The Virtual and Augmented Realities Technologies in the Educational context: evolution and challenges

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Abstract. The innovation of intelligent tools and virtual worlds is progressing rapidly in the face of the rapid advancement of technology and digital revolutions. Virtual Reality (VR) and Augmented Reality (AR) are prime examples of such innovations. They have the potential to greatly improve and enhance various areas, particularly in educational settings. Since the 1960s, these technologies have undergone periodic development and renewals, from hardware to software. This paper aims to review the historical evolution of VR and AR, including recent advances, and their current applications in education, particularly in mathematics education. The paper will also address the challenges these technologies face in an educational context. This article reviews 30 papers published between 2015 and 2023 from three databases (ACM Digital Library, Scopus, and Web of Science), selected using the PRISMA method, to answer the following research questions: How have VR and AR evolved? What are the educational uses and applications of VR and AR? What are the challenges that could be addressed?

Keywords: Virtual Reality, Augmented Reality, Evolution.

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1 Introduction

Virtual and Augmented realities are becoming increasingly important in improving various fields, particularly education and scientific research, and their emergence has attracted the attention and interest of researchers, developers, investors, and many others users [3,2]. The development of AR and VR technologies has been rapid for several years, and today there are several innovative and accessible applications based on them. [1,2,3]. Therefore, studying the current trend and predicting the future deployment of augmented and virtual realities in several areas and educational contexts, it is can be realized by reviewing the last research concerning the evolution and uses of [9,1,3,37].

In educational contexts, there are many reasons for the integration of AR and VR to improve the teaching process in general, and in the learning of specific subjects and concepts that are incomprehensible using the classical approaches and methods [37,4]. These include concepts based on spatial abilities, the imagination aspect, the visualization of natural objects (in biology, geography, geology, etc.), microscopy abilities, interaction and communication capacities, and artistic skills [32,33,34,17,28]. These innovative approaches offer the potential to provide a new experience for learning and teaching different subjects and fields. Augmented reality and virtual reality aim to enrich the real environment with virtual elements or create a total virtual immersion in a new environment [9,11,3,29,37]. Consequently, these technologies are developing and creating the new generation of modern education, which is suitable for learners of all ages and abilities who are acquiring new skills [5, 29,14].

The term of virtual reality has been variously defined throughout history since its initial appearance. One such definition, proposed in 2003, defines VR as a medium created through the use of interactive computer simulations that are able to perceive the actions and positions of users and subsequently transform those reactions into alternative sensory experiences [18,23,19, 37,6]. However, the definition of virtual reality has transformed and change over recent years, with the concept of users being immersed in an interactive three-dimensional environment instantaneously becoming increasingly prevalent. [25, 22, 14]. In contrast to virtual reality, which has been in existence for a longer period, augmented reality represents a relatively novel technology. It can be defined as a method of superimposing virtual objects in real-time on the user's surrounding environment, thus enhancing their experience [15,34]. Moreover, numerous other definitions have been generated to describe the concept of AR over the years, from its initial appearance to the present day. These definitions typically encompass the use of images, cameras, real environments and virtual objects placed at specific points, intending to create interactions between the various elements and users [17,4,37]. Two of these technologies, VR and AR, provide innovative experiences in several fields, especially in the education domain for many subjects, and for this reason, we are conducted to realize this review paper.

The principal objective of this paper is to identify and scope publications that address the use of augmented and virtual realities in an educational context. In order to achieve this, the following questions will be addressed:

How have the AR and VR technologies developed since their appearance?
Are there any educational applications based on AR and VR?
What are the benefits?
Can they face challenges and limitations?

2 Literature review

In the contemporary era, modern culture, education, and mentality necessitate the implementation of novel tasks and resources that can streamline the modern lifestyle and facilitate rapid access to information through the utilization of sophisticated technologies and devices, such as the Metaverse, VR, and AR tools. Moreover, they are crucial for enabling individuals to engage in simulation learning experiences [25,3,12,37,36].

The Metaverse is defined as a physical environment that allows users to perceive a virtual space in conjunction with the real one, through the use of physical devices and accessories such as sensors, glasses, headsets, and others. These devices and accessories are based on object design, graphics, and other types of software [2,3,36,37]. To attract users to access the virtual and Metaverse worlds, considerable efforts have been made by numerous individuals, including researchers, designers, and others, since the Metaverse's initial emergence [3,5,19]. Furthermore, the Metaverse enables individuals to communicate through avatars in a virtualized global environment, utilizing a range of virtual tools, including AR, VR, XR, AI, and others [2,25]. In essence, the Metaverse may be conceived of as a global network comprising virtual tools, spaces, and devices, in addition to augmented realities, virtual realities, AI tools, and mobiles. This enables the creation of immersive experiences [2,5,37,25].

