AUGMENTED REALITY TECHNOLOGIES IN EDUCATION - A LITERATURE REVIEW

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Abstract: Digital technologies advancements have reshaped the framework of the traditional classroom and taken educational curriculum to a different new level. More than ever, the education systems all over the world, strongly affected by the shock of the COVID-19 crisis, need to rely on innovation and digital resources. Augmented Reality (AR) technology can enable educators and students to access specialised materials beyond time and space. This paper presents a systematic review of literature on AR in education in the last 3 years. In total 30 research papers were analysed in this review, by using the content analysis method. Further research topics concerning the affordances of AR applications in education have been identified.

Key words: augmented reality, education, systematic literature review, learning, digital technologies

1. Introduction

The COVID-19 pandemic has created the largest disturbance of education systems in history, by forcing schools and universities to close their doors and impacting an unprecedented number of learners worldwide. Since March 2020, when WHO declared COVID-19 pandemic, 1.6 billion learners have been affected in more than 190 countries and all continents. Closures of schools and other learning spaces have impacted 94 per cent of the world's student population, up to 99 per cent in low and lower-middle income countries (United Nation, 2020).

According to the latest figures released by UNESCO, more than 18.2% of total enrolled learners around the world, at pre-primary, primary, lower-secondary, and upper-secondary levels of education, as well as at tertiary education levels are still not able to attend school or university as of December 1, 2020. (UNESCO, 2020) Moreover, at the time of writing, the number of COVID-19 infections worldwide exceeded 64 million cases of COVID-19 and deaths have surpassed 1.4 million (3 December 2020; ECDC 2020). The extremely worrying and uncertain evolution of pandemic, along with school's closure measures, set an enormous pressure on education systems, obliging them to make urgent adjustments to ensure learning continuity. This led to a distinctive rise of e-learning, whereby teaching is undertaken remotely and on digital platforms.

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Consequently, innovation within the education sector was highly stimulated (Li and Lalani, 2020).

As Schleicher (2020) highlights, digital distance education platforms were used in nearly all OECD and partner countries. These tools included: educational content for exploring if desired, real-time lessons on virtual meeting platforms, online support services for parents and students, and self-paced formalised lessons. In this context, the opportunities that digital technologies offer go well beyond online learning platforms, using immersive computing technologies, such as augmented reality, that creates new modes for users to experience digital content.

Augmented reality has been used for classroom study, to research several technical areas or to provide learning assistance (Challenor and Ma, 2019). Learning environments based on AR technologies have been already proven effective as an active learning method due to their ability to translate the learned content into long-term memory (Santos et al., 2014). Tools and resources are available for educators to create engaging learning experiences, by using AR embedded in courses, shared on learning platforms, or made available in other ways, such as video or as part of a simulation or game. (Wu et al., 2013) Using these technologies on a larger scale might be an innovative response to COVID-19 impact on an education system, highly driven by social distancing parameters.

A substantial amount of literature has been published on AR applications in educational contexts for a wide variety of learning domains and level of education. The aim of this article is to review literature regarding the use of augmented reality in educational settings, published in the last 3 years (2018-2019-2020). All articles are categorized according to time, fields of education, and topic where the keywords of the articles were considered.

2. Background in AR

Augmented Reality (AR) systems integrate virtual information into the user's physical environment so that information is perceived as existing in the environment (Höllerer et al., 2001). The fundamental distinction between augmented reality and virtual reality is given by the fact that, in the case of AR, virtual content is superimposed on a real environment, whereas in the case of VR, the environment is predominantly virtual. AR consists of merging images from the real environment with virtual layers of information composed of three-dimensional (3-D) models that may include content, images, sounds, and videos (Vogt and Shingles, 2013).

AR technology has quickly become viable for commercial and research projects over the past decade due to the prevalence of head-mounted devices (HMD) and smart devices such as phones, tablets and handheld game consoles, which are now intrinsically woven into everyday life (Challenor and Ma, 2019).

AR technology is applicable in various fields, such as medicine, education and simulated training among others (Yu et al., 2010; Yilmaz, 2016), health sciences (Moro, Štromberga, Raikos, and Stirling, 2017), tourism (Lee, Ng, Tan, Shahauddin, and Wan-Busrah, 2018) or navigation (Chen et al., 2015).

