AN OUTLINE OF AUGMENTED REALITY EDUCATIONAL APPLICATIONS

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ABSTRACT

Augmented Reality is a state of the art technology that finds impressive applications in many areas of education and economy. Specifically, in education, AR constitutes a set of adaptive and interactive tools that facilitate learning, by creating artificial environments capable of simulating real-time complex systems. In this work, we highlight tools and types of AR, analyze the exact use of its applications in different areas and support the argument of its positive impact on the learning process. To better draw the research frame, we also conduct a small scale survey.

Keywords: augmented reality, simulation, learning impact, digital competence

INTRODUCTION

The rapid development of information and communication technologies causes a deep impact on education, significantly changing the learning environment. Such a powerful education tool is Augmented Reality (AR)[1], which can "produce interactive, real-world learning opportunities for learners" (Estapa & Nadolny, 2015).

AR is defined as "an enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device (such as a smartphone camera)". By bridging virtual and real worlds together, AR creates an environment that is both enhanced and augmented (Bronack, 2011; Klopfer & Squire, 2008).

AR "amplifies access to information, bringing new opportunities for learning" (Johnson et al., 2016). It also influences the effectiveness of teaching-learning processes and contribute to adults' learning experience. AR applications have been proven particularly useful in increasing student motivation in the learning process (Di Serio et al., 2013; Chen et al., 2017). AR can be applied in all levels of education, especially in Adult and Vocational Education and Training. Trainers who integrate Augmented Reality into their sessions, make learning an intriguing process for their adult audiences (Akçayır, M. & Akçayır, G., 2017). Furthermore, educational exposure to AR prepares learners for the future workplace (Johnson et al., 2016).

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SETTING THE RESEARCH FRAME

At the same time, the use of AR, as a tool to deliver effective training to adults, requires a satisfactory level of digital skills from the potential users. According to UNESCO[2], "digital skills are defined as a range of abilities to use digital devices, communication applications, and networks to access and manage information". In this document, the European Digital Competence Framework for Citizens framework, which is also known as "DigComp", will be used as reference. It summarizes the effort of the European Commission in identifying the key components of digital competence.

The DigComp 2.0 Framework[3] consists of the following 5 specific areas:

- Information and data literacy: determines users' ability to "locate and retrieve digital data", assess the reliability of online information and classify information in a methodical way using files and folders.
- Communication and collaboration: determine users' ability to "communicate and collaborate through digital technologies", participate in the digital society and be aware and use the rules of online communication.
- Digital content creation: determines users' ability to create digital content and "understanding how copyright and licenses are to be applied".
- Safety: determines users' ability to "protect devices, content, personal data and privacy in digital environments".
- Problem solving: determines users' capability to identify and handle problems in digital environment.

Although AR is not explicitly mentioned in this current version of "DigComp", we have every reason to believe that it will soon be associated, as it is obviously fully compatible with its aims. For the moment, we will try to provide an insight into the field of AR applications used in education by setting the following research questions (RQs):

RQ1: What are the technological tools and types of AR currently used in educational organizations? Identify a) the types of technology (e.g. smartphones, PlayStation, etc.) and b) the types of AR triggering used (e.g. location-based).

RQ2: Which are the main disciplines of AR applications (e.g. health, tourism, engineering, etc.)?

RQ3: In which areas of the educational process does the AR have a positive impact (e.g. learner motivation and performance)?

Answering these questions will define our research frame more accurately. AR systems are generally considered user friendly and in most cases require few prior knowledge of "DigComp"

[2] Follow the link https://en.unesco.org/news/digital-skills-critical-jobs-and-social-inclusion
[3] Follow the link https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework

skills (Bacca et al., 2015). Teachers, though, should receive proper instructions and training, before they use it in the classroom.

METHOD

In order to answer the above RQs, we performed a substantial literature review in large bibliographic databases[4]. The criteria that were used in locating the relevant papers were: a) is AR technology being used for educational purposes, preferable in adult education? b) was the research paper released within the last five years? c) does it answer the research questions above? The researchers also suggested a number of recently published papers, which are mostly characteristic or representative of the field. After analyzing a total of twenty-five articles which were all relevant to one or more or the RQs, their core ideas were distilled and results were summarized. The collection of these papers is listed in bibliography section.

At a first stage of analysis, data relative to the year of publication of each article are presented. The selected articles were published from 2014 to 2019. One can easily observe that the interest of the research community in this field is steadily growing all these years. The following table summarizes the list of articles by year of publication.

Year of publication	Number of papers
2014	2
2015	9
2016	5
2017	3
2018	3
2019	3

Table 1: Year of publication of the selected articles

RQ1 analysis

As Table 2 suggests, most papers (N=17) have used AR technology through mobile devices. It is worth noting that in some articles more than one AR application/example is mentioned. Moreover, AR technology was used through computer monitor in three articles, while in two through projector glasses. However, there are some articles which do not refer to the type of technological medium used. It is evident that mobile AR applications are becoming popular due to the growth of mobile phone industry.

Medium	Number of papers
Mobile devices	17
Computer monitor	3
PlayStation	-
Projector glasses	3
Not mentioned	7

Table 2: Types of technological medium used in augmented reality

[4] namely http://scholar.google.com and http://www.scopus.com

Table 3 shows the different types of AR triggering used within the articles that are included into this review. Some of them are mentioned in more than one application/example. Depending on the AR activator used, three types of AR presentations can be identified: a) Marker-based by using a trigger image or a QR code b) Location-based by using a specific location and c) Markerless, where there is no need for a trigger image. The majority of the articles (N=15) utilized marker-based technology for integrating AR applications into learning processes. Moreover, four (N=4) articles were identified in which location-based technology were used and three (N=3) where no marker is needed. However, there are some articles which do not refer to the type of AR triggering used. It is obvious that there is a preference in using marker-based technology for integrating AR applications. A possible explanation is that by comparing marker-based AR with markerless AR the accuracy of marker-based AR is much higher and also the complexity is lower (Cheng et al., 2017).

Type	**Number of papers**
Marker-based	15
Location-based	4
Markerless	3
No mention	8

Table 3: Different types of AR triggering

RQ2 analysis

Table 4 below shows the distribution of papers into disciplines/subjects of the curriculum. It is evident that there are a lot of education fields in which AR technology is applied for training and learning in all educational levels. Some papers refer only to one specific discipline while others refer to more subjects analyzing, in a general perspective, the various areas in which AR can be applied. According to Fernandez (2017), AR technology can introduce real experiences to educational programs through online channels which will equalize distance learning even more with face-to-face teaching.

According to Table 4, most of AR impact on teaching concerns the fields of "Physics/Chemistry/Math". There are papers involved in teaching abstract concepts of these subject (Irwansyah et al., 2018; Coimbra et al., 2015; Estapa & Nadolny, 2015; Hsu et al., 2017) and also simulation systems application in a chemistry course (Cai et al., 2014).

In the field of "Health/Medicine" education, nine papers were identified. These papers concern the field of medical training (Barsom et al., 2016; Fernandez, 2017; Herron, 2016; Sanna & Manuri, 2016; Oh et al., 2018) and learning human anatomy (Jamali et al., 2015). According to Sanna and Manuri (2016), scientists and physicians have been provided a huge amount of data through medical AR that can support diagnostic of preoperative and intraoperative data or in training tasks.

In the field of "Architecture/Construction" education, five papers were identified which concern the development of an AR prototype (Kerr & Lawson, 2019), construction safety education (Le et al. 2015), constructions of electrical machines (Martín-Gutiérrez et al., 2015) and architectural and building design (Sanna & Manuri, 2016; Ayer et al., 2016).

In the field of "Assembly/Maintenance/Repair", AR can easy replace paper instructions and manuals (Sanna & Manuri, 2016) while also providing an immersive experience (Oh et al., 2018).

In the field of "Cultural Heritage/History/Tourism", the selected papers demonstrate AR as a medium for teaching history and as a result to promote importance of cultural heritage (Kysela & Štorková, 2015; Saidin et al., 2015; Sanna & Manuri, 2016).

In the field of "Entertainment/Sport", AR plays an important role (Sanna & Manuri, 2016) and also simulation game technologies can influence learners' performance and support their learning (Ayer et al., 2016).

In the field of "Military applications", AR technologies can help create lifelike battlefields (Oh et al., 2018; Sanna & Manuri, 2016).

Disciplines	**Number of papers**
Physics/Chemistry/Math	9
Health/Medicine	9
Architecture/Construction	5
Assembly/Maintenance/Repair	4
Cultural Heritage/History/ Tourism	3
Entertainment/Sport	2
Military applications	2
Others	4

Table 4: Distribution by subject

RQ3 analysis

The literature review reveals that AR demonstrates a positive impact on a number of factors in the educational and learning process. The main results are summarized on Table 5. It is worth noting that many papers refer to the impact of AR usage in multiple table categories.

Research findings depict that AR technology use within a training session increases learning outcomes (N=22). The significant added-value of AR-based training in terms of learning outcomes has been highlighted in several papers (Cabero et al., 2016; Cai et al.,2014; Coimbra et al., 2015; Bacca et al., 2015; Barrow, Forker, Sands, O'Hare & Hurst, 2019; Fernandez, 2017; Jamali et al., 2015).

AR technology also enhances learners' motivation (N=13) during their learning session (Ayer et al., 2016; Cabero et al., 2016; Hsu et al.; Jamali et al., 2015). AR supports learners' collaboration (Fernandez, 2017; Marcel, 2019) and participation (Cabero et al., 2016). AR has a positive effect on learners regarding concentration and confidence (Bacca et al., 2015), excitement (Barrow at al., 2019) and satisfaction (Cai et al., 2014).

Individual areas	**Number of studies**
Learning outcomes	22
Motivation	13
Collaboration	10
Participation	6

Concentration	5
Excitement	3
Satisfaction	3
Confidence	1
Other	3
No mention	1

Table 5: Areas where AR has a positive impact

CONCLUSIONS

The increasing diffusion of AR applications within school curricula was the main motivation in writing this manuscript. AR technology has the potential to disrupt the educational process in many ways, which justifies the increasing research interest for this area. An effort to explain its basic characteristics that could lead to the development of corresponding scenaria of sample activities was made. At this point, a simple reflection report from teachers, who have tested AR in the classroom, could help accumulate and disseminate their experience, as it is gained from practical implementation.

Summing up the results, we noticed that the majority of the papers has used AR technology through mobile devices. It also utilized marker-based technology for integrating AR applications into learning processes, probably due to its accuracy and low complexity (Cheng et al., 2017). Moreover, there is a wide range of educational fields in which AR technology is applied. They are mainly physics/chemistry/math but also health/medicine is reported. In architecture/construction a lot applications were also spotted. We highlighted that AR applications have the potential to increase learning outcomes, mainly motivation and collaboration among learners. However, according to Fernandez (2017), educators need to be trained on AR technologies first, as they do not know their prospective uses in teaching and learning. After completing their training, they will be able to leverage the full AR educational potential.

Generalizing beyond capabilities and skills, AR is compliant with the upcoming developments' prospective (like spatial web, or web3.0), which will allow better human understanding and deploy a wider discussion about the power and boundaries of human intelligence. This will accelerate the process of transition to an artificial intelligence society, increasing the complexity of the surrounding ubiquitous digital ecosystem with which we are inevitable intertwined.

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