Virtual reality (VR) has been employed in research domains for over a quarter of a century. The origins of this technology can be traced back to the field of computer graphics, but it has since been extended to other disciplines [27,30]. The term "virtual reality" has previously been defined as a three-dimensional computer-generated environment that is integrated with a range of display and interface devices, to engage and immerse users in interactive virtual spaces. [9,10, 11]. However, Chang & Shao posit that the primary objective of VR systems is not merely to provide an immersive experience through technology, but rather to enhance and enrich the cognitive, experiential, and interactive capabilities of individuals [11,10].

In the mid-1960s, VR was first described by Ivan Sutherland as a window through which users could view a virtual world that would appear realistic, with the ability to interact with it realistically. Furthermore, the concept of virtual reality was outlined in 1992 as a tangible, three-dimensional digital realm that affords users the opportunity to become immersed in a virtual environment through the utilization of real-time, graphical interactive techniques [20,21,37,15]. In 1993, another definition of VR was proposed, which relies on a 3D stereoscopic headset that enables users to move their bodies, hands, and heads, and use their senses to create an immersive experience [3,20, 22] addition to that, the next years until today, all the evolution of the virtual reality technologies are presented VR as immersive technology based on three common features: interaction, immersion with its several degrees, and perception in a space [24,16].

However, augmented reality (AR) offers a novel and exceptional experience to humans by superposing virtual 3D or 2D objects and models on the real space, thereby enriching the environment and creating a positive, removable experience that augments the motivation, imagination and progress of several human abilities. [13,14,27]. Consequently, augmented reality is defined as the integration of diverse types of information into the tangible world through sophisticated hardware and devices that possess the capability to scan, detect, and process a range of inputs, including visual images, positions, and markers [8, 37,7]. In contrast, augmented reality experiences diverge from those of virtual reality. They are perceived as more realistic and capable of engendering a high degree of realism and a sense of presence [33]. These qualities are indicative of the superior quality of AR experiences in comparison to those of VR [24, 27]. Furthermore, AR has the potential to be integrated with VR, resulting in the emergence of mixed reality, which offers novel and innovative experiences and tools [33, 36, 25, 18].