3. Method

In this paper, qualitative research has been done through a systematic literature review to identify the knowledge that exists on AR technology used in education. A systematic literature review must "comprehensively identify, appraise and synthesise all relevant studies on a given topic" (Petticrew and Roberts, 2006). Furthermore, it can be defined as "a synthesis of published materials that provide examination of recent or current literature, that may include research finding". It may or may not include comprehensive searching and a quality assessment. The synthesis is typically narrative, and the analyses may be chronological, conceptual, and thematic (Grant and Booth, 2009).

In this review study the Arksey and O'Malley's (2005) five-stage framework is utilized. The five stages of this framework are:
(1) identifying research questions,
(2) identifying relevant studies,
(3) study selection,
(4) charting the data,
(5) summarizing and reporting the results.

3.1. Identifying research questions

The aim of this review was to explore the literature regarding the use of AR application in educational scenarios. To capture the relevant research studies, following research questions were posed to guide the research: Which fields of education are covered with the research articles? What are the main categories of the research articles considering the used keyword? What other technologies are being used related to AR? What are future directions of research of AR applications in educational settings?

3.2. Identifying relevant studies

To cover a broad range of studies regarding the use of AR in education, the search was performed using the following keywords: "Augmented reality", "AR". The literature source was the Google Scholar, which provides a simple way to broadly search for scholarly literature. Relevant papers were considered only papers published in the last 3 years (from 2018 to December 2020). This was considered appropriate due to the rapid technology development and the wider use of AR applications in education.

3.3. Study selection

Thirty research studies were selected and included in this review. These articles were selected according to the following inclusion/exclusion criteria. The inclusion criteria were:
(1) Papers published in the last 3 years;
(2) Studies that are carried out in formal education context;
(3) Studies where an AR application is integrated with or applied in the teaching

learning process, and learning outcomes are reported.

The exclusion criteria were:

(1) Papers explaining some commercial application, available on market, but not scientifically based;

(2) Previews of thesis and dissertations, or review papers;

(3) Studies that were carried out in informal or non-formal learning contexts.

3.4. Charting the data

The first step was to make a descriptive analysis. The aim of the descriptive analysis was to give a preliminary result on the papers focusing on the AR in education. For the descriptive analysis of the selected papers, three perspectives were defined: papers by time, papers by the fields of education, and papers by topic where the keywords of the articles were considered.

According to the distribution of papers over time, as shown in Figure 1, we can see that consideration of the topic has been increasing in 2020 due to the actual context of pandemic.
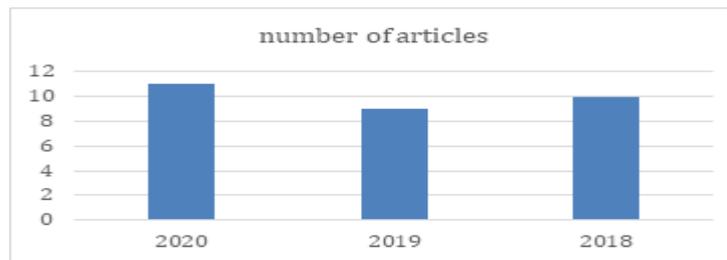

Fig. 1. *Distribution of papers over time*

Regarding "Fields of education", analyses show that most articles explored "multiple fields of education" and "science", while "medical studies", "early childhood education" are the least explored. Figure 2 summarizes the results regarding the use of AR by field of education.
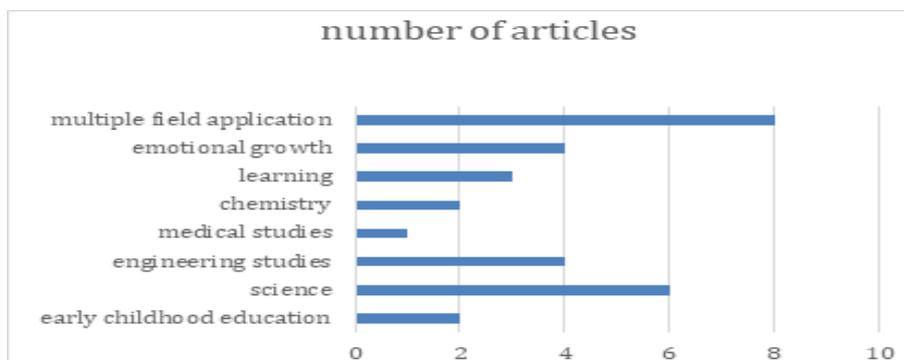

