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The Role of AR and VR Technologies in Education Developments: Opportunities and Challenges

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***Abstract*—Technology has been growing fast and noticeably influencing different aspects of life such as education. Studies have revealed that *(AR)* and *virtual reality (VR)* have strong potentials for helping students to improve their skills and knowledge. In fact, bridging AR/VR and education can bring teaching and learning experiences in an attractive and effective way.**

In this review paper, we initially present an introduction to and a definition of AR/VR. We then briefly study ongoing research and latest products in AR/VR, that have pedagogical values and potentials to improve educational systems. We then highlight the capabilities and limitations of AR/VR to identify what AR/VR can provide for learners and teachers.

***Index Terms*—Augmented reality, Virtual reality, Education, Technology, Opportunities, Challenges**

I. Introduction

In recent years, technology has been growing fast and noticeably influencing different aspects of life; our thinking, habits, social activities, and lifestyle are all changed in different ways compared to a few years ago. Regardless of positive and negative impacts of technology, a purpose of technology is typically to increase productivity in the industries, to ease life, or to improve education. Accordingly, the development of education systems and learning methods is always a part of research programs, which includes the use of new technologies to take into account educational issues. Imperfections and challenges in current education systems such as accessibility, funding, autonomy, one-size-fits-all approach, and big changes in future jobs indicate teachers need to employ new methods for improving education [1, 2, 3]. Integrating technology into education allows to facilitate learning methods and improve learning performance by creating and managing appropriate technological materials [4]. In addition, this integration promotes students' skills to learn how to use new technologies in their future life. Jobs and future requirements change at a fast speed, so students must be prepared to adapt to new environments and be proactive.

Emerging and advanced technologies such as robotics, artificial intelligence (AI), cloud computing, and 3D printing are reshaping education systems. For instance, search engines can answer a lot of questions that people might need to memorize too much information to find solutions for them, so students need to learn to be differentiated from automated machines. In this research, we address virtual reality (VR) and augmented reality (AR) technologies for improvements of learning processes. In Dale's Cone of Experience that shows the progression of learning experiences from the bottom of the cone (learning by doing direct experiments) to the top of the cone (learning through abstracts), learners involve more the bottom rather than to be just spectators at the abstract level [5]. At the bottom, learners have opportunities to sense and understand their new knowledge in real life with learning contexts. AR and VR technologies can be embedded at the lowest level of the cone; they can enrich environments where students can learn with the help from the most of their five senses. Furthermore, students will be able to discover new knowledge, motivate to learn, develop their own experiences with the help of AR/VR [6, 7]. In this research after the definitions of AR and VR in Section II, we present these potentials along with AR/VR products in Section III. Section IV provides a discussion on AR/VR and gives an overview of opportunities and challenges in the implementation of these two technologies for learners and teachers. Finally, we conclude in Section V.

II. Definitions

AR and VR technologies are related but they are different things. Before we begin to define these terms precisely, first we need to know what *real* and *virtual* are. In Figure 1 which presented by Milgram et al. [8], the virtual environment and real environment are two ends of a spectrum. Regardless of a complicated concept of reality in the philosophy, we consider a real-world environment where it is limited to laws of physics and things in real-world can be sensed directly as they actually exist. In contrast, a virtual world is a computer-based simulated environment [9] which may or may not follow laws of physics such as time, gravity, material properties and so on. In a wider definition, participants are totally immersed in a virtual world that synthesized by computers. In contrast, participants are directly presented in the real world [8]. The spectrum between real and virtual environment was called Reality-Virtuality (RV) continuum [8] and the different types of AR or VR can be placed on this continuum. Schnabel et al. [10] presented a

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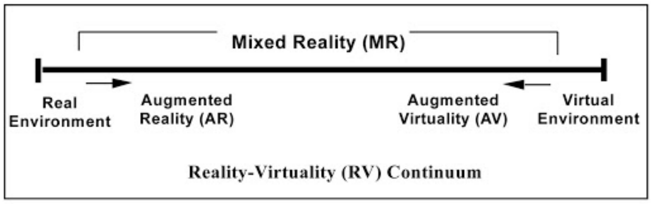

Fig. 1. A representation of a Reality-Virtuality (RV) Continuum [8]

classification to indicate the differences in the different types of AR and VR. As illustrated in Figure 2, from the left to right, the degree of reality decreases; so a more detailed classification of AR and VR is shown on the continuum based on their attributes, activities, and designs. Although this

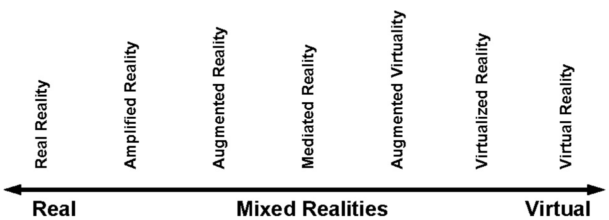

Fig. 2. A different classification ranging from the real environment to the virtual environment [10]

classification is more precise, most products in AR/VR do not apply this terminology. Therefore, we address research and products according to a more general framework. In Figure 3, the RV continuum is divided into two main subcategories AR and VR technologies; it is more convenient to study the research in the literature.

