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REVIEW ARTICLE

The advantages of using augmented reality as a pedagogical teaching resource

Las ventajas del uso de la realidad aumentada como recurso docente pedagógico

As vantagens de utilizar a realidade aumentada como um recurso pedagógico de ensino

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KEYWORDS

education, students, innovation, augmented reality, systematic review.

ABSTRACT. Augmented reality (AR) has been described as an interactive platform that presents a combination of virtual and real-world elements. Educators must incorporate ICT in the classroom and understand that its primary advantage is to enhance and facilitate the teaching-learning process of the learner. The aim of this paper is to identify, through a systematic review, the advantages of AR as a pedagogical teaching tool. To this end, a search for articles was carried out in different databases, such as Web of Science and Scopus. A total of 529 studies were obtained and, after applying the established inclusion criteria, 38 papers were left for review. The results showed that when AR-based activities are integrated, students of any educational level suggest a higher motivation and academic performance, considering this innovative resource as a more fun and interactive way of learning. In conclusion, it would be interesting to implement AR as a standard approach to learning, given its innovative character and the multiple benefits derived from its interactive nature, immediacy and student motivation.

PALABRAS CLAVE

educación, estudiantes, innovación, realidad

RESUMEN. La realidad aumentada (RA) ha sido descrita como una plataforma interactiva que presenta una combinación de elementos virtuales y del mundo real. Los educadores deben incorporar las tecnologías de la información y comunicación (TIC) en el aula y entender que su primera ventaja es mejorar y facilitar el proceso de enseñanza-aprendizaje del alumnado. El objetivo del presente trabajo consiste en identificar mediante una revisión sistemática las ventajas que ejerce la RA como herramienta docente pedagógica. Para ello, se realizó una búsqueda de artículos en

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aumentada, revisión sistemática.

distintas bases de datos, tales como Web of Science y Scopus. Se obtuvieron un total de 529 documentos que, tras aplicar los criterios de inclusión establecidos, quedaron 38 trabajos para su revisión. Los resultados mostraron que cuando se integran actividades basadas en el empleo de la RA los estudiantes de cualquier nivel educativo sugieren presentar mayor motivación y rendimiento académico, al considerar este innovador recurso como una forma más divertida e interactiva para aprender. En conclusión, sería interesante implementar la RA como un enfoque estándar de aprendizaje, dado que posee un carácter innovador y múltiples beneficios derivados de su naturaleza interactiva, inmediatez y motivación por parte del alumnado.

PALAVRAS-CHAVE

educação, alunos, inovação, realidade aumentada, revisão sistemática.

RESUMO. A realidade aumentada (RA) foi descrita como uma plataforma interativa que apresenta uma combinação de elementos do mundo virtual e real. Os educadores devem incorporar as TIC na sala de aula e entender que sua primeira vantagem é melhorar e facilitar o processo de ensino-aprendizagem do aluno. O objetivo deste trabalho é identificar, através de uma revisão sistemática, as vantagens do RA como ferramenta pedagógica de ensino. Para este fim, foi realizada uma pesquisa de artigos em diferentes bancos de dados, tais como Web of Science e Scopus. Foram obtidos um total de 529 documentos e, após a aplicação dos critérios de inclusão estabelecidos, restaram 38 artigos para revisão. Os resultados mostraram que quando atividades baseadas no uso de AR são integradas, estudantes de qualquer nível educacional sugerem maior motivação e desempenho acadêmico, considerando este recurso inovador como uma forma mais divertida e interativa de aprender. Em conclusão, seria interessante implementar o RA como uma abordagem padrão de aprendizagem, dado seu caráter inovador e seus múltiplos benefícios derivados de sua natureza interativa, imediatismo e motivação estudantil.

1. INTRODUCTION

Throughout history, human beings have been able to evolve and adapt to different situations thanks to their ways of communicating (Cabero-Almenara & Barroso-Osuna, 2019). Currently, in the 21st century society, education requires a coherent training that allows a response to the presence of information and communication technologies (ICT) through active and dynamic approaches (Day et al., 2021), which promote the well-being of students (Requejo et al., 2022). This requires a methodological change that allows the adaptation of material resources to the required competencies (Sáez-López et al., 2020). In this sense, augmented reality (AR) is becoming increasingly popular in the educational context, as it allows students to interact with each other and with the digital environment. This has been possible thanks to different devices such as cell phones, Tablet, etc. (Bolek et al., 2021) that allow the creation of new environments and promote interactive learning (Bogomolova et al., 2020).

AR has been described as an interactive platform that presents a combination of virtual and real-world elements (Sahin & Yilmaz, 2020). Other authors, such as López-García et al. (2019) define it as an emerging technology that enhances the field of view to perform a task, through computational processes that can transform and plot simple graphics in real time. Thus, it differs from virtual reality (VR), because while AR superimposes effects generated through real-time technology, VR immerses the user in a virtual environment simulation (Bork et al., 2019). Thus, AR consists of a combination of the real and virtual world, being considered an innovative technique generating an intermediate reality between the virtual and physical world, by converting everyday elements to 3D digital objects (Lopez et al., 2019). Specifically, it is an interactive system that meets the following criteria: (a) integration of the real and virtual world; (b) user experience in three dimensions; (c) interaction with virtual objects in real time (Phon et al., 2019).