Fig. 2. *Distribution of papers by field of education*

The selected papers were also classified considering the keywords of the articles. "Augmented reality" and "Education" were eliminated as they can be considered redundant for the analysis.

We can see that virtual reality is associated with augmented reality technologies in 11 papers. "Mobile learning" and "digital educational resources" can be found in many articles. It is important to note that "teacher education" and "learning process", "learning strategy" or "learning tools" are also very important in these studies as it can be seen in Figure 3.
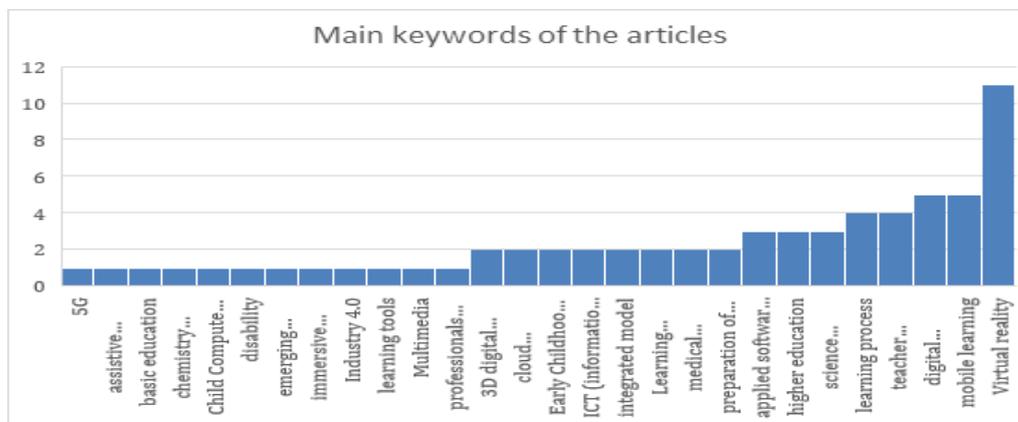

Fig. 3. *Distribution papers by topic where the keywords of the articles were considered*

3.5. Summarizing and reporting the results

For this extensive literature review 30 studies were analysed, by using the content analysis method of the purpose and conclusions of each article. All information has been grouped in six major categories based on the rank occupied by the used keywords as presented in Figure 3. The categories are virtual reality, mobile technologies, digital educational resources learning process, teacher's education, infrastructure.

a. Virtual reality

AR technologies have great potential in many application fields for education (Iatsyshyn and al., 2020). Often, AR and VR technologies are complemented in the opinion of many researchers. The closures of educational institutions affected teaching and learning processes and had an impact on students' motivation and engagement. In this context, AR/ VR technology can aid students and support educators. There are many articles which combine the information about augmented reality and virtual reality (Timovski et al., 2020; Marienko et al., 2020; Elmqaddem, 2019; Baratè et al., 2019; Huang et al., 2019; Gudonienė andRutkauskienė, 2019; Sural, 2018; Pantelidis et al., 2018). The findings illustrated a set of studies that provide evidence of increased learning achievement, students' engagement, motivation, and collaboration through the educational environments that are enriched with AR/VR applications.

Huang at all (2019) considers that AR and VR can both be used effectively to teach

science-based information. However, AR and VR have their own set of strengths and weaknesses that should be considered while integrating these technologies into learning environments. In the end, both technologies provide students with an exciting new educational reality.

An actual integration of these technologies requires lots of improvements and changes not only on the part of engineers and experts of AR and VR, but also teachers and all persons related to the field of education. Engineers must propose VR and AR headsets that are more comfortable and accessible. In fact, a long use of the VR and AR headsets proposed for now causes some discomfort. As for persons related to education, they must deploy more forward educational programs that fit well with the nature of these technologies and fulfil the needs of the learner (Elmqaddem, 2019).

VR/ AR training displays certain advantages toward other simulation techniques. Although expensive to buy, VR/AR simulators provide a relatively costless opportunity for reproducible training under various environments and difficulty levels. Moreover, they do not raise ethical issues, compared with other animal and living tissue simulation models. They provide immersion for the user and the ability to perform complete procedures, in contrast with partial task trainers (Pantelidis et al., 2018).

b. Mobile technologies

The most used devices for AR applications are mobile or handheld devices, followed by the desktop computer or PC (Quintero et al., 2019). In some of the articles studied, the authors correlate AR with mobile technologies (Cabero-Almenara et al., 2019; Nechypurenko et al., 2020; Oleksiuk and Oleksiuk, 2020; Huang et al., 2019; Quintero et al., 2019; Hruntova et al., 2018; Masmuzidin and Aziz, 2018; Sáez-López et al, 2018)

According to Huang at all (2019), AR technologies provided by smartphone-based mobile applications are cost-effective and portable and have a tremendous potential for education. The results of Oleksiuk and Oleksiuk study (2020) show that IT teachers have access to computers and mobile devices and have a high level of interest in AR technology. Marker-based AR and mobile device has been chosen widely in augmented reality in early childhood education (Masmuzidin and Aziz, 2018) but also in higher education (Cabero-Almenara et al., 2019).

c. Digital educational resources

Some articles consider the use of AR educational resources as didactic teaching tool (Molnár, Szűts, and Biró, 2018; Osuna et al., 2019; Barrow et al., 2019; Tzima, Styliaras and Bassounas, 2019). Application of digital technologies, in particular AR, is important in preparing new professionals (Iatsyshyn et al., 2020).

In their study, Nurbekova and Baigusheva (2020) state that the use of digital educational resources with AR as a didactic tool enriches the learning process with advantages: it makes the learning material interesting and understandable, contributes to the visibility of the learning material, and better reveals theoretical material. Moreover, the results of experimental studies indicate the feasibility of augmented reality with the observance of classical didactic principles: visibility, the connection of theory with practice, consciousness and activity, accessibility, strength, science, system, and consistency.

d. Learning process

In the context of COVID-19 pandemic, AR technology can aid students and support educators in the learning process (Timovski, Koceska, and Koceski, 2020). Due to the variety, interactivity of visual presentation of educational objects, currently, the use of AR in education has been a success (Oleksiuk and Oleksiuk, 2020). Using this technology increases the motivation to learn and the level of mastering the material. Learning gets a new dimension. The latest educational technologies related to learning personalization and the adaptation of its content to the individual needs of students and group work are considered by Marienko, Nosenko and Shyshkina (2020).

Hanid, Said and Yahaya (2020) identified four types of learning strategies based on AR. These strategies are interactive learning, game-based learning, collaborative learning, and experiential learning. Therefore, the AR technologies must be integrated with appropriate learning strategies for the purpose of making an impact on improving the quality of the learning process.

A study conducted by Nurbekova and Baigusheva (2020) shows the effectiveness of the application of AR and notes the diverse advantages in education: an increase of the interest towards learning, high level of comprehension and permanency in learning, high learning achievements,laboratory skills improvements, a positive attitude of students towards laboratory work, effective improvement of visual thinking skills, and a greater students' enthusiasm.

Guntur et al. (2020) offers another perspective. The use of AR technology in-class learning has the potential to improve learning outcomes of spatial abilities, student motivation, problem-solving abilities, and student achievement. Some other studies present ways of improving learning in specific domains. In Nechypurenko et al. (2018), AR technologies are actively used in chemistry education and their effectiveness has been proven. Frequently AR technologies of the chemistry education are used for 3D visualization of the structure of atoms, molecules, crystalline lattices. The most promising thing, according to the authors, is the development of methodological recommendations for the implementation of laboratory works, textbooks, popular scientific literature on chemistry with the use of the AR technologies and the creation of the AR simulators for working with the chemical equipment and utensils.

