Hacettepe Üniversitesi Eğitim Fakültesi Dergisi

Hacettepe University Journal of Education

e-ISSN: 2536-4758

Augmented Reality and Primary Education: Linkage, Potentiality and Applicability from the Perspective of Teachers in Initial Training

Olga MORENO-FERNÁNDEZ[*], Carmen SOLÍS-ESPALLARGAS[**], Pilar MORENO-CRESPO[***], Mario FERRERAS-LISTÁN[****]

Article Information

Received: 07.07.2021

Accepted: 25.06.2022

Online First: 04.05.2023

Published: 31.07.2023

ABSTRACT

Augmented reality is presented as a new technology that offers a different way of teaching in an effective and attractive way, allowing the enrichment of educational scenarios by providing complementary virtual information. This study aims to know the notions that teachers in training have about augmented reality in terms of its conception, its potential and its possible didactic application in primary education classrooms. For this purpose, a questionnaire has been developed from a previous study which, after being validated, has been passed on to a sample of 239 Primary Education students. The SPSS statistical package (v25) was used for the analysis of the data and among the results of the dimensions studied; it should be noted that Augmented Reality is perceived as a very useful educational resource. It also has great potential for primary school student learning, since it helps to promote the development of curricular content, being an attractive, fun, dynamic and versatile tool, among other characteristics. It is concluded that, although augmented reality is a technology that helps and facilitates the understanding of curricular content, it is necessary to train teachers to use it correctly, and the use of these tools continues to be a challenge for educators.

Keywords: Augmented reality, didactic resource, teacher training, primary education

doi: 10.16986/HUJE.2023.488

Article Type: Research Article

Citation Information: Moreno-Fernández, O., Solís-Espallargas, C., Moreno-Crespo, C., & Ferreras-Listán, M. (2023). Augmented reality and primary education: Linkage, potentiality and applicability from the perspective of teachers in initial training. *Hacettepe University Journal of Education, 38*(3), 388-398. doi: 10.16986/HUJE.2023.488

1. INTRODUCTION

To approach the characterization of augmented reality (hereinafter AR), it is first necessary to establish how it differs from virtual reality, since normally both terms tend to be used interchangeably. Thus, the main difference between one and the other lies in the fact that AR does not replace the real world with a simulated one, as occurs in virtual reality.

The AR, through the use of a digital instrument, allows a virtual interaction with the real environment by amplifying the information of that environment, so that both overlap to increase the sensory experience (Moreno and Leiva, 2017; Cabrero and Barroso, 2016; Cabero et al., 2020). The aim is to add visual, sound and virtual elements to the perceived reality, enriching the original environment with more information (Jeřábek, Rambousek, and Wildová, 2014). In this way, both realities are combined and allow us to interact, normally in real time, through any device (tablet, mobile or computer) (Red Guadalinfo, 2018).

According to Di Serio, Ibáñez and Delgado (2013, p. 587) "AR is characterized by three basic properties: the combination of real and virtual objects in a real space; an alignment of virtual and real objects with each other; and the execution of the object interactively and in real time". In addition, AR is driving important innovations by allowing the addition of stored data, 2D/3D images, videos, or access to Internet sources making any particular space interactive (Fombona, Pascual-Sevillana and González-Videgaray, 2017).

[*] Dr., University of Seville, Faculty of Education Sciences, Department of Experimental and Social Science Didactics, SPAIN. e-mail: omoreno@us.es (ORCID: 0000-0003-4349-8657)

[**] Dr., University of Seville, Faculty of Education Sciences, Department of Experimental and Social Science Didactics, SPAIN. e-mail: carmensolise@us.es (ORCID: 0000-0002-6934-0607)

[***] Dr., University of Seville, Faculty of Education Sciences, Department of Research Methods and Diagnosis in Education, SPAIN. e-mail: pmcrespo@us.es (ORCID: 0000-0002-6226-0268)

[****] Dr., University of Seville, Faculty of Education Sciences, Department of Experimental and Social Science Didactics, SPAIN. e-mail: mferreras@us.es (ORCID: 0000-0001-9430-8310)

The Guadalinfo Network (2018) highlights a series of advantages that the AR has and its use in the classroom, such as establishing contact naturally between students and new technologies (ICT). It also improves interactivity and participation in the classroom as it establishes a synergy between learning and recreational entertainment. As it is an accessible material, it allows knowing complementary information to the one that usually appears in the text books, helping to wake up the curiosity and betting for a practical knowledge. It is a key tool to increase students' motivation through the approach of knowledge through entertainment, in which they can check and add up learning achievements (Bacca, Baldiris, Fabregat & Kinshuk, 2019).

On the other hand, it should be noted that studies focused on researching the educational potential of AR and how it influences learning are on the rise (Radu, 2014; Kurilovas, 2016; Akçayır and Akçayır, 2017; Gavilanes, Abásolo Guerrero and Cuji, 2018), but we find fewer studies focused on analysing teachers' conceptions of it, who will ultimately be the ones to use this tool (Moreno and Leiva, 2017; Marín-Díaz and Sampedro-Requena, 2020).

Kysela and Štorková (2015), propose AR as a new technology that offers a different way of learning in an effective and attractive way, allowing the enrichment of real educational scenarios where student motivation is a special priority. The works of Lin, Chen and Liu (2017), highlight the variety of possibilities offered by the AR for the dynamization of learning experiences and the studies of Cabero, Barroso and Obrador (2017) point out its adaptive capacity to the current preferences of the students. In this line, several authors highlight the great variety of application catalogues that the AR has in its different formats (Kamphuis et al., 2014; Toledo and Sánchez, 2017; Montecé-Mosquera et al., 2017; Cabero et al., 2020). On the other hand, Garay, Tejada and Castaño (2017), highlight the adaptability of AR for any educational stage due to its ease of use and its interdisciplinary nature. Fombona, Pascual-Sevillana and González-Videgaray (2017), propose that this emerging phenomenon can go beyond the mere technological fact to affect the methodologies and habits of students, even changing learning procedures drastically with new training scenarios.

Other researches specify their field of investigation attending to the educational levels to analyse the viability of the implementation of the AR. Specifically in the field of Primary Education we highlight the studies of Cózar-Gutiérrez and Sáez-López (2016), Toledo and Sánchez (2017) and Piqueras, Cózar and González-Calero (2018), whose results show from improvements in the acquisition of knowledge and development of digital competence, to a positive perception by students and teachers for being motivating, encouraging and capable of promoting improvements in the teaching-learning processes.

The works developed by De la Horra-Villacé (2017), state that when adapting innovative tools to the educational environment it is important to bear in mind: the ease of creation of material for the teacher; the ease of use for the student; whether the interface is attractive and friendly, and finally the interdisciplinary nature offered by the tool itself.

For teachers it is important to have free resources that allow the implementation of AR in a teaching-learning environment. Among them we highlight "Layar" that has a web page where you can design the intervention or activity on the platform, which allows its use by installing the application on the mobile or tablet. In this way, the device's camera allows to focus the shutter (a photo, an image, a text, etc.), where the inserted information appears in AR format. This information can be text, images or links that allow us to access video, music, etc. Another resource at our disposal is HP Reveal (formerly known as Aurasma) that allows us to make the designs from a computer or mobile device, including additional information that appears when the camera is focused on the shutter.

On the other hand, we can count on applications that already incorporate created content, through templates that can be printed for their use and manipulation (cutting and/or colouring, for example) and their later recreation in AR. Among the most popular we highlight: Elements 4D that allows visualizing elements in four dimensions; Quiver, that allows visualizing elements in AR in movement and Chromville, that allows visualizing elements in AR by layers. That is, in Chromville if the template of the human body is coloured, using the device on that coloured template can actually see the body customized with the colours that have been used and can also change to the vision of the skeleton or muscles. In this way, the experience of studying the human body is improved, since starting from a drawing (the coloured template) the different layers of the human body can be alternated.

Finally, among other applications that originally have not been designed for educational purposes, but that can become tools that promote a teaching-learning environment, we highlight: Google earth, or Google Sky Map which has a star map of stars, galaxies and constellations; Anatomy 4D, self-defined as an encyclopedia of three-dimensional anatomy; Cyberchase 3D Builder, which is a game where you have to reconstruct the structure of a city from two to three dimensions; Quiver - 3D Coloring App, formed by templates with the only purpose of being coloured and through the augmented reality animate them; and ZooBurst, which allows to generate 3D books with text, images, music, etc.

Therefore, we consider that training Primary Education teachers in initial training for the use of AR as a teaching resource can complete their professional profile, facilitating the search for new more interactive teaching-learning scenarios. Specifically, in this paper we focus on analysing what these future teachers think about whether AR is an adequate resource that they would use in the development of their professional practice. To do so, we investigate what are the opinions they have about the

conception and characterization of AR, the educational possibilities and capacities it has and if it can really be applied in the classrooms.

This work has the following objectives:

– To determine the conceptions that students in the Primary Education Teachers' Degree have about what Augmented Reality is and what its characteristics are.
– To find out the opinion of pupils in the Primary Education Teachers' Degree on the educational possibilities and capacities of Augmented Reality.
– To establish, from the perspective of the Primary Education Teachers' Degree students, the applicability of Augmented Reality in the classroom.

2. METHODOLOGY

This is an exploratory, quantitative, ex post facto study. The data collection technique is the questionnaire that gives access to information of various kinds, this being an instrument that allows us to collect a large amount of information from a large group in a relatively short time (Ala-Mutka, 2011; Colás-Bravo, Conde-Jiménez and Reyes-de-Cózar, 2019) to obtain information on the opinions of the subjects regarding their digital uses and knowledge. This is why a questionnaire was chosen to provide answers to the objectives set. All participants were informed of the purpose of the research and gave their informed consent to participate in the research.

2.1. Participants

A total of 239 students of the Primary Education Teacher Degree of the University of Seville (Spain), aged between 19 and 21, participated in the study. These are students who have previously studied the subject of Information and Communication Technologies Applied to Education. The group was made up of 55 subjects who indicated the option of the male gender (23%) and 184 who indicated the option of the female gender (77%).

2.2. Instrument

The instrument used is the questionnaire called "Attitudes on the Potentialities and Applicability of Augmented Reality in the Primary Education Degree of the University of Seville" (APAEdu-AR), which has been designed taking as a reference the questionnaire of "Attitudes and competencies of didactic use of augmented reality in the Primary Education Degree of the University of Málaga" (Moreno and Leiva, 2017) and the "LabinTic_RA Questionnaire" (Cózar-Gutiérrez et al., 2015). For the study of content validity, the instrument was submitted to expert judgement, taking into consideration and incorporating their observations for the improvement of the instrument. Finally, the final version was created in digital format (Google Forms) and filled in by the sample by telematics means. The questionnaire includes three dimensions with different items for each one (table 1). The data were analysed with the IBM SPSS program (version 25).

Table 1.
Structure of the APAEdu-AR instrument

Dimensions	Items
Conceptualization and characterization of AR	Do you consider ICT training important for teachers? Do you know what the AR is? Could you define the AR with your words? Have you had any educational experience related to the use of AR? Which of the following characteristics would define AR tools as a learning resource?
Possibility and educational capabilities of AR	What educational potential do you think AR has? Do you think that the AR offers educational possibilities to favour the teaching-learning processes? Why do you think that the AR offers educational possibilities to favour the teaching-learning processes? Do you think that AR favours the creation of amplified, enhanced, reinforced and enriched learning scenarios?
Applicability in AR Primary Education Classrooms	At what point in a Didactic Unit would you apply the AR? What kind of activities can you think of where you can apply AR? Would you use AR in your classroom when you are in the teaching profession?

3. RESULTS

3.1. Conceptualization and characterization of AR

To contextualize the study, it opens with the question Do you consider ICT training important for teachers, where the answer is a clear yes from 100% of the sample. It is clear that teachers in initial training believe that ICT training in education is currently very important.

As regards whether they know what AR is, 79.5% (n= 190) answered positively, while 20.5% (n= 49) said they did not know (Table 2).

Table 2.
Approach to AR

Items	Frequency	Percentage	Cumulative percentage
I know what AR is.	190	79.5	79.5
I'm not sure what the AR is.	49	20.5	100.0
Don't know/No answer	0	00.0	100.0
Total	**239**	**100.0**	

If we go deeper into how they understand what AR is, the response spectrum opens up and in this case 25.5% (n=61) do not respond and 5.8% (n=14) indicate not being able to explain in their words what AR is. The 43.1% (n=103) AR is reduced to the use of glasses or paper through which to have a technological experience, while 21.0% (n=50) extends this vision emphasizing that it is an element of new technologies that allows visualizing figures in 3D through a technological device and helps us to visualize the world around us through digital devices. If we analyse this question more closely we see that in general there is a rather simplistic view of what AR is, only 4.6% (n=11) is able to give a more or less complete definition (Table 3).

Table 3.
Identification of the AR

Level	Indicator	Frequency	Percentage	Cumulative percentage
0-0	Don't know/No answer	61	25.5	25.5
0-1	He points out that he is unable to explain	14	5.8	31.3
1	Augmented reality is reduced to the use of glasses or paper through which to have a technological experience	103	43.1	74.4
2	Augmented reality is an element of the new technologies that allows the visualization of 3D figures through a technological device. It helps us to visualize the world around us through digital devices	50	21.0	95.4
3	Augmented reality is an element of the new technologies that allows us to have a different vision of reality. It consists of the combination of elements of a real environment with other elements of a virtual environment that have been created in three dimensions	11	4.6	100.0
Total		**239**	**100.0**	

As for whether they have had any experience with this educational tool, 54% (n=129) indicate that they have not had any experience, while the rest of the participants indicate that they have experimented with AR. In this sense, 35.6% (n=85) of the participants claim to have had limited experience, with only 10.5% (n=25) of the participants claiming to have had full experience with this technological resource (Table 4).

Table 4.
Experience with AR resources

Items	Frequency	Percentage	Cumulative percentage
No experience	129	54.0	54.0
Limited experience	85	35.6	89.5
Full experience	25	10.5	100.0
Total	**239**	**100.0**	

With respect to which characteristics define AR, respondents have mostly indicated that it is innovative and interactive and less often ease of use and cost (Figure 1).

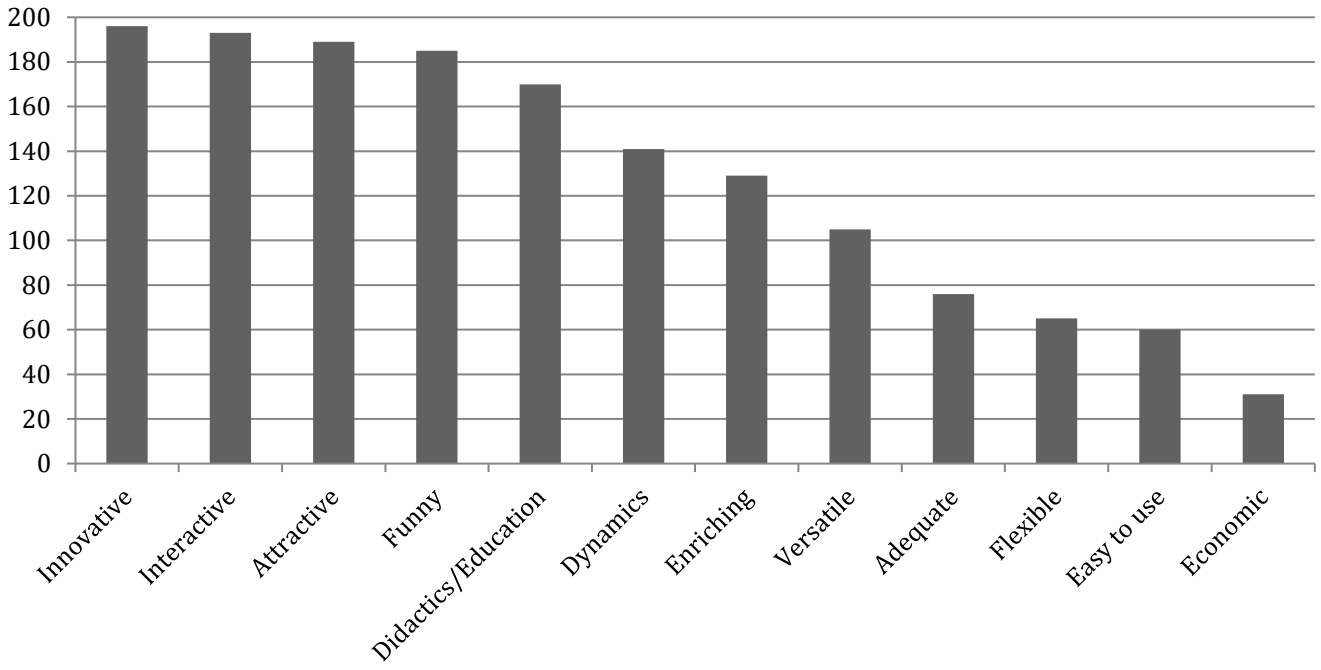

Figure 1. Characteristics that define the AR

3.2. AR's educational potential and capabilities

As for the potential that AR can have in the educational field, only 55.6% (n=133) indicates that it can have full potential. Thirty-six percent (n=86) of respondents consider the potential offered by AR in education to be limited, while 8.4% (n=20) do not see any potential in this educational tool (Table 5).

Table 5.
Teaching Potential of AR

Items	Frequency	Percentage	Cumulative percentage
No potential	20	8.4	8.4
Relative potential	86	36.0	44.4
Full potential	133	55.6	100.0
Total	**239**	**100.0**	

Regarding educational possibilities, only 0.4% (n=1) considers that this didactic instrument has no educational possibilities, while 5.9% (n=14) points out that few educational possibilities can be extracted from the AR. The rest of the sample considers that it is a didactic tool with enough educational possibilities (70.7%) or excellent possibilities (23%). Based on the collected results, the highest accumulated percentage is gathered around the answers which indicate that AR has enough educational possibilities, around which 70.7% (n=169) is placed (Table 6).

Table 6.
AR Educational Possibilities

Items	Frequency	Percentage	Cumulative percentage
No educational opportunities	1	0.4	0.4
Few educational possibilities	14	5.9	6.3
Quite a few educational possibilities	169	70.7	77.0
Excellent educational possibilities	55	23.0	100.0
Total	**239**	**100.0**	

If we go deeper into why the students of the Primary Education Degree offer educational possibilities that favour the teaching-learning processes, 10% (n=24) do not know or do not answer, while 17.2% (N=41) of the surveyed students argue that these possibilities are based on the fact that they are novel technologies. 47.7% (n=114) values how AR favours motivating learning scenarios, only 25.1% (n=60) goes one step further and identifies AR with a tool that allows students to "immerse" in a topic of interest and actively participate in the teaching-learning process (Table 7).

Table 7.
Educational Possibilities of the AR

Level	Indicator	Frequency	Percentage	Cumulative percentage
0	You don't know or don't answer the question	24	10.0	10.0
1	Low foundation. The arguments are mainly focused on a novel technology that offers new ways to learn attractively (Kysela and Štorková, 2015)	41	17.2	27.2
2	Medium foundation. Justifications related to the conceptual enrichment of real educational scenarios usually predominate, contributing to the motivation of students (Lin, Chen and Liu, 2017)	114	47.7	74.9
3	High foundation. Allows students to "immerse themselves" in the subject of interest and their active participation in the teaching-learning process (Albrecht, Folta-Schoofs, Behrends and vonJan, 2013; Eishita, Stanley and Mandryk, 2014; Kysela and Štorková, 2015)	60	25.1	100.0
	Total	**239**	**100.0**	

The educational possibilities are closely related to the belief of whether AR favours the creation of amplified, enhanced, reinforced and enriched learning scenarios. In this sense, the percentages are in line with the previous question. 0.8% (n=2) considers that AR does not favour the creation of learning scenarios, while 5% (n=12) considers that this contribution is small. 71.1% (n=170) considers that the contribution made by AR to the creation of new learning scenarios is considerable, while 23% (n=55) considers that it favours them completely (Table 8).

Table 8.
The AR Favours Learning Scenarios

Items	Frequency	Percentage	Cumulative percentage
Nothing	2	.8	.8
Little	12	5.0	5.9
Quite a lot	170	71.1	77.0
Completely	55	23.0	100.0
Total	**239**	**100.0**	

3.3. Applicability of AR in Primary Education Classrooms

The third dimension that has been addressed is that of applicability. The first item that has been investigated refers to indicating the moment in which they as future teachers would use AD as a didactic resource. In this sense, the vast majority, represented by 78.2% (n=187) indicates that they would use AR in development activities, while 10% (n=24) would do so at the beginning of the didactic proposal as a resource for the collection of previous ideas, and 7.1% (n=17) would use it as an alternative to evaluation. 2.9% (n=7) indicated that they would use it in other aspects of the didactic proposal, although they did not specify what these would be and 1.7% (n=4) stated that if they used the AR they would not really know where to insert it (Table 9).

Table 9.
The AR as an Educational Resource in the Didactic Proposals

Items	Frequency	Percentage	Cumulative percentage
Previous ideas	24	10,0	10,0
Development activities	187	78,2	88,3
Evaluation	17	7,1	95,4
Others	7	2,9	98,3
Don't know/No answer	4	1,7	100,0
Total	**239**	**100,0**	

In terms of the types of activities where AR can be applied, responses have been broad and diverse. A total of 340 proposals were received, as students were able to specify more than one. Of the 340 responses obtained, 17 do not know what to specify, thus not giving any proposal. Among the types of activities indicated, the responses were mainly focused on working on specific contents in the areas of Natural Sciences, Social Sciences and Mathematics. The type of activities that most participants recorded were those that addressed content related to the Natural Sciences, such as: activities to work on the human body, different parts of animals, the solar system, or the water cycle, among other questions (28.2%). They are followed by the contents of the Social Sciences such as rivers, maps, other cultures and periods, historical representations, time lines, etc., which account for 14.1% (n=48) of the answers. In the category others, questions related to computers or

technologies have been grouped, general questions that did not specify types of activities and where a percentage of 13.2 (n=42) has been placed. The remaining answers are below 10% (table 10).

Table 10.
Types of activities in which to apply AR

Items	Frequency	Percentage	Cumulative percentage
Contents related to Natural Sciences (human body, animals, the Earth, solar system, water cycle...)	96	28,2	28,2
Contents related to Social Sciences (rivers, maps, other cultures and times, historical representations, time lines,...)	48	14,1	42,3
Game to find elements like Gymkana or Escape Rooms	22	6,5	48,8
Activities previous ideas, evaluation, strengthening ... but without specifying content	22	6,5	55,3
Specific applications (Google Sky Map, Quiver, Aurasma, Plikerts, Kahoot, Layar, Elements 4D)	21	6,2	61.5
Contents related to the Natural and Social Sciences, jointly.	16	4,7	66,2
Mathematics Contents (geometry)	14	4,1	70,3
Contents related to artistic and plastic education (3D drawings, artistic techniques,...)	12	3,5	73,8
Contents for Extracurricular Activities (museums, parks, theatres...)	11	3,2	77,0
Road Safety Education Content	7	2,0	79,0
Matching/Association Games	5	1,5	80,5
Contents for learning vocabulary and other languages	4	1,2	81,7
Others	45	13,2	94,9
Don't know/No answer	17	5,1	100
Total	340	100,0	

Having explored the moment in which the AR would be worked on in a didactic proposal and the type of activities that would be used, it is pertinent to know if they, as future teachers, consider the AR an interesting tool to be used in the classroom. In this sense, 95% (n=227) indicated that they would use it. Only 5% (n=12) answered negatively, emphasizing that it is a tool that they would not use with their students (Table 11).

Table 11.
Use of AR as a Teaching Resource in the Classroom

Items	Frequency	Percentage	Cumulative percentage
Yes	227	95,0	95,0
No	12	5,0	100,0
Total	**239**	**100,0**	

4. DISCUSSION AND RECOMMENDATIONS

We consider relevant to open the conclusions referring to the age of the participants of this study, students of the Primary Education Teacher's Degree with ages between 19 and 21 years, which entails a positive attitude towards the download, installation and use of applications (Ruiz and Belmonte, 2014) as they are considered digital natives (Prensky, 2001).

The results of our study indicate that despite the fact that the respondents have had no or limited experience in the use of AR, they consider it a useful educational resource with great potential for the learning of primary school students, coinciding with similar studies (Wu et al, 2013; Bower et al., 2014; Phon, Ali, and Halim, 2014; Cubillo et al., 2015; Barroso and Gallego, 2017; Moreno and Leiva, 2017; Luna, Ibañez and Rivero, 2019). The students of the Primary Education Teacher Degree, future teachers of this stage, consider that the AR is a didactic resource that can be used in the classroom, since it favours the development of curricular contents of diverse areas (Wu et al., 2013; Joan, 2015; Marín-Díaz and Sampedro-Requena, 2020; Rahman, Ling and Yin, 2020). Thus, AR is perceived as a didactic tool that reinforces the acquisition of curricular contents, which can be approached from different subjects and educational areas and which complements other didactic strategies or methodologies such as project-based learning (PBA), gamification and play strategies, Gymkanas, Escape Room, didactic itineraries, drawings or AR books... (Diegmann et al., 2015; Prendes, 2015; Akçayır and Akçayır, 2017).

According to those surveyed, the AR is a resource that has a series of intrinsic characteristics that favour its inclusion and use in the educational field as it is a teaching tool that is attractive, fun, dynamic and versatile among other characteristics, coinciding with other research carried out (De la Horra Villacé, 2017; Marín-Díaz and Sampedro-Requena, 2020; Cabero et al., 2020). In this sense, the element most valued by students has been interactivity, which does not coincide with other previous studies where creativity was the most valued characteristic (Wei et al., 2015; Marín-Díaz, 2017).

The students of the Primary Education Teacher's Degree consider that they could use AR as an educational tool within the classroom, since it has many possibilities (Bongiovani, 2013; Chang, Wu and Hsu, 2013; Kamarainen et al., 2013; Han, Jo, Hyun and So, 2015; Cabero, Barroso and Obrador, 2017; Moreno and Leiva, 2017; Garay, Tejada and Castaño, 2017). This has also been reflected in educational experiences that have already been implemented and evaluated with primary school students in their schools (Sáez-López, Sevillano-García and Pascual-Sevillano, 2019; Toledo and Sánchez, 2017; Piqueras, Cózar and González-Calero, 2018). Therefore, we can say that the AR is an educational resource that future teachers could incorporate into their classrooms.

In short, we can determine that, although the AR is a technology that helps and facilitates the understanding of the curricular contents, it is necessary to train teachers for a correct use, being still the use of these tools a challenge for the educators (Ávila and Bailey, 2016; Burden and Hopkins, 2016; Cabero and Barroso, 2016; Garay, Tejada and Castaño, 2017; Marín-Díaz and Sampedro-Requena, 2020).

Research and Publication Ethics Statement

All information contained in this document has been obtained and presented in accordance with academic standards and ethical aspects. The research presented was conducted with the informed consent of all participants prior to data collection.

Contribution Rates of Authors to the Article

Olga Moreno-Fernández: Conceptualisation, data collection, data analysis, writing - original draft, writing - revision and editing. Carmen Solís-Espallargas: Conceptualisation, data collection, data analysis, writing-revision and editing. Pilar Moreno-Crespo: Conceptualisation, methodology, data analysis, writing-revision and editing. Mario Ferreras-Listán: Conceptualisation, Data collection, data analysis, writing - original draft, writing - revision and editing.

Support Statement

This research is part of the project "Working socio-environmental problems. Augmented Reality as an educational tool to implement didactic itineraries in the classroom", with code 22161, granted by the University of Seville's Own Teaching Plan for the 2018/2019 academic year, obtained by competitive concurrence.

Statement of Interest

There is no conflict of interest to declare

5. REFERENCES

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review, 20*, 1-11. https://doi.org/10.1016/j.edurev.2016.11.002

Ala-Mutka, K. (2011). *Mapping digital competence: Towards a conceptual understanding.* Luxembourg: JRC-IPTS.

Avila, L., & Bailey, M. (2016). Augment your Reality. *IEEE Computer Graphics and Applications, 36*(1), 6-7. https://doi.org/10.1109/MCG.2016.17

Bacca, J. L., Baldiris, S. m., Fabregat, R., & Kinshuk, K. (2019). Framework for designing motivational augmented reality applications in vocational education and training. *Australasian Journal of Educational Technology, 35*(3), 102-117. https://doi.org/10.14742/ajet.4182

Barroso, J. M., y Gallego, O. 2017. Producción de recursos de aprendizaje apoyados en Realidad Aumentada por parte de los estudiantes de Magisterio [Production of learning resources supported by Augmented Reality by students of Teaching]. *EDMETIC, Revista de Educación Mediática y TIC, 6*(1), 23-38. https://doi.org/10.21071/edmetic.v6i1.5806

Bongiovani, P. (2013). Realidad aumentada en la escuela: tecnología, experiencias e ideas [Augmented reality in school: technology, experiences and ideas]. *Educ@conTIC*. http://www.educacontic.es/blog/realidad

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented reality in education. Cases, places and potentials. *EducMedia Int.*, 51, 1-15. https://doi.org/10.1080/09523987.2014.889400

Burden, K., & Hopkins, P. (2016). Barriers and Challenges Facing Pre-Service Teachers use of Mobile Technologies for Teaching and Learning. *International Journal of Mobile and Blended Learning, 8*(2), 1-20. https://doi.org/10.4018/IJMBL.2016040101

Cabero, J., & Barroso, J. (2016). The Educational Possibilities of Augmented Reality. *Journal of New Approaches in Educational Research, 5*(1), 44-50. https://doi.org/10.7821/naer.2016.1.140

Cabero, J., Barroso, J., & Obrador, M. (2017). Realidad aumentada aplicada a la enseñanza de la medicina [Augmented reality applied to medical education]. *Educación Médica, 18*(3), 203-208. https://doi.org/10.1016/j.edumed.2016.06.015

Cabero, J., Vázquez-Cano, E., López Meneses, E., & Jaén Martínez, A. (2020). Posibilidades formativas de la tecnología aumentada. Un estudio diacrónico en escenarios universitarios [Training possibilities of augmented technology. A diachronic study in university settings]. *Revista Complutense de Educación, 31* (2), 141-152. https://dx.doi.org/10.5209/rced.61934

Chang, H., Wu, H., & Hsu, Y. (2013). Integrating a mobile augmented reality activity to contextualize student learning of a socioscientific issue. *Brit J Educ Technol., 44*, E95-99. https://doi.org/10.1111/j.1467-8535.2012.01379.x

Colás-Bravo, P., Conde-Jiménez, J., & Reyes-de-Cózar, S. (2019). The development of the digital teaching competence from a sociocultural approach. *Comunicar, 61*, 21-32. https://doi.org/10.3916/C61-2019-02

Cózar-Gutiérrez, R., De-Moya-Martínez, M.V., Hernández-Bravo, J.A., & Hernández-Bravo, J.R. (2015). Tecnologías emergentes para la enseñanza de las Ciencias Sociales.: Una experiencia con el uso de Realidad Aumentada en la formación inicial de maestros [Emerging technologies for social science teaching.: An experience with the use of Augmented Reality in initial teacher training]. *Digital Education Review, 27*, 138-153. https://doi.org/10.1344/der.2015.27.138-153

Cozar-Gutiérrez, R., & Sáez-López, J.-M. (2016). Realidad aumentada, proyectos en el aula de primaria: experiencias y casos en Ciencias Sociales [Augmented reality, primary classroom projects: experiences and cases in Social Sciences]. *EDMETIC, 6*(1), 165-180. https://doi.org/10.21071/edmetic.v6i1.5813

Cubillo, J., Martin, S., Castro, M., & Boticki, I. (2015). Preparing Augmented Reality Learning Content should be Easy: UNED ARLE- an Authoring Tool for Augmented Reality Learning Environments. *Computer Applications in Engineering Education, 23*(5), 778-789. https://doi.org/10.1002/cae.21650

Diegmann, P., Schmidt-Kraepelin, M., Van den Eynden, S., & Basten, D. (2015). Benefits of Augmented Reality in Educational Environments-A Systematic Literature Review. *Wirtschaftsinformatik, 3*(6), 1542-1556.

Di Serio, Á., Ibáñez, M. B., & Delgado, C. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education*, *68*, 586-596. https://doi.org/10.1016/j.compedu.2012.03.002

Fombona, J., Pascual-Sevillana, Á., & González-Videgaray, M. (2017). M-learning and augmented reality: A review of the scientific literature on the WoS Repository. *Comunicar. Media Education Research Journal*, *25*(2). https://doi.org/10.3916/C52-2017-06

Garay, U., Tejada, E., & Castaño, C. (2017). Percepciones del alumnado hacia el aprendizaje mediante objetos educativos enriquecidos con realidad aumentada [Students' perceptions of learning through educational objects enriched with augmented reality]. EDMETIC, *Revista de Educación Mediática y TIC, 6*(1), 145-164. https://doi.org/10.21071/edmetic.v6i1.5812

Gavilanes, W., Abásolo Guerrero, M. J., & Cuji, B. (2018). Resumen de revisiones sobre Realidad Aumentada en Educación [Summary of reviews on Augmented Reality in Education]. *Revista Espacios*, *39*.

Han, J., Jo, M., Hyun, E., & So, H. (2015). Examining young children's perception toward augmented reality-infused dramatic play. Education Technology Research Development, 63, 455-474. https://doi.org/10.1007/s11423-015-9374-9

De la Horra Villacé, I. (2017). Realidad Aumentada, una revolución educativa. *EDMETIC, Revista de Educación Mediática y TIC, 6*(1), 9-22. https://doi.org/10.21071/edmetic.v6i1.5762

Jeřábek, T., Rambousek, V., & Wildová, R. (2014). Specifics of visual perception of the augmented reality in the context of education. *Procedia-Social and Behavioral Sciences*, *159*, 598-604. https://doi.org/10.1016/j.sbspro.2014.12.432

Joan, R. (2015). Enhancing education through mobile augmented reality. *Journal of Educational Technology, 11*(4), 8-14. https://doi.org/10.26634/jet.11.4.3147

Kamarainen, A., Metcalf, S.H., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M., & Dede, C. (2013). EcoMOBILE: Integrating augmented reality and probe ware with environmental education field trips. *Comput Edu., 68*, 545-556. https://doi.org/10.1016/j.compedu.2013.02.018

Kamphuis, C., Barsom, E., Schijven, M., & Christoph, N. (2014). Augmented reality in medical education? *Perspectives on medical education*, *3*(4), 300-311. https://doi.org/10.1007/s40037-013-0107-7

Kysela, J., & Štorková, P. (2015). Using augmented reality as a medium for teaching history and tourism. *Procedia-Social and behavioral sciences*, *174*, 926-931. https://doi.org/10.1016/j.sbspro.2015.01.713

Kurilovas, E. (2016). Evaluation of quality and personalisation of VR/AR/MR learning systems. *Behaviour & Information Technology*, *35*(11), 998-1007. https://doi.org/10.1080/0144929X.2016.1212929

Lin, M. H., Chen, H. C., & Liu, K. S. (2017). A study of the effects of digital learning on learning motivation and learning outcome. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3553-3564.https://doi.org/10.12973/eurasia.2017.00744a

Luna, U., Ibáñez, A., & Rivero, M.P. 2019. El patrimonio aumentado. 8 apps de Realidad Aumentada para la enseñanza-aprendizaje del patrimonio [The increased wealth. 8 Augmented Reality apps for teaching and learning about heritage]. *Revista Interuniversitaria de Formación del Profesorado, 94*, 43-62.

Marín-Díaz, V. 2017. The relationships between Augmented Reality and inclusive education in Higher Education. *Bordón, 69*(3), 125-142. https://doi.org/10.13042/Bordon.2017.51123

Marín-Díaz, V., & Sampedro-Requena, B. (2020). La Realidad Aumentada en Educación Primaria desde la visión de los estudiantes [Augmented Reality in Primary Education from the Students' Viewpoint]. *Alteridad, revista de educación, 15*(1), 61-73. https://doi.org/10.17163/alt.v15n1.2020.05

Montecé-Mosquera, F., Verdesoto-Arguello, A., Montecé-Mosquera, C., & Caicedo-Camposano, C. (2017). Impacto de la realidad aumentada en la educación del siglo XXI [Impact of augmented reality on education in the 21st century]. *European Scientific Journal, ESJ*, *13*(25), 129-137. http://dx.doi.org/10.19044/esj.2017.v13n25p129

Moreno, N., & Leiva, J. 2017. Experiencias formativas de uso didáctico de la realidad aumentada con alumnado del grado de educación primaria en la Universidad de Málaga [Training experiences in the didactic use of augmented reality with primary school students at the University of Málaga]. *EDMETIC, Revista de Educación Mediática y TIC, 6*(1), 81-104. https://doi.org/10.21071/edmetic.v6i1.5809

Phon, D. N. E., Ali, M. B., & Halim, N. D. A. (2014). Collaborative Augmented Reality in Education: A Review. In 2014 International Conference on Teaching and Learning in *Computing and Engineering* (78–83). IEEE. https://doi.org/10.1109/LaTiCE.2014.23

Piqueras, E. M., Cózar, R., & González-Calero, J. A. (2018). Incidencia de la realidad aumentada en la enseñanza de la Historia. Una experiencia en tercer curso de educación primaria. *Enseñanza & Teaching, 36*(1), 23-39. https://doi.org/10.14201/et20183612339

Prendes, C. (2015). Realidad Aumentada y Educación: análisis de experiencias prácticas [Augmented Reality and Education: analysis of practical experiences]. *PixelBit. Revista de Medios y Educación, 46* (1), 187-203. http://dx.doi.org/10.12795/pixelbit.2015.i46.12

Prensky, M. (2001). Digital natives, digital immigrants. *On the horizon*, *9*(5).

Radu, I. (2014). Augmented reality in education: a meta-review and cross-media analysis. *Personal and Ubiquitous Computing*, *18*(6), 1533-1543. https://doi.org/10.1007/s00779-013-0747-y

Rahman, M.A, Ling, L.S., & Yin, O.S. 2020. Augmented Reality for Learning Calculus: A Research Framework of Interactive Learning System. *Computational Science and Technology. Technology, 603*, 491-499. https://doi.org/10.1007/978-981-15-0058-9_47

Realinfluencers (2016). Las 10 mejores apps de realidad aumentada para educación [en línea]. Realinfluencers. Always learning. https://www.realinfluencers.es/2016/11/29/10-mejores-aplicaciones-realidad-aumentada-eduacion/

Red Guadalinfo (2018). