality technology have made VR as well as AR affordable and appropriate interfaces for education at all levels, including elementary schools, secondary schools, colleges, and universities. Virtual sandbox environments, for example, are virtual reality environments that allow users to freely walk around in a virtual world, determine how and when to accomplish tasks, and build domain-specific mods. This aids the teacher in creating VR-based teaching and learning environments, as well as allows students to freely explore new knowledge. The rapid growth and development of this and other virtual reality (VR) and augmented reality (AR) technologies thus motivated this study, which examines the conceptualization and utilisation of AR and VR technologies in educational development. The paper begins by establishing what virtual reality (VR) and augmented reality (AR) technology are.

The Concept of Virtual Reality (VR) and Augmented Reality (AR)

It is important to clarify what Virtual Reality (VR) is and what Augmented Reality (AR) is and to distinguish between them. This is because both terms do not necessarily mean the same thing: they have slight differences in meaning, usage, and scope. Virtual reality (VR) is a technology that uses computer simulation to create a three-dimensional virtual world, allowing users to simulate their vision, hearing, touch, and other senses and then create a realistic setting (Liyuan, 2020). It's a real or virtual setting where a perceiver can feel telepresence (Minocha et al., 2017). AR, on the other hand, is a technology that superimposes a computer-generated image over a person's view of their surroundings (McMillan et al., 2017). Based on virtual reality technology, augmented reality is a type of comprehensive technology that is progressively upgraded and developed (Liyuan, 2020). A summary comparison of virtual reality and augmented reality is given in Figure 1.

AR	VR
The system augments the real-world scene	Completely immersive virtual environment
In AR User always have a sense of presence in the real world	In VR, visual senses are under control of the system
AR is 25% virtual and 75% real	VR is 75% virtual and 25% real
This technology partially immerses the user into the action	This technology fully immerses the user into the action
AR requires upwards of 100 Mbps bandwidth	VR requires at least a 50 Mbps connection
No AR headset is needed.	Some VR headset device is needed.
With AR, end-users are still in touch with the real world while interacting with virtual objects nearer to them.	By using VR technology, VR user is isolated from the real world and immerses himself in a completely fictional world.
It is used to enhance both real and virtual worlds.	It is used to enhance fictional reality for the gaming world.

Figure 1: Comparing Virtual Reality and Augmented Reality. Image source: Huawei

Virtual reality (VR) is a novel technique for humans to use a computer to visually control and interact with complex data. It is a comprehensive integration technology that interacts with computer graphics and mutual technology between humans and computers, as well as sensor technology, artificial intelligence, and other domains. Computer vision, image processing, graphics, multi-sensor technology, and display technologies are all part of augmented reality. It combines the real environment viewed by users with virtual information generated by the computer, allowing users to stack the real environment and virtual items in the same picture face or space, enhancing user perception and perception experience. It is not a stand-alone technology, but rather one that is intimately linked to all types of information in real life to better mine data and present unique scenes. See Figure 2 for a summary of the difference between AR and VR.

Figure 2: Difference between AR and VR. Source: i-boson Innovations

Virtual Reality and Augmented Reality: Forms, Types, and Applications

Since the 1960s, when the first digital flight simulators were developed and used by the world's leading airlines and air forces, virtual reality has existed in many forms (Pantelidis, 2010). The pilot's view was displayed using a camera and projector, and the motion was frequently used to enhance the realism and immersion of the simulation. "Virtual reality" became the term for gadgets that produce an immersive, interactive environment with visual realism as technology progressed.

Desktop VR (Merchant et al., 2014) is the least immersive version of virtual reality, in which a 3D virtual environment is displayed on a conventional computer monitor. Figure 2 depicts Ausburn's Desktop VR approach for learner pre-immersion in a CTE desktop virtual environment (2009). Although not as immersive as more immersive kinds of virtual reality, it nonetheless acts as a window into a 3D virtual world and is far less expensive and accessible. Because personal computers became strong enough to create and render 3D virtual worlds in the early 2000s, desktop VR arose. The 3D virtual worlds of Second Life are a popular example of Desktop VR today. Second Life is accessed via the Internet, and users are represented in the virtual world by an avatar. Text and audio can be interacted with, 3D objects can be created, and users can own their own "land" in the world. MMORPGs such as World of Warcraft or EVE Online, where thousands of users interact and coexist in a persistent virtual world, is another example of Desktop VR.

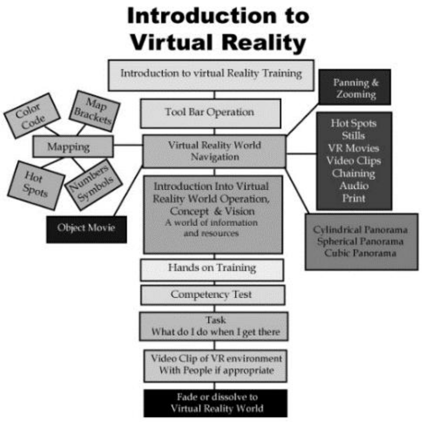

Figure 3: Ausburn training model for learner pre-immersion in CTE desktop virtual environments. Copyright 2009, Floyd B. Ausburn. Image source: Researchgate.net

Figure 4: 3D virtual worlds of Second Life. Image source: onlinelibrary.wiley.com

Figure 5: The interface of World of Warcraft. Image source: Researchgate.net

Figure 6: Eve Online Image Source: wired.com

CAVE (Cave Automatic Virtual Environment) is an intermediate type of virtual reality that uses projectors to display a virtual environment on the walls around the user. Users may be required to wear stereoscopic glasses to observe the virtual world in three dimensions and so increase immersion. Although costly, CAVE VR has the advantage of allowing several people to share the same virtual reality experience while still interacting face-to-face.

Figure 7: Cave Automatic Virtual Environment (CAVE). Image Source: Wikipedia

Virtual reality's most immersive form employs a stereoscopic head-mounted display with motion tracking to determine where the user is looking. The user's vision of the outside world is fully blocked, giving the user a powerful sense of immersion while simultaneously allowing the user to see the virtual environment. Although helmet-mounted displays have been around for decades, the Oculus Rift was the first to make them available to the general public in 2014. The HTC Vive, Google Cardboard, and Samsung Gear VR are just a few examples of consumer helmet-mounted displays available today.

Figure 8: HTC Vive. Image source: Wikimedia

Figure 9: Google Cardboard. Image source: Wikimedia

Figure 10: Samsung Gear VR in Use. Image source: Wikipedia

The term "augmented reality" refers to a type of visualization that blends the actual and virtual worlds (Choi, 2016). With the debut of the smartphone game Pokemon Go, which has been downloaded over 500 million times, augmented reality became a part of popular culture in 2016. Augmented reality adds computer-generated components to the user's perspective of the real environment, usually in the form of 2D or 3D visuals and text (Kamphuis et al., 2014). Mobile devices or head-mounted displays, such as Google Glass, are commonly used to visualize this improved view.

Figure 11: Pokemon Go. Image source: Wikipedia

Figure 12: A user controls Google Glass using the touchpad built into the side of the device. Image source: Wikipedia

The approach utilized to determine how to enhance the image defined how augmented reality is classified or grouped. Typically, augmented reality is classified as either marker-based augmented reality or markerless augmented reality. In marker-based augmented reality, image processing is used to identify a point in the real world and display virtual content based on the marker. Typically, the marker is in the form of a QR code, but it could also be any easily identifiable object. The other form of augmented reality is markerless augmented reality, which employs a combination of sensors to establish the device's location and orientation, such as the GPS and compass on a smartphone, and then augments the original image with digital content based on its location.

Uses and Benefits of AR/VR to Learners

Immersive technologies are currently being used in education and have proven to be a successful tool for enhancing the learning of a variety of disciplines and/or subjects (Al-Samarraie & Saeed, 2018). Virtual reality (VR) and augmented reality (AR) are two examples that demonstrate how these new technologies can be used to support lifelong learning (Ozdemir et al., 2018). According to several studies and research, VR and AR complement constructivist learning principles (Bani-

Salameh et al., 2017; Huang et al., 2010; Katz & Halpern, 2015); thus, learners who use VR and AR will be able to process and control a variety of learning activities. Learners have complete control over where and when they explore learning with AR and VR. In a virtual reality environment, for example, learners can choose the speed at which they move and learn. They can connect with friends across a network and decide what to do next once the communication is completed (Ha & Fang, 2018).

Besides, students can quickly visualize virtual objects using AR, making learning more engaging and realistic than with any other technology (Vosinakis et al., 2018; Zhu et al., 2018). Learners can also use a handheld device to overlay virtual electromagnetism content on actual book pages (Wu et al., 2018; Al-Samarraie & Ahmad, 2016) or play an AR game that uses tangible cubes to learn about different animals that are on the verge of extinction (Wu et al., 2018; Al-Samarraie & Ahmad, 2016; Daineko et al., 2017). It is thought that exposing pupils to computer-simulated surroundings can help them understand science more effectively (Chen et al., 2017). This is because merging real and virtual worlds creates mixed reality, which allows learners to explore a wide range of possibilities (Correia et al., 2016).

Killer Snails' BioDive (Figure 13) is a web-based virtual reality simulation tool that teaches middle school pupils about marine biodiversity. As marine biologists, students investigate an undersea ecosystem, with the app prompting them to make observations and formulate ideas in an online journal. Individual student progress can be viewed by teachers, who can then assist them in their learning. Students can use any web-enabled device to enjoy the immersive experience as well as the online journaling option.

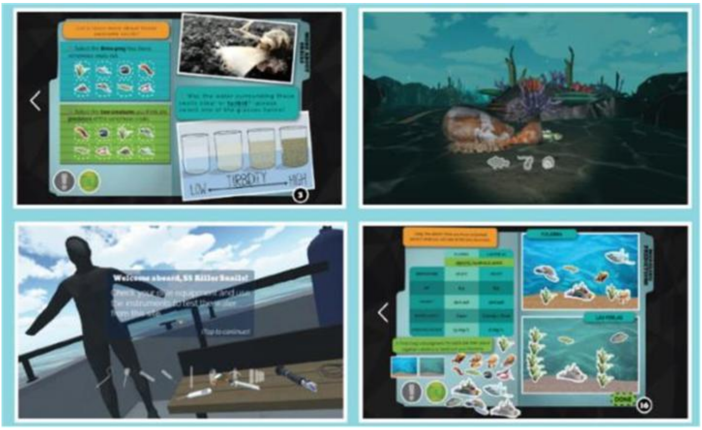

Figure 13: BioDive lets students experience a marine expedition from an immersive, first-person view. Image source: Killer Snails.

Applications of VR and AR in Medical Education

Virtual reality is used in a variety of surgery trainers and simulators, including laparoscopy (Huber et al., 2015), temporal bone surgery (Fang et al., 2014), and even dental training (Steinberg et al., 2007). Some of these virtual reality applications include haptic (tactile) input, and they all allow students to practice their abilities in a secure setting without having to use human or animal cadavers. In addition, virtual reality has been utilized to assist medical students to visualize anatomy in 3D, giving them a considerably better sense of context and scale than the cutaway diagrams and photographs seen in most anatomy textbooks (Falah et al., 2014).

In addition, augmented reality has been utilized to aid in the visualization of anatomy, lung dynamics, and laparoscopy (Kamphuis et al., 2014). "Miracle," for example, is a system that employs a camera to simulate a mirror view of the user while superimposing images from a CT scan to provide the user a glimpse of "their" anatomy. By using a Microsoft Kinect sensor to create an infrared-based depth image, determines where the image should be displayed (Blum et al., 2012). ProMIS is an augmented reality laparoscopic simulator that employs a dummy and superimposes labels and internal organs on the camera feed to instruct and assess students (Botden, 2009).

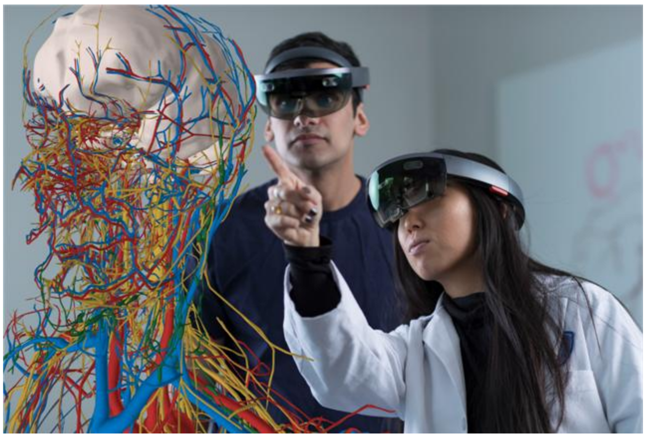

Figure 14: Using HoloAnatomy software and MR headsets, medical and life sciences students can view and manipulate anatomical models in real-time. Image source: Interactive Commons at Case Western Reserve University.

Use of AR/VR in Science Education

In the early days, Virtual reality was used in science education to visualize chemical reactions and learn about molecules by putting them together in a virtual setting. Marker-based augmented reality specifically was and is used to date to show the process of respiration and human meiosis (Weng, 2016). Another recent example is an astronomy application that uses a head-mounted display to explore the solar system and offer pupils a sense of scale (Hussein and Nätterdal, 2015). A good example is HoloAnatomy, a medical teaching program created by Case Western Reserve University that incorporates Microsoft HoloLens MR devices with anatomy programs (Figure 14). HoloAnatomy, rather than using cadavers, allows students to interact with 3D anatomical models and receive real-time feedback. Remote learning is possible with the collaborative, MR-based method, which was important for medical education during the COVID-19 epidemic. Virtual reality and augmented reality allow students to visualize topics that are abstract or difficult to link to real-world experiences, such as an augmented reality application that teaches electromagnetism and the interactions between different circuit elements (Ibáez, 2014).

AR/VR in Engineering

In introductory electrical engineering classes and courses, a variety of augmented reality apps have been built and evaluated for teaching and learning (Martn-Gutiérrez et al., 2014). ElectARManual is a good example of this. This device overlays animations and instructions on top of electrical machines in the lab to assist students in learning how to use them (i.e. electrical machines) safely. Besides, ELECT3D is a markerless electrical diagram reading and interpretation system (Figure 15). Also, ElectAR notes, a third application, is a study assistant that recognizes marks on course study notes and presents topics with video, animations, and more extensive information. Another study used Google Cardboard headsets to create a virtual reality application to educate microcontrollers and Arduino boards (Ray and Deb, 2016)

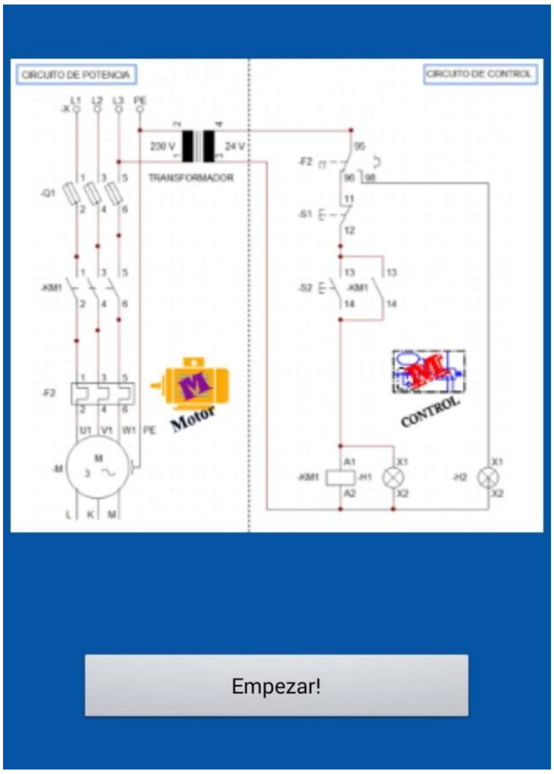

Figure 15: ELECT3D. Source: apkpure.com

A model of a complete charcoal mini-blast furnace with all of its sub-subsystems was modeled recently by a Brazilian university (Figure 16). Their model includes detailed information, videos, as well as 360-degree pictures from actual blast furnaces, and it was used to teach engineering students the process and interaction of the various subsystems in a blast furnace (Vieira et al., 2017).

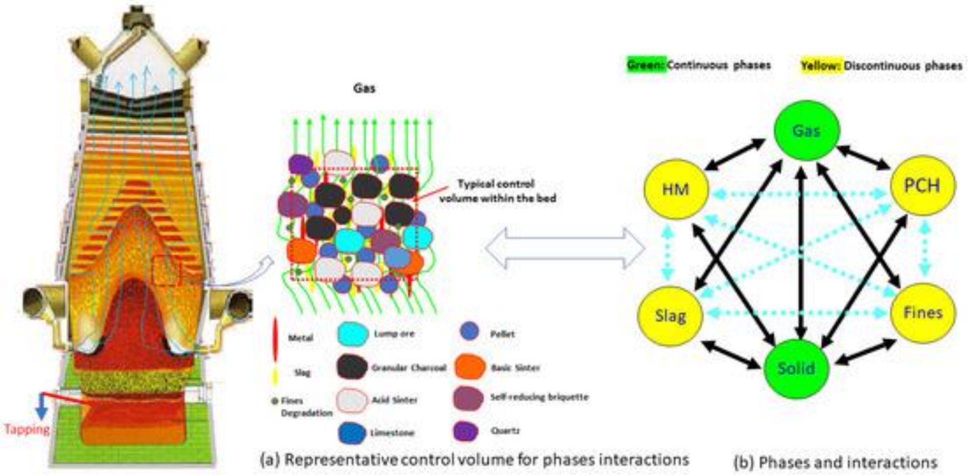

Figure 16: The multiphase and multicomponent approach of the internal state variables of the charcoal mini blast furnace modeling. (a) A representative control volume of the inner furnace. (b) The corresponding local multiphase interactions of mass, momentum, and enthalpy. In (a), the color particles represent the type of the granular materials inside the reactor, and (b) color represents the phases and their interactions: green is continuous phases, and yellow is discontinuous phases. Continuous lines indicate momentum, chemical reactions, and energy exchange. Dotted lines are for only chemical reactions and energy exchanges among the phases with single interactions for momentum. Source: mdpi.com.

AV/VR for teaching History and Social Sciences

Virtual field tours to historical sites or "first-hand" witnessing historical events are two of the most popular uses of virtual reality in teaching and studying history (Choi, 2006). The Google Expeditions Pioneer Program does exactly that: students travel to their virtual destination and explore it using Google Cardboard (Figure 9.) and their smartphones. The teacher is the tour guide for the field trip, and the teacher's app (i.e. The Google Expeditions Pioneer Program) can highlight spots on the students' perspectives to assist focus attention, as well as provide more information to describe students' particular sights in greater depth (Ray and Deb, 2016). Augmented reality travel guides for mobile platforms are available on live field trips to historical locations to enhance the students' experience and allow them to explore on their own (Olsson et al., 2013).

Virtual reality has also been used in behavioral studies to mimic or produce scenarios that may naturally be troublesome or dangerous. For example, virtual reality simulations were utilized in fire evacuation studies to capture how people would react in the event of a fire, yielding more accurate results than the traditional approaches for studying people-fire reactions (Kinateder et al., 2014).

AV/VR for learning Foreign Languages

In foreign language teaching, virtual reality has been used to allow students to communicate with native speakers in 3D virtual worlds utilizing Desktop VR (Figure 3). Second Life (Figure 4) is a popular 3D virtual world used as an educational tool since it is free to use, permits voice and text communication with other users, and is an open-ended world where anybody may generate content (Baker et al., 2009). This reduces the distance in assimilation between students who are learning a foreign language and the native speakers of the language, allowing both to converse and exchange value from all over the world (Jauregi et al., 2011; Ibáez et al., 2011; Blasing, 2010).

Application of AV/VR in Distance Learning

Although the Internet has made distance learning considerably more accessible and rich in content than ever before, online message boards or e-mail is often the only platform for discussion and interaction with students. Distance learning can benefit from virtual reality since it allows for more natural and easier class discussions. Giving lectures in a virtual classroom, such as Second Life, is one of the most basic examples in this regard (Jarmon, 2009).

In a virtual reality space, participants can ask questions if a concept is not well-understood, the teacher can use classroom discussion tactics to develop critical thinking, and the students can communicate or coordinate with colleagues before and after class. This is possible because both instructors and students are in the same virtual space.

For classes that require hands-on application in labs, such as science, engineering, or technology, remote learning presents greater problems. One way out is to design and produce a 3D virtual lab environment in which students can complete their tasks easily and on time. Although virtual labs cannot replace the requirement for hands-on experience, they can be utilized to teach fundamental skills, perhaps reducing the number of visits and time spent in a physical lab (Potkonjak et al., 2016).

The Current State of Virtual Reality, Augmented Reality in Africa

AR and VR can assist Africa in addressing key challenges such as education and healthcare, as well as other critical issues facing the continent. Many government-funded schools in Africa have too many students that they can cater to, as well as limited teaching/learning resources to fast-track meaningful education. Virtual reality and Augmented Reality are cutting-edge technology around the world. Regardless, these are solely limited by the creator's creativity. Although the ecosystem of AR and VR continues to attract new stakeholders, there is more room to determine and accommodate VR's and AR's future trajectory, particularly in Africa, where these technologies are attempting to address concerns such as healthcare and education.

Virtual reality and augmented reality are slowly but steadily gaining traction in Africa. However, these technologies can be expensive to pursue, especially given that the framework which they build on is still gaining acceptance. In Africa, VR and AR adoption is not progressing as swiftly as their proponents would want. Africa is just getting started. However, with a concerted effort from the government and the private sector much can be achieved. After all, with careful planning and execution, a school's VR lab can be less expensive than a computer lab and this can be easily integrated into the learning framework if generally or fully accepted and integrated into learning classrooms (Chiefe, 2019).

The possibilities of Virtual Reality and augmented reality are illuminated by inspiring stories from VR content makers. The prestigious Venice Film Festival recently screened a 360 VR Nigerian documentary, demonstrating VR's expanding appeal in Africa. The startup hosted Nigeria's first VR/AR hackathon in November 2016.Furthermore, proponents such as Nubian VR provide instructional content for Virtual Reality, which is backed by UNICEF Innovate. VR360 Stories, Imisi 3D, StanLab, and Quadron studios are some of the prominent AR/VR solutions in Nigeria (Kamalu, 2021).

In Africa, infrastructure and money are only two of many issues that are preventing VR adoption. Finding people with experience and skills in Extended Reality (XR) technologies (ranging from AR to VR) is a huge difficulty on its own. Thus, despite that there is a global demand for persons with expertise in this subject, AR and VR is still faced with these challenges. Aside from that, in most parts of Africa, there are currently no government policies or incentives to explore Virtual Reality and augmented reality as a business (Chiefe, 2019). In the best of circumstances, starting and running a business in most regions of Africa is challenging. Regardless, the cause must continue. Most of the AR/VR equipment are not locally available in Nigeria and most African countries and thus have to be imported thus incurring exorbitant financial costs and delays in execution of AR/VR projects. Further, electricity and the internet which are basic infrastructure upon which this technology thrives are largely unreliable, and most times unavailable (Okonkwo, 2019)

The good news, though, is that across Africa, there are pockets of AR/VR adoption at various educational levels in some countries. Table 1 captures some of the usages and studies on AR and VR across several disciplines in Africa.

Table 1. Augmented and Virtual Reality in Different Fields of Education

Author	Year	Country	Technology	Tool/Methodology	Sample	Objective
Narh	2019	Ghana	VR	Internet searches, interviews, semi-structured questionnaire		To assess the challenges students face when they use VPs for e-learning.
Irhebhude, et al.	2019	Nigeria	AR	Questionnaire	33	To assess the impact of AR usage in teaching and learning among selected students in the northern central part of Nigeria
Soetan et al	2020	Nigeria	VR	Questionnaire	360	To investigate awareness of teachers towards the use of virtual reality for instructional purposes based on teacher's gender and experience.
Shittu et al	2020	Nigeria	AR	Augmented Reality Instructional Tool (ARIT), open-sourced AR mobile application (ARSJA), performance and retention test on physical geography (PRTPG), 7-Item questionnaire.	25	To examine Geography learners' performance and retention when they are exposed to its' use in learning Physical Geography concepts.
Noah and Das	2021	-	AR, VR	Systematic literature review	61	To understand the advancements in AR/VR enabled education
Hussein, W. A.	2014	Ghana	AR	Multiplayer Mobile Game	-	To solve the problem of mundane interactions by using augmented reality as a means of extending the screen of a mobile device.
Agyemang, S. A.	2016	Ghana	VR	Virtual Chemistry Lab, Google Cardboard.	-	To improve the interactivity of chemistry in Senior Secondary Schools in Ghana.
Moila and Simelane-Mnisi	2021	South Africa	VR	Questionnaire	6	To explore the lecturers' experiences with VR resources in teaching and learning environments.
Jantjies et al.	2018	South Africa	VR, AR	Qualitative study	-	To establish the potential role that AR and VR can provide in enhancing experiential learning
Gregory, C.	2019	Zambia	AR	Virtual Lab (Gene X. 2.0 simulation software)	45	To find out the effects of integrating ICT on the performance, and attitudes of pupils and teachers in genetics
Amara et al.	2021	Algeria	AR, VR	eLearning platform based on 3D interaction	-	To facilitate the teaching process and administrative workload in schools

Abbreviation: VR, virtual reality; AR, augmented reality.

Conclusion

Exploring the full potentials of AR and VR technologies begin with the full understanding of how these technologies work and that is exactly what this study examined. The study shows that virtual reality and augmented reality technologies hold a lot of potentials for the education sector. Virtual Reality immerses the user in a computer-generated environment, giving them the sensation of being present in that place. Augmented reality on the other hand (AR) augments a user's physical world with computer-generated digital data. In other words, augmented reality information such as text, image, music, and other forms of augmented reality is superimposed on the real world. This study showed that both technologies can benefit students' learning by developing a positive attitude among teachers, thus promoting technology utilization in and outside of the classroom.

Despite the benefits of AR and VR to education, Africa to date lags in the adoption of the technologies due largely to lack of interest, finance, knowledge of usage, corruption, amongst others. At present, the adoption of AR and VR in schools across Africa is still at its infancy stage. With time, and with the little evidence of AR/VR adoption in African schools, there is hope that the continent will catch up with the rest of the world sooner than expected.

Recommendations

1. As a way out, educational policymakers should develop and implement measures to deal with the difficulties associated with the availability of equipment and trained staff in AR/VR in schools.
2. Also, education administrators and school managers should set priorities for using VR and AR to carry out various reflective practices and exploration tasks in schools.
3. School administrators should take the time to explain the benefits of VR and AR to teachers, parents, and students/pupils.
4. Teachers should be at the forefront of VR and AR use in teaching. Furthermore, educators must be updated and trained on various educational technology practices including the use of VR/AR technology to disseminate knowledge. It further implies that education departments of government and schools should offer more related courses to refine teachers' VR/AR skills and knowledge.
5. Information on technology should be disseminated in a manner that could benefit educators and students.

6. The parents should provide their children and wards the necessary material and moral support to use AR/VR technology to learn school subjects thus complementing the traditional learning approach.

7. Parents/guardians should allow their children/wards to bring their own devices to school for learning. If parents resist educational technology, students would have lesser exposure to VR. Understanding the challenges of using VR and AR in teaching science subjects would ultimately provide the means for educational policymakers to suggest the necessary measures to effectively reflect upon the current trends, experiences, and practices to support and build capacity for educational change.

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