Other articles present the possibilities of using augmented reality in the study of mathematics, anatomy, physics, chemistry, architecture, as well as in other fields (Pochtoviuk, Vakaliuk and Pikilnyak, 2020). AR can facilitate the study of anatomy by visual effects and information on the organs and bones. You can see the result of the impact of surgical intervention or medicinal preparation as in one body, so also in the group of, not causing harm to a living organism. According to the same authors, in science education, AR can be used for virtual experimentation or in architectural studies as real-time AR visualisation service for architectural models.

e. Teacher education

Teachers play a central role in the educational process (Tzima, Styliaras, and Bassounas, 2019). The practical significance of the research results is that compliance with the revealed didactic principles will allow teachers to organize the didactic process on the basis of a systematic and reasonable approach to the choice of content, methods,

means and forms of learning, when using AR. The role of teachers in implementing AR tools in the learning process was also discussed in the selected articles.

It has been determined that e-learning improvement is especially important and can offer a perfect technology for individualized learning based on interactive learning objects. As well as a group learning through online chat rooms (Gudonienė and Rutkauskienė, 2019). Sural (2018) unveils the results of a survey study that intends to explore the candidate teachers' opinions about using augmented reality (AR) in classrooms. This survey results show that although candidate teachers have good knowledge of smartphones and laptop computers, they have fair knowledge about augmented reality. Most of the candidate teachers have general knowledge about the term but not in detail about the AR technology and possible use in many settings. After using AR resources, candidate teachers were excited and stated that augmented reality has big potential in teaching and learning materials.

Using AR technology, teachers or even students can create content. For example, triggers using the provided website. The triggers can be image or videos, so the AR experience can be customized. In their study, Molnár, Szűts, and Biró (2018) first introduced the augmented reality and a specific application, Pokémon Go, then demonstrated the use of AR in education and finally presented a survey conducted among students of a higher education in Hungary.

Sáez-López et al. (2020) assess the impact, practices and attitudes that are generated from AR in the initial training of future teachers, and the presence of these practices in a university training context. The results obtained from an audience with a particular educational background, concluded that the students positively value the approach of initial teacher training that made use of augmented reality. Particularly, motivation was considered the key and most notable factor in working with this resource.

f.   Infrastructure

Infrastructure for AR technologies is also described in the studied articles. Therefore, with the use of hybrid cloud solutions, educational systems are becoming more adaptable, based on the integration of different types of services and their integration into teacher education into a single environment (Marienko, Nosenko, and Shyshkina, 2020). Baratè et al. (2019) described the expected characteristics and performance of 5G with respect to the requirements of AR applications. Current network technologies prove to be unable to fulfil those requirements, while 5G will provide services that are expected to fit them, thus opening new perspectives in the deployment of innovative educational scenarios. The real pervasive deployment of 5G will be able to show the effective performance of the technology, that may significantly differ from those extracted from currently existing trials, due to either high concurrency amongst users in the same cell or to the behaviour of future hardware and software components.

4. Conclusion

The present article contributes to expanding the current state of research in the field of the application of Augmented Reality (AR) in education. The findings of this extensive literature review validate the premise that AR offers its own unique advantages for

virtual learning in education. A considerable amount of literature has been published in AR application in various domains. However, the state of current research in AR for the education domain is still in its infancy. The research in this field should continue and should be addressed to discover the true potential of AR applications in education. Based on the results of this study, future research needs to cover the following topics:

- AR technology application in training (Iatsyshyn and al., 2020)
- Peculiarities of implementing the principle of virtual reality in learning with the use of different systems of augmented reality (Nurbekova and Baigusheva, 2020)
- Integration of adaptive cloud-oriented systems, the AR technologies, and the modern pedagogical techniques (Marienko et al., 2020)
- Role of cognitive or perceptual load while using these AR technologies (Huang et al., 2019)
- Impact of previous experience using these technologies on the efficacy of AR and VR for education (Huang et al., 2019)
- AR usage in creating new learning environments, implementation of new platforms (Gudonienė and Rutkauskienė, 2019)
- New types of content that can be used and not used with AR (Hantono et al., 2018)
- Motivational design of augmented reality technology for young children (Masmuzidin and Aziz, 2018).

Acknowledgement

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