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The Integration of Augmented Reality (AR) in Education

Victor Marrahi-Gomez
PhD Assistant, Department of English Linguistics
University of Alicante, Spain

Jose Belda-Medina
Associate Professor, Department of English Linguistics
University of Alicante, Spain

ABSTRACT

New teaching techniques have been adopted as a result of the emergence of innovative technological tools in the field of Augmented Reality (AR), as investigated in several articles to date (Hsu 2017; Forsythe & Raine 2019). The availability of AR applications, both vision, and location-based, allows students today to learn foreign languages in a more contextualized and immersive manner, thanks to the use of smartphones and other electronic devices. Thus, this study seeks to analyze and review the recent trends in AR implementation in education and to present the main projects aimed at teaching with AR-based projects that have been published in the latest years in WOS and Scopus.

Keywords: Augmented Reality; teaching; Immersion; Educational Technology; Advantages and Limitations

INTRODUCTION

Recent advances in technology have paved the way for its effective application in education as pointed out in several studies (Belda-Medina [6,8], Wu et al. [44]). Augmented Reality (AR) has become a breakthrough technology with a strong potential in education thanks to the emergence of new AR types (markerless and marker-based), tools (Software Development Kits or SDKs), and wearables (head-mounted displays, smart glasses, mobile apps, etc). Consequently, AR technology has numerous educational benefits and some limitations according to different authors (Ávila-Garzón et al., [2]; Billinghurst, [9]; Chen, [16]; Cooperstock, [18]; Klopfer et al., [32]; Shelton et. al. [42].). Some of the affordances include contextual learning, better representation of abstract concepts, and enhanced student motivation (Marrahi-Gomez & Belda-Medina [36], Belda-Medina [6,8]). For this reason, this article aims to review and examine the benefits and limitations of integrating AR technology in education as analyzed in previous works.

LITERATURE REVIEW

AR Definition

AR is used to describe a set of technological elements that allow the user to have a clear image of the real world while using a tool or device that generates additional graphical information. AR is a term coined over the years and is used to describe the set of technological elements that allow the user to visualize part of the real world through a technological device with graphic

information, added by said device, in the real world. That is, physical elements are combined with virtual ones. This term was coined by Caudell [14]. However, the author who best combined the concepts was Ronald T. Azuma in 1997.

According to Azuma [3] "Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called". The author states that, unlike Virtual Reality (VR from now on), the user can observe the real world with superimposed real-world objects. Instead, VR creates a completely virtual world without using elements or spaces of reality. Therefore, it could be said that AR complements the real world by mixing elements created through external tools with elements already existing in reality, instead of completely replacing it by creating worlds and virtual elements, as VR does.

According to Azuma [3], to limit RA to the use of certain external elements, such as the use of glasses or an AR suit, the concept of AR can be defined based on three common characteristics:

1. AR combines the virtual and the real world. That is, it allows us to interact in the real world with elements of the virtual world, allowing users of technology to have unique experiences that would not be possible without the use of AR.
2. AR is interactive in real-time. A user change or action has immediate repercussions on the scene created by the AR allowing the user to get a more realistic experience.
3. RA has elements captured in three dimensions (3D). Information is always shown in that perspective, giving you a sense of belonging to the real world. Thanks to the evolution of AR you can interact directly with the physical abilities of the surroundings.

Therefore, AR does not include two-dimensional (2D) elements, so films using 2D are discarded. It also needs to be interactive, meaning that the user can interact through virtual tools with the 3D elements created.

Main concepts of AR

AR introduces us to a world that mixes real and virtual elements. However, this requires several external elements that allow the user to have a complete experience. Belda-Medina & Calvo-Ferrer [7] indicate that there are different technological elements necessary for the use of AR such as the use of triggers and overlays to represent illustrative and contextual information in a digital format. Triggers are real elements used for the inclusion of virtual elements in physical reality. There are several types of triggers:

1. **Based on markers**. In this case, the user must orient the camera towards the marker that has been set to create the augmented elements on the device used. This connection is created between the real and the virtual world using a code in the image, the text, the object, or the QR code. The element chosen as the trigger must be clear and large enough for the capturing element to be able to recognize it.
2. **Without markers**. In this case, the AR can be integrated into the real environment in a very effective way since no element stands out, as was the case before. Here, the trigger that triggers the appearance of augmented elements is the detection of a surface, either vertical or horizontal with the capturing element. Once the surface is detected, the increased content can be placed and anchored on the surface. In this way, you can walk around and observe the increased element from all possible angles. This marker is widely used by interior designers to observe the size of the furniture and see if they mimic their surroundings.

3. **Based on geolocation.** By using GPS and positioning the magnifying tool can detect if we are in a particular position where the trigger must be activated and trigger the increase.

According to Rabbi et al. [39], tracking is based on the virtual alignment of objects with the real world. Tracking techniques can be categorized into three forms:

1. **Sensor-based tracking.** Active sensors are used to position and analyze the camera's motion position relative to the object. These sensors can be optical, magnetic, acoustic, or ultrasonic. The choice of the latter depends on several factors that you want to consider such as precision, caliber, cost, and pressure among others; although each has its advantages and disadvantages.
2. **Vision-based tracking**. According to Rabbi et al [39], it is the most popular of the three. Computers are used to calculate the position of the camera in the real world and to be able to track the alignment of both realities.
3. **Hybrid tracking.** The two previous forms have certain limitations, so the hybrid model was designed to improve this technology. Using small sensors, better results can be obtained without the failures of the two previous models. By combining an optical sensor and a vision based on proximity, an element with a greater range and reliability is created.

Regarding overlays, they are considered to be the augmented element that appears on the visualization tool. The main elements used as overlays are text, videos, and 3D elements.

OBJECTIVES AND METHODOLOGY

The present study seeks to analyze and review recent trends in AR implementation in an educational environment. Besides, it aims to examine the main projects used for teaching with AR-based projects that have been published in the latest years. Specifically, the research objectives are:

1. To analyze the latest research on AR-based education.
2. To examine the main educational areas where AR is being effectively used
3. To discuss the benefits and limitations of the implementation of AR-based projects in education.

Augmented Reality in Education

The implementation of AR technology in education

In an educational context, RA has been used as a complement to a pre-established and standard curriculum, based mostly on a traditional methodology according to Ávila-Garzón et al. [2]. Text, 3D graphics, video, and audio can be overlaid in the student environment in real-time. There are other tools such as reading materials, textbooks, and reading cards that may contain markers or triggers scanned by a device that can support an AR application. Among the main tools we can find:

1. **AR-based books**. According to Yuen [50] and Yang [46-47], AR books are one of the cornerstones that help to unite the digital world with 45 real environments. This interactive experience seems to please digital native students. For example, one of the first documents to appear is a book called The Future is Wild: The Living Book developed in 2011. The book consisted of 42 integrated triggers to demonstrate the potential of RA in education and, promote the creation of a connection between readers and reading.

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Another notorious case was the book developed by Yuen [49-50] a tool consisting of pop-ups that created 3D elements for each page. Special glasses were required for reading this book. These elements are ideal for inclusion at any educational level and open a new interface in the educational field, as it requires superior attention by the reader and the writer since many elements have to control part of the narrative thread, such as AR quality or immersive AR.

Figure 1. Augmented Reality book example

2. **AR Note.** According to Pasaréti et al. [38] and Theodorou et al. [43], another implementation system that encourages the use of AR in education is “AR Note", a system that allows taking notes in a virtual notebook with the advantage that it can be much more efficient and allows the introduction of graphics or the search for information in such notes. This promotes student retention and improved study habits, as the experiment conducted by Pasaréti et al. [38] showed. Using an application known as OpenCV, developed in Unity, it is possible to project digital documents on paper using an optical flow. This application allows you to write on a paper document and project it on the virtual tool. This application is available for mobile phones and electronic tablets and is being developed so that in the future it can work with the use of AR glasses.

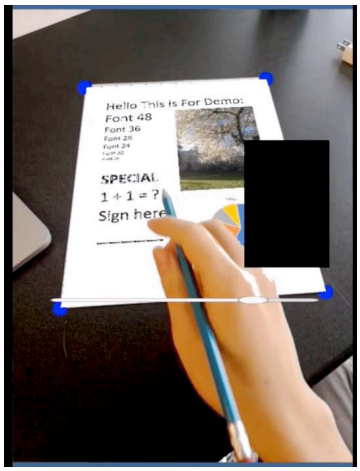

Figure 2. Augmented Reality note-taking example

3. **Games based on AR.** According to Pasaréti et al. [38] and Kerr et al. [31], teachers can use games to help students with certain concepts. Through AR technology games can be based on a real environment mixed with virtual elements. This allows students to create new relationships and connections between different items.

AR technology has been constantly improving over the years. As a result, Dunleavy et al. [19] states that educators and researchers are continuously developing new teaching methods based on the latest advances to make them more interactive and engaging for learners. Mobile AR has become quite popular today thanks to the fact that mobile devices are widely spread and affordable, which facilitates AR integration in education. In addition, some industry experts such as Kerr et al. [31] have predicted that mobile AR will continue expanding as they can support more effectively and with better quality AR content, which will lead to further development in the educational field of AR-based applications and elements.

Main areas of study of AR in education

Garzón et al. [22] carried out a study of the main areas of the educational field to establish in which the greatest number of investigations had been carried out and which areas of knowledge were least exploited in the inclusion of RA in their educational curricula. For this purpose, they relied on certain scientific journals indexed in the database known as the "Social Sciences Citation Index" (SSCI) and their conference publications "Conference Proceedings Citation Index-Science" (CPCI-S). The research was based on key terms such as “Augmented Reality and Education", and "Augmenting Reality and Education" and papers in English were only considered. The articles followed the pre-established criteria as follows:

- Studies related to keywords.
- Studies that include case analysis.
- Studies accepted or published.
- Studies containing a pre and post-test.
- Studies containing one control group and one experimental group.
- Studies focused on the educational field.

In this study, they followed the ISCED classification standards proposed by UNESCO in 2011. The research confirmed previous information (Baca et al. [4], Blake [10]), which stated that the two educational areas where AR was more widely adopted were Natural Sciences, Mathematics, and Statistics; possibly because AR can effectively complement the learning of abstract concepts, as demonstrated by Ibáñez et al. [27].

In the field of Arts and Humanities, the studies that exist regarding the application of the RA are mostly oriented toward artistic manifestations. Apart from complementing abstract elements, AR technology can provide students with better spatial vision.

Use of AR at different educational levels

The educational levels here refer to the different stages of the educational system following the 2011 United Nations International Standard Classification of Education. According to it, student distribution would be as follows:

- Early Childhood Education.
- Primary Education.
- Lower Secondary Education.

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- Upper Secondary Education.
- Bachelor.
- Vocational Training and Education.

In terms of equivalence, the first group includes children attending preschool (usually between 2 years and 5 years); the second refers to students attending a primary school (from 6 years of age to 12); the third place corresponds to the first cycle of Secondary Education covering students between 12 and 15 years of age; the second cycle of Secondary Education includes students from 15 to 17 years of age; finally, college students are included in higher studies.

Yilmaz's review of the use of AR technology in education (2017) was based on the analysis of research articles published until 2017 in several indexed journals, such as Web of Science, SSCI, SCI-EXPANDED, A&HCI, CPCI-S, CPCI-SSH, and ESCI indexes. The works were related to the keywords would be Augmented Reality and Educational Scope.

1. **AR in preschool education**. Most research in this area focuses on observing student attitudes, enjoyment level, and comprehension. For this, researchers found that the main tool used was AR books to tell stories to children. The results show the use of AR in the preschool classroom improved their understanding and also concluded that there was significant evidence between the control and experimental groups regarding student interaction. Finally, the effectiveness of vocabulary acquisition related to colors in the art class was explored through the ColAR mobile application, used to perform activities related to the use of colors and their vocabulary. The study concluded with the statement that thanks to the use of AR enjoyment was superior and an improvement in the effectiveness of learning was observed. In conclusion, Yilmaz (2017) states that the inclusion of RA in several educational areas had, in general, acceptance and very positive results.
2. **AR in primary education.** Yilmaz [48] analyzed 11 studies including those of Joo-Nagata et al. [30], Nadolny [37], Hsu [25], Cascales-Martínez [13] and Laine [33] stand out. These works focused on analyzing the improvement of the effectiveness of education through the use of RA and its influence on the educational process and the opinions of students and faculty regarding the application of this new tool in the curriculum of a primary school. For example, Nadolny [37] studied patterns to observe the influence of marker use on math teaching. Their analysis showed that user interactions and cognitive exercises interested users and improved their understanding of mathematical language.

In another study Hsu [25] developed two different AR games, one based on a semi-directed education and another based on activities, but with the use of the same tool; in this research, the student's anxiety and learning effectiveness were analyzed. The students showed equal results, although the semi-directed system showed that the students acquired a greater experience and, likewise, affirmed that the anxiety in both groups was almost non-existent. Finally, Cascales-Martínez [13] analyzed, through the use of an interactive whiteboard, the teaching of mathematics to primary students with special needs to observe the motivation of students with the use of AR. His conclusions showed that the attitude towards mathematics was more positive in the group who worked with the blackboard than those who used another methodology not based on AR.

3. **AR in secondary education.** Four studies based on secondary education are those of Cai [11-12], Huang [26], and Ibáñez [27-29]. These works examined the effectiveness of AR through natural interaction among students and related it to students' attitudes. They compared using AR with a more traditional methodology in different fields such as Physics and Mathematics. Through the use of sensory movement software, these works explored the creation of materials. The results obtained showed that there was an improvement in the learning of the group that used this tool, as well as an improvement in students' attitudes toward the concepts established for research. Similarly, Huang [26], experimented in the field of biology in a secondary school. He considered three different groups: a self-managed group using AR; a guided group using AR; and a group using a traditional methodology. The results showed that the second group had a higher improvement in terms of knowledge acquisition; in addition, the first group mentioned had a better emotional feeling and freedom and, Overall, the first two groups achieved a significant improvement in student motivation.

On the other hand, Rabbi et al. [39] focused also on learning and motivation but used an AR application for mobile devices in the area of Science in a class combining AR with a more traditional methodology. The results showed that students who used the AR application achieved better results on the specified tests and were more motivated than students using a traditional method.

Finally, Ibáñez [27-29] used AR-based simulations to teach a subject based on scientific concepts. The experiment included two groups, an experimental and a control group, and, while the first was assisted in carrying out the activities, the second did not receive any assistance. The results showed that the experimental group obtained better grades in the execution of the specific tests and that the students of this group had a greater predisposition for the individual search for concepts and information.

4. **AR in higher education**. Several works have been published about AR integration at his levels such as those of Redondo Domínguez et al. [40], Bautista-Salinas [5], Ferrer-Torregrosa [20], and Harley [23]. Redondo Domínguez et al. [40] examined the use of AR in Architecture with two groups of students. The first group used AR technology with their mobile applications. The result of the experiment confirmed a better performance among participants in this group. In addition, the motivation and satisfaction of the students who used the new tool were significantly higher. The results also revealed that the use of AR among students can improve their spatial perception of Architecture.

Ferrer-Torregrosa [20] compared three tools: notes with images, video, OS, and marker-based materials in the context of health education. The research focused on time spent learning, learning itself, the perception of metacognition, and the possibilities offered by AR. The results showed that AR was the most effective material of the three tools tested in all aspects under study.

Bautista-Salinas [5] developed an application to implement AR technology in a university context among math students. The results included decreased student anxiety in relation to mathematical knowledge and increased effectiveness in the learning of mathematical concepts.

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Finally, Harley [23] explored the use of AR to teach history in a university setting. He organized an RA tour with local history by using geographic locators and mobile devices to examine students' emotions and learning.

Advantages and Limitations of the implementation of AR in Education

AR technology can be applied to different educational contexts since students can simultaneously interact with virtual elements and real objects in different areas. For example, AR can be used in textbooks to create a more interactive experience and enhance students' engagement as demonstrated by Hsu [25]. There are several benefits and limitations to the use of AR technology in education.

Advantages

Among the main advantages some works mention the following:

1. Greater emotional relationship. As stated by Wu [44-45], AR systems can help students develop skills and knowledge more effectively, building on students' emotions toward learning.

2. The Motivation factor. Being an everyday element with which students possess considerable familiarity, the motivation of students for using mobile devices for the acquisition of knowledge is growing compared to that produced by materials used in traditional education. This motivation is a direct consequence of another significant advantage, according to the studies of Belda-Medina [6] which stated that there was a sensory interaction that was considered " related to how children learn in their natural mode, using several of their senses in a constructive process." Likewise, Chang et al. [15] stated that when various senses of the students are activated, the brain speeds up the constructive process, which is considered a great advance in the learning process.

3. The economic factor. According to Liu [34-35] and Belda-Medina [6], mobile learning is superior to traditional learning in terms of flexibility, cost, portability, and ease of use since it is carried out with materials that students of all ages possess, whether mobile or an electronic tablet, and are already used to their everyday use.

4. The interaction factor. One of the properties that characterize Augmented Reality systems is that there is an interactive implementation in real time. This means that the student can modify activities based on AR.

5. The representation of abstract concepts. According to Akçayir et al. [1], Chang et al. [15], and Lin et al. [34], one of the advantages of using AR in the educational field is that it has the possibility of facilitating the understanding of elements considered as abstract. Similarly, Ibáñez et al. [28] presented the results of their study comparing two teaching tools, AR and web teaching, the evidence obtained suggested that students who had used the first methodology achieved an improvement in their academic achievements in a more efficient way than those who used the second. In addition, it found that improvement could also be observed in the teaching of abstract concepts that the web methodology could not match.

6. The retention factor. Chiang et al. [17] showed that one of the advantages in the educational field of the implementation of AR in their curriculum is the greater retention of concepts. Santos et al. [41] could observe by analyzing 87 research articles: 1) contextual visualization, that is, students have a better representation of the concepts studied; 2) real-world annotation; 3) visual applications that are interactions with virtual content. These three common characteristics can be observed in students exposed to AR as a teaching method. This tool applied to pedagogy allows greater retention in long-term memory.

7. The autonomous learning factor. According to Ibáñez et al. [28], the combination of the virtual world increases the incorporation of the virtual world into teaching increases the autonomy of students because they show natural skills and great motivation to use technological tools. AR technology creates the possibility for students to learn and share knowledge through interaction.

In the same line of research, Wu [44-45] states that can improve learning outcomes in five aspects: 1) It can create 3D perspectives of the material; 2) it has the property of ubiquity and collaboration; which indicates that it can be transferred outside the educational field or stop being face-to-face, as well as favoring the collaboration of the students among themselves or with the teacher; 3) enhances the sense of presence, immediacy, and immersion of the students; 4) to visualize the invisible and act as a bridge between formal and informal education, eventually merging it; 5) helps students to overcome the barriers of learning that may exist and can improve the effectiveness of learning in various areas of knowledge, for example, spoken English and listening.

Limitations

There are also certain challenges related to some technological and pedagogical problems. They could be summarized in five general ideas:

1. The complexity factor. There is some complexity in the use of AR, especially if learners have not previously worked with this technology. Herpich et al. [24] stated that, as it is such a recent and complex technology, the lack of previous technological knowledge could become an obstacle. This disadvantage could be solved through proper training and the use of more AR-oriented methods [36].

2. The technological factor. As Marrahi-Gomez & Belda-Medina [36] stated there is a technological gap between different generations in the classroom. Teachers usually report technical difficulties when trying to implement AR in the classroom due to a lack of technical knowledge and lack of support.

3. The control factor. Wu et al. [44-45] stated that it may be caused by a lack of experience and ignorance of instructions among students, which would hinder their learning. It is also claimed that, despite recognizing the advantages of RA, many teachers tend to prefer to have full control of their student's education. AR technology may facilitate collective learning as opposed to more traditional methodologies. In addition, some students may experience certain difficulties recognizing the information and navigating between the virtual and real world. And finally, this control could pose a problem when working with children, who lack the technical skills to succeed in a self-learning environment. This could lead to a loss of attention among some students

4. The content factor. Wu et al. [44-45] also indicated that there are certain disadvantages in terms of the content taught and, more specifically, in its flexibility. Teachers cannot accommodate the knowledge to be imparted to all students, as it is widely used and therefore certain pupils may have a sense of exclusion which is sought to avoid in schools. Similarly, implementing AR in the classroom can become a complication for teachers and school leaders. The lack of knowledge and the need to cover a large amount of knowledge in an academic year can generate certain problems by requiring the RA to a more thorough preparation than in the traditional methodology, where the materials are already prepared and the school curriculum specifies the contents to be examined and the time is given to the teaching staff to teach them.

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5. The (lack of) Skills factor. This refers to the low training of the instructors to deal with some technical issues that may arise when using AR in the classroom. Wu et al. [44-45] and Herpich et al. [24] indicated that teachers should believe that the implementation of AR can be beneficial in the educational process and understand what strategies need to be followed.

6. The distraction factor. The use of AR in the classroom generates a lot of information for the students to assimilate; this fact requires constant multitasking which may fail. It can also be caused by the lack of technological knowledge among students or poor collaboration. Due to the lack of student concentration, the learners may decide to use this technology for other recreational or communicative activities aside from the educational objectives.

CONCLUSIONS

The present study is based on a review of the integration of AR technology at different educational levels, and its affordances and limitations. Several works about the use of AR in preschool, primary, secondary and higher education have been analyzed (Yuen [50], Yang [46]). Recent research in AR-based projects in education has proven that this breakthrough technology can be effectively implemented for different reasons: contextual learning, better representation of abstract concepts, enhanced interaction, and increased motivation among learners. Therefore, AR can be implemented in different disciplines using various tools, particularly mobile AR (Wu [44-45], Chiang et al. [17]).

Finally, some advantages and disadvantages have been examined such as improved performance and increased motivation but there are also some challenges, for example, the lack of digital skills and technological support (Marrahi-Gomez et al. [36], Belda-Medina [6, 8]). However, researchers have also highlighted some limitations, such as the adaptation of new technological devices into the educational system or the distraction factors among others (Wu et al. [44-45]). There is a need for better training in AR among students and the adoption of modern methodologies that may facilitate the effective use of such breakthrough technology in the classroom.

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