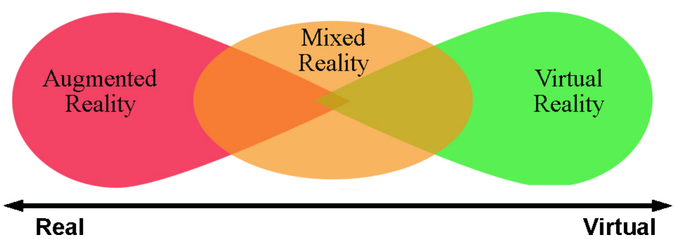

Fig. 3. A general representation for AR and VR classification

A. AR (augmented reality)

According to the framework that is shown in Figure 3, AR can be defined as an interactive experience in the real world environment where the computer-generated information and elements are linked to the real world. The computer-generated information is virtual content that is synthesized with the help of multiple sensors (i.e., camera, microphone, GPS) and haptic devices. The AR productions can take place in three steps: first, all real-world data is collected by various sensors. Second, this information is then analyzed and additional information from different information sources. Finally, the gained information is displayed as digital elements.

B. VR (virtual reality)

In contrast to AR, VR takes place within an artificial environment and a participant becomes a part of this artificial world as an immersive or a non-immersive member. The people can interact and manipulate computer-generated objects in a virtual environment with the help of some gadgets like haptic devices. In addition, VR gadgets have influenced VR content and enhances VR capabilities for better experiences. For instance, smell, wind, sounds, heat, body movement detection are elements that potentially create VR experiences more real and interesting.

III. AR/VR Products

In the literature, AR/VR products tend to create new experiences in several fields, from education to games. Here, we studied VR/AR products in two categories: hardware and software.

A. AR/VR hardware

VR and AR technologies need to mix real environment information and computer-generated objects properly to create desirable experiences but participants never are able to have a perfect feeling of VR/AR content without tools and gadgets. The AR/VR tools work based on human perceptions and can engage the several human senses. The tools can be visual, auditory, haptic, olfactory devices and the external devices like position system can incorporate in these tools.

The visual perception in VR can be done either by a head-mounted display (HMD), in a space with back-projected stereo projection screens around (e.g., CAVE[1]), or a desktop display. An HMD is a box worn on the head and consists of a one or two small displays in front of one or each eye. The Google Cardboard is a low-cost HMD developed by Google [11]. A smartphone is placed into the back of lenses to present content to viewers. This cardboard is also linked to a software development kit (SDK) that provide a designing platform to simply produce VR content for the Android and iOS operating systems. The HTC Vive, Sony PlayStation VR, and Samsung Gear VR are other HMD products that are mostly targeted for games and entertainment purposes (Table I). In education, price, quality, and user-friendly are important factors for student use. The Google Cardboard seems to be a good choice for education but the quality of a display is also can be taken into account. Because, side effects of VR such as dizziness and eye fatigue may encourage students to use better ones, therefore the expensive HMD may be considered for education. The HMD is also developed for AR applications. AR HMDs look like eyeglass with components such as camera, IMU, microphone. Users see a real environment optically and computer-generated elements appear on the glass simultaneously. Although AR HMDs are relatively costly for education but it can revolutionize classrooms by presenting 3D models and other interesting demonstrations (Table I).

[1]Cave automatic virtual environment

TABLE I
THE SPECIFICATIONS OF POPULAR AR/VR HMDS

Name	AR/VR	Price ($)	Weight (gr)	Type	Software	Position tracking system	Sensors	Other features
Oculus Rift	VR	399	470	Tethered	Oculus	Yes	Accelerometer, gyroscope, magnetometer	6DoF dual controllers, hand trackers, built-in headphones
PlayStation VR	VR	300	610	Tethered	Console	Yes	Accelerometer, gyroscope	6DoF dual controllers
HTC vive	VR	650	555	Tethered	SteamVR	Yes	Accelerometer, structured light, gyroscope	6DoF dual controllers, camera
Samsung Gear VR	VR	93	318	Mobile	Android	No	Accelerometer, proximity sensor, gyroscope	Handheld remote, touchpad
Google Cardboard	VR	5 and up	96	Mobile	Android and iOS	No	-	Easy to use
Microsoft HoloLens	AR	∼3000	579	Tethered	Windows mixed reality		IMU, cameras light ambient sensor microphone array	Clicker
Vuzix Blade	AR	∼1000	85	Tethered	Android		Head motion tracking sensors, cameras	Remote control app for Android & iOS device, voice control, touch pad
Epson Moverio BT-300	AR	700	69	Tethered	Android		GPS, geomagnetic, accelerometer, gyroscopic illumination sensor	Remote control