2.1 Evolution through history:

The chronology of the evolution of VR and AR reveals a series of developments and changes in hardware and software, spanning from the initial emergence of VR in the 1960s to the advent of AR at the beginning of the 1990s, and continuing to the present, marked by unparalleled innovation and potential. In 1962, Morton Heilig, an inventor, created the inaugural 3D example, which he presented in his innovation, the Sensorama [34, 37]. This enabled the user to experience a journey on a motorcycle through Brooklyn, incorporating a range of sensory impressions (olfactory, auditory, haptic stimuli, and wind). Concurrently, Ivan Sutherland developed the Ultimate Display, a system that integrated interactive graphics into all the sensory functions employed in the preceding creation, "Sensorama." Furthermore, in 1965, the first head-mounted display (HMD) was developed by Philco, which had previously created the Ultimate Display of Sutherland. This involved the addition of virtual images and the tracking of the user's head position and orientation. [25,36]. The 70s saw the emergence of numerous innovative creations, with the University of North Carolina pioneering the development of a force-feedback display system [35,37]. This was followed by the VIDEOPLACE of Myron Krueger, which offered an immersive artificial reality experience. Unlike previous attempts, this system did not require the use of goggles or gloves, instead responding to the user's movements and actions. Additionally, the software facilitated two- or multi-user interaction in a virtual two-dimensional space. The introduction of the initial flight simulator, the Visually Coupled Airborne System Simulator (VCASS), developed by Tom Furness for the United States Air Force in 1982, signified a substantial advancement in the domain of aviation simulation [36]. The VCASS enabled pilots to control the flight path and targets through the use of an HMD (Head-Mounted Display) device [36]. Other notable contributions were made by the VPL company, which was responsible for the initial devices, including the Data Glove and the Glove Sensor in 1985, as well as an HMD system for complete immersion in the virtual environment [15]. Subsequently, in the late 1980s, the Fake Space Labs developed a novel system based on VR, comprising a stereoscopic-displaying device to facilitate movement in a virtual space and enable mechanical tracking. This system was designated the BOOM (Binocular-Omni-Orientational Monitor) [16,20]. Additionally, numerous VR systems were developed and introduced in the 1990s, with the advent of the CAVE (cave automatic virtual environment) in 1992. This immersive VR system employs direct projectors on three walls of a 3D cave, as designed by the Electronic Visualization Laboratory of the University of Illinois. In 1995, the appearance of the Virtual Workbench and Immersidesk marked a significant advance in the field. Finally, in 1999, the first IEEE VR was invented, and more recently, numerous VR devices have been developed by a number of videogame companies. The HTC Vive, the Oculus Rift, and other HMD devices are examples of such devices. [35,10,9]. However, at the beginning of the 1990s, augmented reality (AR) was established. In 1990, Thomas Caudell introduced the term AR, which was subsequently developed by The Boring Corporation into a prototype AR system for demonstrating how to set up a writing tool for employers [5,7,36]. Following this, in 1992, Rosenberg developed the inaugural fully immersive AR, which was created for the US Air Force. This technology enabled the military to remotely control virtually guided machines to perform space operational tasks [34, 14]. Additionally, in the year 1993, Rosenberg and Feiner collaborated to develop the KARMA (Knowledge-based Augmented Reality for Maintenance Assistance), which was the inaugural augmented reality system to be utilized in conjunction with maintenance tools, employing a see-through head-mounted display to convey maintenance instructions. [12,34]. In 1997, Feiner created the first outlook AR system, which employed a head-mounted display (HMD) in conjunction with a global positioning system (GPS) and orientation tracking [34,9]. Furthermore, over the subsequent years, from 1998 until 2006, numerous innovations were employed in the realms of augmented reality and virtual reality. In 2007, the advent of AR systems with CAD (Computer-Aided Design) models marked the beginning of a new era [35,36,15]. In 2009, the development of augmented reality (AR) applications marked the beginning of a new era in which the physical environment could be enhanced with virtual elements and information. This was exemplified by the introduction of AR Toolkit and Site Lens. Following this period, between 2013 and 2015, Google Glass and Google HoloLens were developed by Google, and since then, they have been incorporated into numerous tools and domains [26,10]. Recently, the inventions of AR, VR, and XR applications, headsets, and devices are ongoing with the addition of new functions enabling new and effective experiences to serve several fields of life [1].

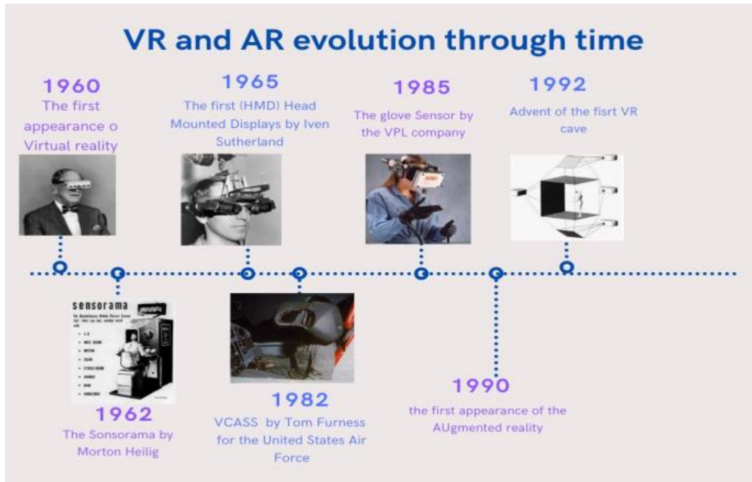

Figure 1. short historical timeline

2.2 Advantages and applications:

The progressive use of technological tools, especially immersive innovations, has had a revolutionary impact on the way we live our lives. Virtual Reality, Augmented Reality, AI and all the Metaverses applications and devices are the current subject of interest, creation and revolution.

From their inception until the present day, AR and VR have been in a state of constant evolution, with the advent of new devices, tools and applications. The range of virtual reality applications is vast and diverse, with examples including gaming VR apps, military training, architectural design, decorative design, education, learning and teaching, surgical simulations, and electricity simulations. [36,25,11]. However, AR technologies and applications are numerous and based on three essential components: virtual objects and markers or tracked images, cameras, smartphones, and machines that are capable of scanning, and the third component is the user. Additionally, there is the possibility of merging virtual objects in transparent space through the use of glasses, Google Cardboard, headsets, HoloLens, and all types of HMD devices. [36,34,25,4,7,19]. Consequently, all VR, AR, and immersive technologies and applications have many important benefits and they play a very important role in different fields of life, starting by augmenting persons' motivation, attracting attention, enhancing all types of human performances and several abilities such as imagination, spatial intelligence, reading, comprehending concepts, visualization of real objects virtually, facilitating a lot of hard works task and skills [13, 25, 2, 33, 34, 11]. Furthermore, in the field of education, the integration of AR and VR applications is of great importance in facilitating all processes of teaching, learning, and practicing difficult concepts and subjects. It is also essential to consider the role of gaming and serious games based on VR and AR in realizing the education processes [3,4,9,22,26,27].

The following table presents a comprehensive overview of all types of AR and VR applications that have been cited and discussed in papers selected in our review process. This overview is provided following the methodology outlined in the Methods phase:

Table 1. AR &VR applications

Applications	Description	References
STEM	science, technology, engineering, and mathematics: applications and tools for enhancing all of the STEM subjects	[25, 15, 9, 6, 1, 2,3,4,5,7,8,10,18,19,22,24,32]
ARGeo, ARGeo Its	An AR application allows students to practice basic geometry concepts and visualize geometrical forms by scanning markers which are downloaded from the static website of the company ARGeo	[15, 25]
VR for Musical Instrument Learning	Virtual learning environment based on VR technology for providing and learning musical instruments	[30]
3D Contrast	AR applications for STEM fields	[2, 12, 17]
AI applications in K-12 for education	For aiding teachers in classrooms, assessing essays and dropout prediction….	[3, 25]
VR design activity based on peer assessment	VR system based on the approach of peer assessment to enhance student's motivation and performances through the teacher's edit system module	[6, 25]
MAR games, Pokemon GO, and serious games	The use of games for serious goals, especially in education and STEM domains	[25, 23, 4,12]
Metaverses' applications	AI, VR & AR tools, IoT, Edge computing, Blockchain, 3D reconstruction	[25, 2]
IVR	Immersive virtual reality application for reading ability and comprehension	[9,25]

Virtual classrooms	Enhancing classroom management competencies of student	[23,25,2]
Feedback applications as 3D printing technologies	Make better interaction between users and machines and virtual environment	[25,2, 17]

3 Methodology

The main aim of this work is to review and collect information on the evolution history, some of the applications, and challenges of AR and VR technologies in education, particularly in mathematics education, using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA 2020) approach for systematic literature review [3,32].

3.1 Selection of Databases

The databases used in this study were selected for their significant impact on the fields of education and mathematics education, as well as their adherence to scientific indexing standards:

1-Scopus
2-Web of Science
3-ACM Digital Library

Table 2. Search String

Databases	Search items	Results
Scopus	("Augmented reality" OR "Virtual Reality") AND "Education" AND ("Evolution" OR "Challenges" OR "applications" OR " review")	18
Web of Science	("Augmented reality" OR "Virtual Reality") AND "Education" AND ("Evolution" OR "Challenges" OR "applications" OR " review")	8
ACM Digital Library	("Augmented reality" OR "Virtual Reality") AND "Education" AND ("Evolution" OR "Challenges" OR "applications")	12

Table 3. Exclusion and Inclusion Criteria

Exclusion criterion (EC)	Inclusion criterion (IC)
EC1: Studies outside of fields of education and mathematics education	IC1: Studies inside of fields of education and mathematics education
EC2: Studies not focusing on VR & AR , evolution & education	IC2: studies focusing on VR & AR , evolution & education

EC3: Documents types : book reviews, editorials, notes ,& whole book	IC3: Journal articles, reviews, proceeding papers, and some chapters
EC4: Non-full text works	IC4: full text works

3.2 Search Strategy

The search began on March 22, 2024, and we followed the search strings outlined in Table 1 to locate relevant works and papers related to our subject.

3.3 Data Collection Process

The selection process was based on four criteria of inclusion and exclusion, which are presented in Table 2. This was done to precisely choose the publications appropriate for the review of the main subject and field. Additionally, the selection process was carried out in three steps following the PRISMA approach: identification, screening, and inclusion. The PRISMA diagram of the selection process is shown below. This article included 30 papers, after many refinement steps, using the selected databases and search terms.

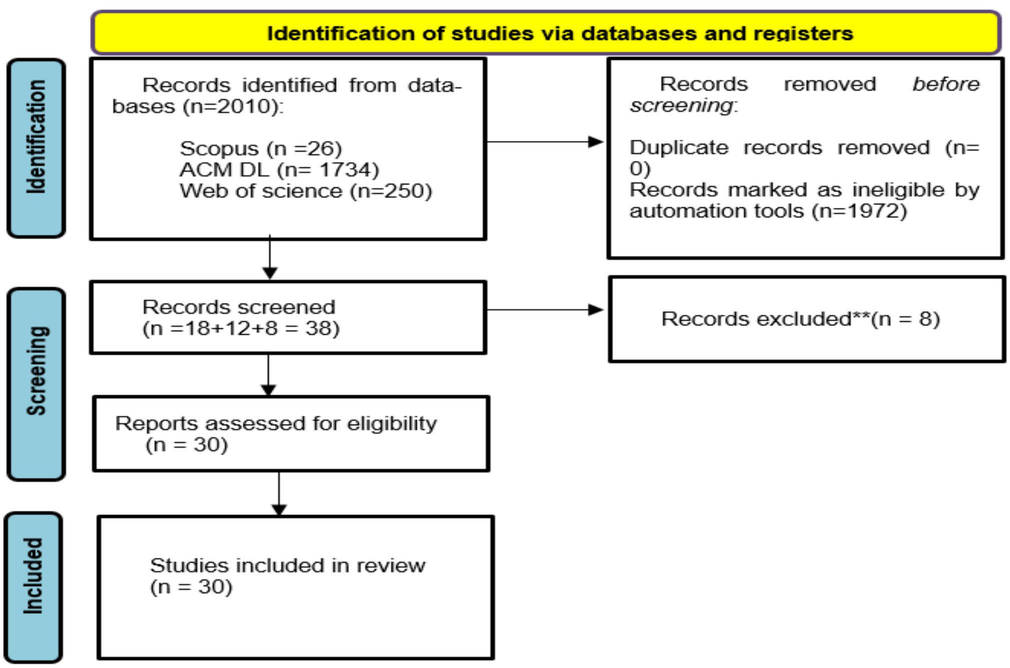

Fig. 2. Flow diagram of the manuscript selection process of our paper

4 Discussion

The analysis of the literature papers concerned Virtual and Augmented realities, evolution, benefits, and their applications, and according to the data collected through the

PRISMA approach, has been conducted to highlight specific results and conclusions that resumed all the important historical times of AR and VR evolutions through years since the first basic appearance and creation which was at the beginning of 1960s, and it has been very rich by traversing important quantity of creations, innovations, developments ... and all of that is characterizing by the higher quality of hardware and software until today, which leads to better performing and reaching the main goals. Moreover, AR and VR benefits are unlimited, but generally, they play very interesting roles in enhancing overall human abilities, bits of intelligence, behaviors, capacities, and competencies and serving all different human needs of life specifically in education fields, medicine, military domains, architecture and design, they facilitate numerous type of hard tasks of life fields. In addition to that, all of its benefits are appearing thanks to the use and integration of different AR and VR tools, devices, and applications which are many, different, rich, and serve human needs. It can be argued that AR and VR are of great importance in the real world and in the future. However, there are limitations that hinder the use and integration of these technologies. One reason for this is that many people are unfamiliar with technological tools. Additionally, there is a lack of devices in some countries and in rural areas. Furthermore, there is a lack of continued training, in addition to the higher costs and potential health risks associated with the use of headsets and all HMD types.

5 Conclusion and perspectives

The current work presented the narrative literature review of previous papers and realizations that have been deployed the augmented and virtual realities and technologies, through of the PRISMA approach with the collecting and analyzing data from 30 papers published between 2015 and 2023 from three databases (ACM Digital Library, Scopus, and Web of Science), in order to scope the principals' historical dates of evolution of VR and AR tools, discus the global of its importance and benefits in all of life' domains, extract of some interest precede creations and applications, and finally conclude some limitations and challenges that are obscuring the use of them.

The results of the study indicated that the VR and AR technologies have undergone significant historical developments that have shaped their current performance and functionality. It is evident that these technologies should be integrated into all domains, as evidenced by the results of extracting VR and AR applications and the analysis of their benefits. It is also crucial to differentiate between AR and VR. In conclusion, the results of our paper indicate that the use of VR and AR is of great importance, particularly in the domains of education and medicine. This is due to the advantages they offer in facilitating numerous challenging tasks and objectives, and in positively affecting these domains. Nevertheless, we identified numerous challenges that require prompt resolution.

The future perspective of this paper is to create an original VR and AR application for educational purposes. This application will engage students' motivation, performances, learning, and teaching. In addition, the perceptions and effects of the use of augmented and virtual realities will be studied.

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