The importance of AR gained momentum worldwide after the presentation of the game "Pokemon Go", presented in a mobile App. This fact allowed highlighting the importance of AR on students' education, regardless of the

educational stage and subject studied (Toledo-Morales & Sánchez-García, 2018). Among the reasons for incorporating this technology in education are several, including cost reduction and the need to work with other teaching methodologies founded on more active and dynamic practices (Del Rio-Guerra et al., 2019). As well as, the ease of access to information, since it is usually accessed thanks to mobile devices, which are very present in the students that integrate today's educational system. However, as for its limitations, the fact that there are more technological developments than educational ones, the lack of theoretical basis for its incorporation and the need for a greater amount of research work are present (Cabero-Almenara et al., 2019). Consequently, the integration of ICTs in the framework of an education in equality and equity requires competent teachers, both from a technological and pedagogical point of view (Fernández-Batanero et al., 2022).

Educators should incorporate ICT in the classroom and understand that their first advantage is to improve and facilitate the teaching-learning process of learners (Marín & Sampedro-Requena, 2019). Thus, from the earliest stages, previous literature reveals that students obtain positive results in communication skills, attention, collaboration and participation, as well as greater enjoyment in activities (Redondo et al., 2020). Therefore, from an educational perspective, it has been considered that AR-based applications could be the beginning of a didactic interaction with different environments to enable educational activities aimed at motivating students (Sáez-López et al., 2019; Soriano-Sánchez & Jiménez-Vázquez, 2022a). On the other hand, different curricular areas such as, for example, science, has considered that the use of an AR-based system can help students to visualize unobservable scientific concepts or summarize such concepts through virtual objects embedded in environmental or physical elements (Baran et al., 2020). Therefore, nowadays, creative thinking has to be promoted with the help of new techniques (Rehman et al., 2022), so that innovation and divergent thinking are encouraged, through optimal pleasant spaces for the promotion of meaningful and comprehensive learning (Shirazi et al., 2020).

Consequently, the teacher must know how to transmit that knowledge that favors the improvement in the coexistence of citizenship (Martí-Belda et al., 2019). In this direction, students show a proactive attitude through the use of innovative methods to acquire media competencies, through a more reflective behavior and in the teaching and learning process, enhancing cognitive processes that favor innovation in learning and, with it, the development of skills for the transferability of new knowledge (Soriano-Sánchez & Jiménez-Vázquez, 2023). Thus, it is necessary to know how to connect with the knowledge to be transmitted, so as to enhance the co-construction and transferability of knowledge, through participation to adjust a quality educational response (Gros & Cano, 2021).

For his part, Karagozlu (2018) has stated that the efficiency of classes depends largely on the methods, techniques and materials used. Thus, the goal set by teachers should be to develop skills and the acquisition of new concepts from practical experience (Tarng et al., 2018). In any case, the use of AR in education is of great importance because, by presenting information features for learning such as videos, audios and various three-dimensional content, it stimulates students more to learn new ideas as opposed to traditional learning based on reading a textbook (Wang, 2017). Likewise, the use of AR could strengthen the understanding of complex concepts, while supporting contextualization (Flores-Bascuñana et al., 2020). Likewise, a search has been conducted through ICT to respond to current educational needs, through an element that would be motivating for students and effective for teachers (Ayala et al., 2017; McBain et al., 2022). Thus, it has been observed how the realization of activities through the use of AR allows the development of adaptive capacity in front of any space, being a tool for approaching the imaginable and the unknown (Amaya & Santoyo, 2017). Therefore, it can be a promising resource to address difficulties in the stimulation of activities based on practical cases in

Primary Education (Tsai, 2018), in Secondary Education (Cai et al., 2017) and/or in Higher Education (Llena et al., 2018).

Therefore, the aim of this paper is to identify, through a systematic review, the advantages of using AR as a pedagogical teaching tool for learners at different educational stages.

2. METHOD

This study is based on a systematic literature review. For its preparation, the steps proposed by the PRISMA statement (Moher et al., 2015) were followed. Likewise, following Petticrew and Roberts (2006), the following guidelines have been integrated: a) evidence the relevant studies on the stated objective; b) select, evaluate and include/exclude relevant research; c) locate and store the selected elements; d) group the information obtained; e) use a narrative method to synthesize the information.

In this sense, a search for research has been carried out in different scientific databases. In particular, in the electronic resources: Web of Science and Scopus. For this purpose, the following search formula was used: ((((augmented reality) AND (education) AND (teaching))). The search filters used in both databases were: "papers published in the last five years" and "article".

After filtering the documents, we proceeded to transfer the titles presented in the different electronic resources to an Excel sheet, where the information obtained was ordered in order to exclude those studies that were duplicated. Finally, we proceeded to read each of the titles, as well as the abstracts of the papers. However, if there were any doubts, we proceeded to read the entire document. The search was carried out during the month of May 2020. To facilitate the incorporation of references and bibliography and, to avoid a possible error in them, the computer tool Mendeley (Elsevier, 2019) was used.