In contrast to HMD, the displays can be placed far from participants' eyes. For instance, CAVE is an immersive virtual reality environment and takes place inside a room whose walls, ceil and floor may have projection screens. Users typically interact through input devices such as joysticks or gloves with virtual objects on the screens. CAVE can be a suitable choice for education because a number of students can experience VR once. It can decrease the cost of a school (not individual) in respect to HMDs and can help a teacher to conduct all students during experiments but users cannot move around freely.

The CAVE or HMDs are still inaccessible and expensive for teachers and students. Desktop VR is a low-cost visual perception that can be easily applied by users; the users just need to watch a desktop computer monitor and interact with VR objects by a controlling device (i.e., a computer mouse) [12, 13].

VR cabins are usually simulators that look like CAVE but they can provide motions in the three axes. These cabins are basically employed in education and job training, for instance, cockpit simulator for pilot training [14], vehicle simulator for driver training [15] and so on.

The haptic technology allows to produce more attractive VR content; haptic devices can reconstruct and simulate the effects of real force feedback phenomena in VR. For instance, Teslasuit is wearable in which haptic feedback system is embedded; it covers the entire body and transfer hits and strikes to body [16]. Gloves and other small wearable devices were presented to make touch feeling and transfers the force to hands (i.e., HaptX[2], unlimitedhand[3]). Handling users' motions in minimal physical space causes to develop a walking system for virtual worlds (i.e., KATVR[4], virtuix[5], vrgochair[6]).

B. AR/VR software

During the last few decades, several AR/VR applications have been produced to be used in several fields such as advertisement, tourism, maintenance, and training. In the education fields, applications have been developed for adoption AR/VR into learning processes and attractive ones were presented in mathematics, physics, astronomy, biology and other scientific subjects. In physics, virtual electricity and Newton labs were presented by Zspace to learn electricity concepts and troubleshooting circuits. Newtons Park was designed to teach Newtonian Mechanics by building simulations and interacting with data. Moreover, zSpace applications support teaching a wide range of learning objectives from learning Newton laws to learn anatomy [17]. The Hololens was used to show heat conduction of metals for an introductory laboratory course in thermodynamics [18]. Chemistry lab may include dangerous experiments which may happen when a student combine wrong elements. VR helps students to learn chemistry without using real materials and give more understanding of what are

[2] www.haptx.com
[3] www.unlimitedhand.com
[4] www.katvr.com
[5] www.virtuix.com
[6] www.vrgochair.com

atoms and molecules [19] (i.e., MEL [7], Labster [8]). Real chemical components were also replaced with virtual ones with the help of AR technology and more tangible interaction in real environment was provided for learner [20, 21]. In astronomy, richer AR/VR content were introduced than other fields. The studies have shown that students misunderstand some concepts in astronomy [22] and some of these misconceptions have remained for several years [23]. AR/VR astronomy products aim to change conventional teaching methods and content, then help students to clarify their misconceptions. DVREMS was designed to teach earth motion in elementary school students [12]. Mintz et al. [24] presented a dynamic 3D model of the solar system and learners travel through it. In the literature, similar VR content were presented to enhance astronomical knowledge in students [25, 26, 27, 28]. In addition, the commercial applications were presented, for instance, Apollo 11[9], Astronomy VR[10], and Star Chart[11]. The AR technology helps students to understand some astronomy concepts as well, for instance, relationships between planets [29]. Fleck and Simon [30] compared AR and physical astronomical models for learner. They highlighted that AR learning methods improved significantly astronomical learning than physical learning method. Reed et al. [31] designed a new sandbox that mixed with AR to explain gravity. AR/VR tours and journeys were attractive parts of these technologies that enhanced historical and geographical knowledge of students. For instance, students just need to turn on their VR HMD and then travel to ancient Iran, Rome, or Egypt (i.e., unimersiv [12]) [32]. In addition, the learners can virtually travel to oceans, visit other countries to familiar with other cultures and so on (i.e., Google earth VR[13], destinations[14]). The AR technology was also used in museums and heritage places to help visitors and learners with additional information simultaneously on objects or visiting places [33, 34]. In biology and anatomy subjects, VR was used to train surgeons and to improve their level of competence before they operate on real patients [35]. Travel inside the human body (i.e., body VR [15]) and representing 3D models of organs [36] can reshape learning processes. AR in Human Anatomy Atlas 2018 Edition was a perfect 3D anatomy reference for learning in the healthcare system [37].