Taking into account the objective of the present systematic review, the following criteria were established:

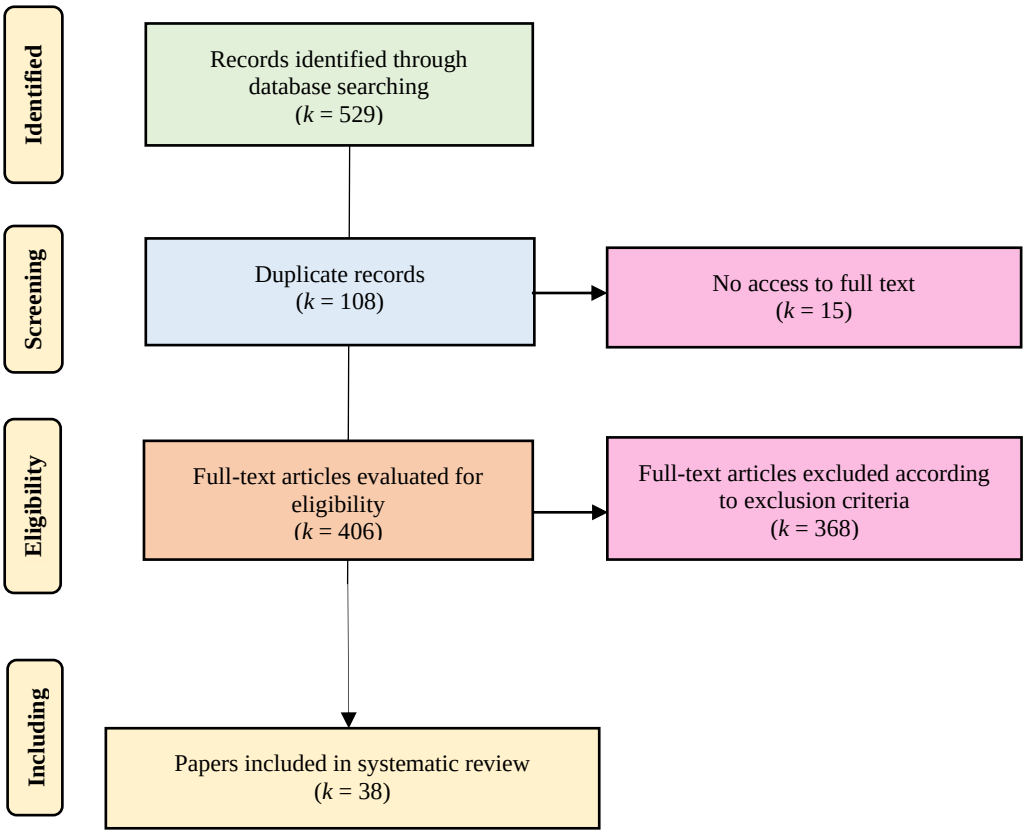
On the one hand, the inclusion criteria were: (a) studies published in English or Spanish; (b) empirical studies; (c) studies that used an instrument to evaluate the effectiveness of AR; (d) studies whose sample consisted of students at any educational stage.

The exclusion criteria were: (a) theoretical research; (b) research on other issues related to AR or teaching (studie environment, patients, etc.); (c) qualitative studies; (d) instrumental studies; (e) research using mixed methods (e.g., AR and VR); (f) case studies; (g) studies in languages other than English or Spanish; and (h) manuscript studies.

Singularly, the results obtained in each of the databases were 268 papers in Web of Science and 261 in Scopus, totaling 529 documents which, after eliminating duplicate research and establishing exclusion criteria, finally left 38 papers for review (Figure 1).

Figure 1

Flowchart with the steps for study selection



3. RESULTS

Of the *K* = 38 investigations comprising the present review, only 6 papers were published in Spanish (Amaya & Santoyo, 2017; Cabero-Almenara et al., 2017; Del Cerro and Morales, 2017; Marín & Sampedro, 2020; Marín-Díaz et al., 2018; Sáez-López et al., 2019), while the rest, were published in English (*k* = 32).

In relation to the place where they were carried out, Spain contributed the most studies (*k* = 17) compared to Taiwan, which in this case had six, followed by Turkey, where four studies were carried out, Cyprus and Malaysia, with two studies, respectively. Finally, in Nigeria, Colombia, China, the Netherlands, Germany, Serbia and India, which, in this case, carried out one study each.

Most of the investigations opted to use a quasi-experimental study design. In this regard, in relation to the number of participants, it was the research carried out by Marín-Díaz et al. (2018) that presented the largest number of subjects. Specifically, the study was composed of three groups: group 1 (learning based on video viewing), group 2 (new learning from AR) and group 3 (traditional learning).

The number of participants in each of the groups was G1 (*N* = 303), G2 (*N* = 148) and G3 (*N* = 155). On the other hand, it has been the study contributed by Wang (2017) that integrated a smaller number of participants. In this case, both the experimental group and the control group had *N* = 15.

However, the results found covered different educational stages: Early Childhood Education (Table 1), Primary Education (Table 2), Secondary Education (Table 3) and Higher Education (Table 4). Although, in all of them AR

was integrated as a learning methodology to see its effects on students, each of the investigations had a different aim.

Table 1

Studies integrating augmented reality in Early Childhood Education

Author/Year	Aim	Place	*N*	Study design
Redondo et al. (2020)	To evaluate the use of AR in early childhood education to see if it improves English language learning, increases students' motivation and helps them to establish more positive social and emotional relationships	Spain	*N* = 52 EG *N* = 50 CG	Quasiexperimental

Note. EG = Experimental Group; CG = Control Group.

Table 2

Studies incorporating augmented reality in Primary Education

Author/Year	Aim	Place	*N*	Study design
Cabero y Baroso (2019)	To determine the degree of motivation that the students of the Pedagogy Degree of the University of Seville interaction with Augmented Reality enriched notes available through mobile devices	Spain	*N* = 527	Quasi-experimental consisting of one single group
Chen et al. (2016)	Integrate concept maps through AR and test students' motivation and attitude	Taiwan	*N* = 36 EG *N* = 35 CG	Quasi-experimental, composed of two groups (EG and GC)

Note. EG = Experimental Group; CG = Control Group.

Table 2

Studies incorporating augmented reality in Primary Education (continued)

Author/Year	Aim	Place	*N*	Study design
Flores-Bascuñana et al. (2020)	Exploring the benefits related to 3D geometry	Spain	*N* = 15 EG *N* = 15 CG	Quasi-experimental, consisting of two groups (EG and GC), of a single test
Joo-Nagata et al. (2017)	Evaluate the effectiveness when applying AR in mobile learning	Spain	*N* = 72 EG *N* = 71 CG	Quasi-experimental, consisting of two groups (EG and CG)
Karagozlu (2018)	To determine the impact of the application on students' achievement and problem-solving skills in science classes through the use of AR	Cyprus	*N* = 77 EG *N* = 70 CG	Quasi-experimental, consisting of two groups (EG and CG)
Phon et al. (2019)	To investigate the possible effect of AR technology on students' spatial visualization ability to facilitate learning of science concepts	Malaysia	*N* = 34	Quantitative, single-group, pre-post design
Sáez-López et al. (2019)	Analyze the impact of educational integration of AR gaming approaches on learning	Spain	*N* = 69 EG *N* = 22 CG	Quasi-experimental, consisting of two groups (EG and CG)
Tarng et al. (2016)	Test the usefulness of the new moon phase observation system that incorporates AR technology and the sensor functions of GPS, electronic compass and 3-axis accelerometer in mobile devices to help students easily observe and record the moon phases	Taiwan	*N* = 27 EG *N* = 29 CG	Quasi-experimental, consisting of two groups (EG and CG)
Tarng et al. (2018)	Develop experimentation skills and conceptual knowledge through practical experiences using AR	Taiwan	*N* = 28 EG *N* = 28 CG	Quasi-experimental, consisting of two groups (EG and CG)

Note. EG = Experimental Group; CG = Control Group.

Table 2

Studies incorporating augmented reality in Primary Education (continued)

Author/Year	Aim	Place	*N*	Study design
Toledo-Morales y Sánchez-García (2018)	To investigate the effects of AR use on students' academic performance and perceptions towards its use	Spain	*N = 25 EG* *N = 24 CG*	Quasi-experimental, consisting of two groups (EG and CG)
Tsai (2018)	Compare traditional flashcard-based versus AR-based English vocabulary learning to see which method is more efficient	Taiwan	*N* = 33 EG *N* = 33 CG	Quasi-experimental, consisting of two groups (EG and CG)

Note. EG = Experimental Group; CG = Control Group.

Table 3

Studies that integrate augmented reality in Secondary Education

Author/Year	Aim	Place	*N*	Study design
Adedokun-Shittu et al. (2020)	To investigate the impact of an AR-based tool in the Physical Geography classroom	Nigeria	*N* = 25	Transversal
Amaya & Santoyo (2017)	Develop a methodology for using the AR technique to create musical didactic material that allows the promotion of autonomy in learning	Colombia	*N* = 28 EG *N* = 28 CG	Cusi-experimental, composed of two groups (EG and CG)
TBaran et al. (2020)	Develop and evaluate an AR application to teach students about electric currents	Turkey	*N* = 30 EG1 *N* = 30 EG2	Quasi-experimental, with two experimental groups (EG1 = individual learning and EG2 = group learning)
Cai et al. (2017)	Explore the effects of AR use and interaction on physics learning vs. traditional learning tools	China	*N* = 19 EG *N* = 19 CG	Cusi-experimental, composed of two groups (EG and CG)
Del Cerro y Morales (2017)	To analyze and compare the benefits on the spatial ability of underachieving students in the subject of Technology through the use of AR didactic material versus the contributions of two-dimensional didactic materials	Spain	*N* = 23	Cusi-experimental, consisting of a single group (EG)

Table 3

Studies that integrate augmented reality in Secondary Education (continued)

Author/Year	Aim	Place	*N*	Study design
Fidan & Tuncel (2019)	To investigate the effects of AR-based learning on achievement and attitude towards physics subjects	Turkey	*N* = 30 GE1 *N* = 31 GE2 *N* = 30 GC	Quasi-experimental, with two experimental groups and a control group
Huang et al. (2016)	To explore the impact of different learning tools and different experimental approaches on emotional affect and effectiveness in an ecological environment	Taiwan	*N* = 7 GE1 *N* = 7 GE2 *N* = 7 GC	Quasi-experimental, consisting of 3 groups (EG 1 = AR-based learning, EG 2 = AR-based learning plus commentators, and CG = traditional learning). GG = traditional learning)
López et al. (2019)	To determine the influence on students of Compulsory Secondary Education in the application of an innovative experience based on the use of AR as a dynamic tool for sessions in which the teacher of a subject is absent and has to be replaced by another teacher	Spain	*N* = 210	Non-experimental, correlational
López-García et al. (2019)	To analyze the perception of students in relation to the use of AR in the school environment	Spain	*N* = 106	Quantitative, non-experimental
Sahin et al. (2020)	Investigate the impact of learning materials developed with AR technology on performance and determine their attitudes towards AR applications	Turkey	*N* = 49 GE *N* = 48 GC	Cusi-experimental, composed of two groups (EG and CG)
Wang (2017)	Investigate whether the use of AR-based learning materials could benefit the writing process	Taiwan	*N* = 15 GE *N* = 15 GC	Cusi-experimental, composed of two groups (EG and CG)

Note. EG = Experimental Group; CG = Control Group.

Table 4

Studies incorporating augmented reality in higher education

Author/Year	Aim	Place	*N*	Study design
Ayala et al. (2017)	Investigate emerging trends in ICT to find a way to present and manipulate information in the classroom in a way that serves as a stimulating element and a tool to perform complex operations	Spain	*N* = 35 EG *N* = 28 CG	Prospective study, consisting of two groups, with a single test (EG and CG)
Bogomolova et al. (2020)	To evaluate the effectiveness of AR-based visualization and the modifying effect of visual-spatial skills on learning in medical and biomedical science students	Netherlands	*N* = 20 G1 *N* = 20 G2 *N*= 18 G3	Quasi-experimental, consisting of three groups (G1 = AR learning model, G2 = 3D learning model and G3 = 2D learning model)
Bork et al. (2019)	To investigate the benefits of AR on teaching integrated radiology in gross anatomy in future physicians	Germany	*N* = 24 (in each group)	Quasi-experimental, composed of three groups (G1 = magic mirror, G2 = anatomy and G3 = theory)
Cabero-Almenera et al. (2017)	To know the evaluations of the students of the Early Childhood Education and Primary Education Degree who had used the AR	Spain	*N* = 145 G1 *N* = 284 G2	Ex post facto, with two groups (G1 = video-based learning and G2 = new model with AR)
Cabero-Almenera et al. (2019)	To determine the degree of motivation that student teachers have about the use of AR through mobile devices	Spain	*N* = 303 EG1 *N* = 308 EG2	Preexperimental, composed of two groups (EG1 = use of ICT and EG2 = educational use of Web 2.0)

Note. EG = Experimental Group; CG = Control Group.

Table 4

Studies incorporating augmented reality in higher education (continued)

Author/Year	Aim	Place	*N*	Study design
Cabero-Almenera et al. (2019)	To understand the degree of technological acceptance of Pedagogy Degree students during their interaction with AR objects, performance achieved and to test whether gender affects their knowledge acquisition	Spain	*N* = 396	Experimental, with a single test
Fauzi et al. (2019)	To determine if the use of AR is effective in undergraduates enrolled in construction technology.	Malasia	*N* = 41	Quasi-experimental, composed of 3 groups (EG1 = magic mirror, EG2 = anatomy and EG- = theory)
Küçük et al. (2016)	To determine the effects of learning anatomy through AR on the academic performance and cognitive load of medical students.	Turquía	*N* = 34 GE *N* = 36 GC	Quasi-experimental, composed of two groups (EG and CG)
Llena et al. (2018)	To evaluate the effectiveness of AR in gaining knowledge and skill advantage in dental students in designing caries preparations and to analyze their degree of satisfaction	Spain	*N* = 20 GE *N* = 21 GC	Formed by two groups (EG and CG)
Marín & Sampedro-Requena (2020)	To evaluate the possibilities and potentials offered by different software used for the creation of technological environments under the AR architecture to be used in university training contexts	Spain	*N* = 520	Ex post facto, from a single group
Marín-Díaz et al. (2018)	To determine whether AR-based technology is a resource that motivates students to learn the subject Educational Technology in the Pedagogy Degree	Spain	*N* = 303 G1 *N* = 148 G2 *N* = 155 G3	Quasi-experimental, with 3 groups (G1 = video learning, G2 = new learning model with AR and G3 = traditional learning)

Note. EG = Experimental Group; CG = Control Group.

Table 4

Studies incorporating augmented reality in higher education (continued)

Author/Year	Aim	Place	*N*	Study design
Mladenovic et al. (2019)	To evaluate the effectiveness of a mobile-based AR simulator for local anesthesia training in dental students administering inferior alveolar nerve blocks for the first time	Serbia	*N* = 22 EG *N* = 19 CG	Prospective study, consisting of two groups (EG and CG).
Ozdamli & Hursen (2017)	Determine the benefits and limitations of Apps employing AR in education when used as a technological adjunct and examine their impact on reflective thinking skills	Cyprus	*N* = 30 EG *N* = 32 CG	Quasi-experimental, composed of two groups (GE and GC)
Sáez-López et al. (2020)	To evaluate the impact, evolution in practices and attitudes generated by the use of AR in the initial training of future teachers	Spain	*N = 87*	Quasiexperimental, consisting of a single group
Singh et al. (2019)	To determine the impact of AR-based intervention on engineering students' laboratory skills, cognitive load and learning motivation	India	*N = 30 EG* *N = 30* CG	Cusi-experimental, made up of 2 groups

Note. EG = Experimental Group; CG = Control Group.

On the other hand, as can be seen in Figure 2 below, it was in Higher Education where most research on the subject was carried out. In particular, 15 studies were carried out in Secondary Education and 11 in Primary Education, respectively. However, only 1 study was carried out in Early Childhood Education.

The results found allowed us to identify how this topic is of great current interest. Thus, as can be seen in Figure 3, the crescent of the line is in the year 2019, where 12 investigations were carried out. Thus, in the time that has elapsed in the current year, 8 studies have already been carried out.

Figure 2

Amount of research in relation to the educational level

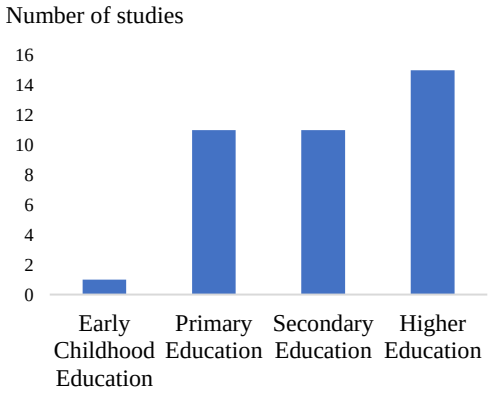
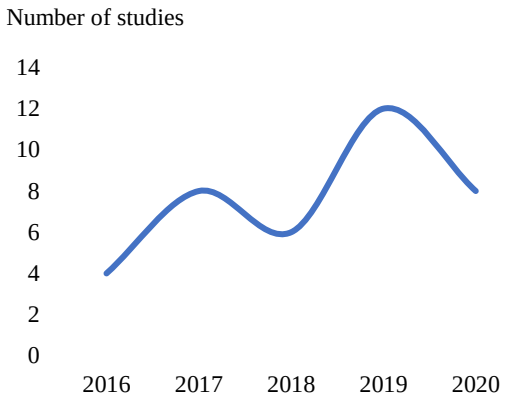


Figure 3

Number of studies in relation to year of publication



The following is a synthesis of the evidence found on the advantages of AR for students at different educational stages:

Advantages of augmented reality in Early Childhood Education

In Early Childhood Education, AR-based activities helped students to enjoy the tasks more, as they were highly motivated. This stage is characterized by the development of social competencies, where AR allowed the establishment of more affective relationships (Redondo et al., 2020).

Advantages of augmented reality in Primary Education

In Primary education, Cabero and Baroso (2019) showed how the use of AR benefited the teaching process, as students reported higher performance and knowledge acquisition (Toledo-Morales and Sanchez-Garcia, 2018; Karagozlu, 2018). Well, activities through AR suggest to be more beneficial than classical didactic methods (Flores-Bascuñana et al., 2020; Joo-Nagata et al., 2017; Tsai et al., 2018).

In fact, Chen et al. (2016) demonstrated that those students who used AR presented higher motivation and attitude towards their learning. Also, conducting classroom activities using AR improved spatial understanding and visualization ability in science subject (Phon et al., 2019; Tarng et al., 2016, 2018). In short, as revealed by other authors, the use of AR in primary education suggests benefits in the learning process of students, specifically in their motivation and cooperation (Sáez-López et al., 2019).

Advantages of augmented reality in Secondary Education

In Secondary Education, the use of AR also improved students' attention and performance by enhancing the learning of the content taught (Adedokun-Shittu et al., 2020; Del Cerro and Morales, 2017). For example, it appeared to be beneficial in increasing writing performance (Wang, 2017), musical academic performance (Amaya & Santoyo, 2017), electronic task completion (Baran et al., 2020), among others (Cai et al., 2017; Sahin et al., 2020). In addition, other research indicated that students achieved positive values on their motivation and participation, achievement of objectives and acquisition of digital competences, also favoring the classroom climate (López et al., 2019; López-García et al., 2019).

Therefore, activities using AR technology could be a potential tool to activate positive emotions in students who have difficulty acquiring new knowledge (Fidan & Tuncel, 2019). For, it seems that it successfully stimulates positive emotions and improves the results of the teaching-learning process (Huang et al., 2016).

Advantages of augmented reality in Higher Education

As in the rest of the courses, in Higher Education, students who participated in activities that integrated the use of AR showed an increase in motivation, presenting a higher attendance to practical classes, as well as a higher rate of delivery of practical work (Ayala et al., 2017; Marín-Díaz et al., 2018). Furthermore, in terms of gender, the use of AR did not seem to influence learning, with both boys and girls showing higher perceived enjoyment (Cabero-Almenara et al., 2019).

ICTs incorporating AR improve student learning by evidencing better results in the subject (Bork et al., 2019; Bogomolova et al., 2020; Fauzi et al., 2019; Mladenovic et al., 2019). In fact, the positive assessments indicated by the university students allowed indicating that these resources may be valid for incorporation in Higher Education (Cabero-Almenara et al., 2017, 2019; Llena et al., 2018).

Likewise, the AR-based approach helped students to improve their cognitive effort by favoring their structures on new knowledge to complete tasks (Küçük et al., 2016). Also, the use of AR provided benefits and advantages focused on pedagogies, which favored enthusiasm for task completion, by presenting relevant advantages on creativity, innovation and, especially, participation of undergraduates (Sáez-López et al., 2020). For their part, Ozdamli and Hursen (2017), revealed that the use of Apps incorporating AR helped to develop reflective thinking.

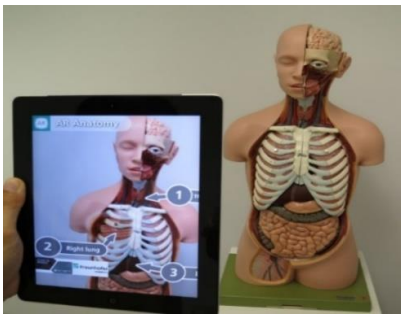
Finally, other studies, such as that of Singh et al. (2019), note that it appears that the use of AR exerted a significant impact on the development of skills related to practical activities, which reduced the cognitive load of students while performing the tasks (Figures 4 and 5).

Figure 4

Augmented reality-based learning via cell phones

Figure 5

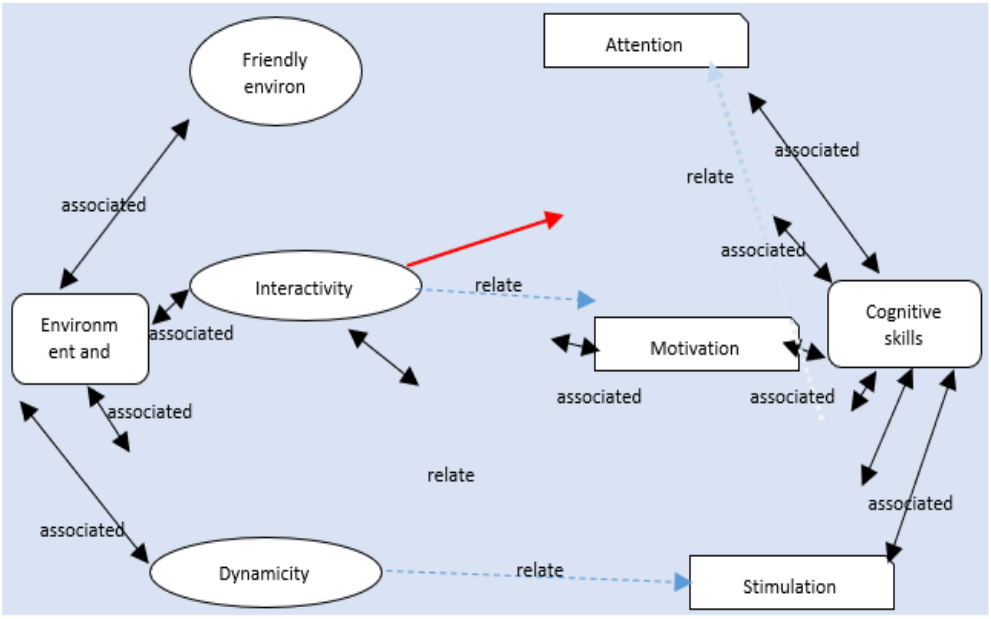
Tablet-based augmented reality learning



The use of AR suggests establishing a friendly and dynamic environment, based on interactivity. In addition, it seems to favor the development of different cognitive skills important in the teaching-learning process. In particular, on attention, positive attitude, motivation, reflection and stimulation (Figure 6).

Figure 6

Hypothetical model of the advantages of augmented reality in education on the development of cognitive skills



4. DISCUSSION

The results found in the different studies have allowed us to achieve the established objective, which was to identify through a systematic review the advantages of using AR as a pedagogical teaching tool for learners at different educational stages. Thus, the potential of using AR in educational contexts highlights that the central themes are learned through the effective design of learning activities (Flores-Bascuñana et al., 2020). Other studies, such as the one conducted by Sáez-López et al. (2020) also expose that AR possesses an advantage on student collaboration and motivation, as do the results found in other lines of research (López-García et al., 2019). Likewise, several investigations have shown the relationship between student performance, positive attitudes towards the course and the use of AR-based applications (Cabero-Almenara et al., 2019; Marín & Sampedro-Requena, 2019).

Therefore, the use of AR in academia suggests offering extraordinary experiences to students, by facilitating a friendlier environment and increasing attention (Adedokun-Shittu et al., 2020). Thus, students' attitude towards AR-based applications has been mostly evaluated in longitudinal design studies, where students indicated to be very happy by the use of this innovative learning methodology (McBain et al., 2022), which starts from the students' prior knowledge to favor the personalization of teaching (Soriano-Sánchez & Jiménez-Vázquez, 2023), guaranteeing the students' well-being (Requejo et al., 2022) and increasing their academic performance (Soriano-Sánchez & Jiménez-Vázquez, 2022a).

For our part, we consider that its relevance in the educational field lies in the possibilities it offers to provide digital information in real time, enriching contents and making learning more interactive and participatory (Bolek et al., 2021). In fact, the interaction of virtual tools with AR in early childhood education seems to allow the creation of a different climate in which young children improve their socio-affective relationships based on values such as respect and tolerance (Redondo et al., 2020). In addition, in Primary Education it provides a greater attitude towards learning and improved understanding of different contents (Phon et al., 2019). The same happens in Secondary Education, since it has been observed in different studies how AR suggests favoring the achievement of curricular objectives by improving the results of the teaching-learning process (Fidan & Tuncel, 2019). Finally, with respect to Higher Education, the use of activities that incorporate AR, in addition to those indicated above, has also been revealed to suggest helping to develop reflective thinking and reduce the cognitive load possessed by the various practical tasks (Soriano-Sánchez & Jiménez-Vázquez, 2023b).

This study offers practical implications relevant to socio-educational and research levels. The results provide validity and reliability of responses that allow us to affirm that the use of AR in the educational context at any stage plays a relevant role in the teaching and learning of students. Thus, they could be used to develop new interventions in the educational context at all levels, in order to verify their cause-effect relationship and provide new theories, given that the central research topic is still an emerging issue that needs a solid information base. Finally, it would be interesting to reveal the importance of the teaching role in carrying out good practices on the use of ICTs to promote the comprehensive development of students (Soriano-Sánchez, 2022a).

However, this study is not free of limitations. First, the main limitation could be in the electronic resources used, so it is possible that papers published in other resources may have been unintentionally omitted, as well as those found in other lines of research (Soriano-Sánchez, 2022b; Soriano-Sánchez & Jiménez-Vázquez, 2022b; Soriano-Sánchez & Jiménez-Vázquez, 2022b; Soriano-Sánchez & Jiménez-Vázquez, 2022c; Soriano-Sánchez & Jiménez-Vázquez, 2022d; Soriano-Sánchez & Jiménez-Vázquez, 2023a).

On the other hand, the second limitation lies in the lack of quantitative results from different studies or in the variety in their presentation. This fact has not allowed us to perform a meta-analysis to verify the efficacy of AR intervention programs as a pedagogical teaching tool (Soriano-Sánchez & Jiménez-Vázquez, 2022e; Soriano-Sánchez & Sastre-Riba, 2022).

For future lines of research, it would be interesting for new studies to apply AR to students with special educational needs. This would make it possible to provide new results based on inclusion and to show what would be the specific advantages for these students or their possible disadvantages.

This systematic review shows that the use of AR in teaching is considered to be a satisfactory and pleasant tool that complements traditional teaching materials to achieve better results. In fact, it is perceived by students as an attractive, useful and interesting resource.

5. CONCLUSIONS

The teacher must take into account that when using activities where AR is present, a better school environment is created, in addition to favoring the achievement of the established curricular objectives, since a more active and dynamic learning process is created.

In relation to learning, when activities based on the use of AR are integrated, students of any educational level suggest presenting greater motivation and performance, considering this innovative resource as a more fun and interactive way to learn. Consequently, the justification for using AR should be supported by the promotion of actions based on practical learning and theoretical models, to develop the various competencies required at different educational stages. Therefore, from the results obtained we argue that the use of AR at any educational level provides a more contextualized and organized way of learning, where AR from a theoretical model is considered a mediating element of knowledge.

In short, AR should be implemented as a standard approach to learning, given its innovative nature and multiple benefits derived from its interactive nature, immediacy, student motivation and ease of use. In turn, it suggests involving direct participation in the teaching-learning process, as well as helping to develop reflective and divergent thinking in students at any educational stage.

Conflicto de intereses / Competing interests:

The authors declare that the present project does not represent any real, potential or evident conflict of interest.

Rol de los autores / Authors Roles:

José-Gabriel Soriano-Sánchez: Conceptualization, data curation, formal analysis, research, methodology, resources, software, supervision, validation, visualization, project management, writing-preparing the original draft, writing-revising & editing.

David Jiménez-Vázquez: Conceptualization, formal analysis, research, methodology, project management, writing-preparation of original draft, writing-revise & edit.

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