AR can provide additional information on books. The experiments, videos, and other materials can be shown since a device is placed in front of pages of books, posters, flashcards (i.e., PAMPAM flashcards[16]). Google Expeditions is an immersive education application that was designed for education. Learners can get new experiences without leaving the classroom; for instance, they can swim with sharks, turn the classroom into a museum, visit outer space, and more [38]. The Google also provides a package to support AR/VR. The Google Cardboard as a cheap HMD, Google Jump to produce 3D-360 video with cameras, Google VR to visit places, and provide a platform for developers to build VR content. The researchers and companies are developing platforms for AR/VR developers to facilitate production of AR and VR content. Google VR provides SDKs (software development kit) allowing to build new VR content. These SDKs are available for the Android, iOS, Unity, Unreal that allow developers to produce VR content for several platforms [11]. The SDKs (i.e., google VR, GOpenVR, and SteamVR) may be linked with the game engines to create 3D elements and environments for AR/VR. ARCore[17] is a platform for producing AR content. It detects images and track the position of the camera relative to the world. Then it builds models on the images [11]. ARToolKit, Vuforia, Wikitude, EasyAR, and DeepAR are similar SDKs that are employed for AR production.

IV. Opportunities and Challenges

Research has revealed that AR/VR technologies are highly beneficial to education and could help students to develop their skills and knowledge in a more effective way [39, 40, 41] AR/VR systems could present educational content in attractive ways and enhance students motivation and interest. Not only students enjoy from AR/VR learning but also they follow learning processes and then AR/VR systems help them to achieve more accurate knowledge [13, 42]. AR/VR systems provide a better understanding of educational difficulties that have been addressed in the educational literature [43]. For instance, some students cannot perceive 3D models or some students cannot imagine invisible phenomena such as the spinning of the earth [44, 45]. AR/VR allows learners to see 3D models, to manipulate objects virtually, to figure out unobservable phenomena, to experience abstract concepts (e.g., travel in wormholes). These virtual experiences can deeply promote students thinking [46] and correct their misconceptions [42].

Recent progress in AR/VR hardware allows the interaction and integration between several senses and an around environment with the help of multi-sensory devices. The sensory integration provides learners to construct meaning from experiences [13]. The importance of collaborative learning in distant has been already stated in the literature [47]. The VR technology potentially provides instant communication and students can attend in a virtual classroom at the same time. They can discuss, receive immediate comments from others and feel a sense of being in the same places as their classmates [48].

AR/VR products help students to overcome learning barriers and improve students' knowledge, skills, thinking, and understanding. However, there are challenges and drawbacks to apply AR/VR as an educational tool in the most classrooms in the world. The first problem is the cost of implementing

[7] www.melscience.com/vr
[8] www.labster.com
[9] www.immersivevreducation.com/apollo-11-vr/
[10] www.play.google.com
[11] www.play.google.com
[12] www.unimersiv.com
[13] www.oculus.com
[14] www.steamcommunity.com
[15] www.oculus.com
[16] www.cafebazaar.ir/app/com.majazkadeh.animals/?l=en
[17] www.developers.google.com/ar/

AR/VR systems. As we have seen, HMDs are relatively expensive. In other cases, computers and display systems for demonstrating the VR/AR products are also needed that may make a challenge for many schools. The second challenge is a lack of realism in VR or AR simulations. Quality of graphics display impresses a feeling of a user, it can improve visual perception and provide a richer experience [49, 50]. The third challenge is health issues and physical effects on students. HMDs are relatively heavy that may cause wearers feel fatigue after a long period of time. Lenses in an HMD may obstruct the view, although they are close to the eye in modern versions. Another side effect that is not limited to HMDs is simulator sicknesses and it appears mostly on VR experiences. The simulator sickness usually results from mismatching between the visual perception and sense of movement. Symptoms of simulator sickness may include nausea, disorientation, and discomfort [13]. Fourth challenge is inherited from hardware limitations. Although recent hardware developments have improved AR and VR demonstrations, the limitations may avoid having a great level of user experiences. Lack of precision, GPS errors and navigation problems, latency between sensors' data and the effects to the visual system are common problems that can cause students' frustration and interruption to their experiences.

V. Conclusion

In this paper, we have attempted to show the capabilities and limitations of AR and VR technologies for education. Technologies progress fast and impress our lifestyles. Researchers are interested in addressing the issues and drawbacks of education systems with the help of potentials of emerging technologies and the latest scientific achievements. AR/VR systems provide opportunities to increase students' motivations and engage them more in learning processes. In addition, AR/VR allows the students to have virtual experiences where traditional learning methods are impossible or expensive. However, there are still some challenges for AR/VR to be used by most learners in the world. These technologies are in their infancy but they have a great potential to overcome the barriers.

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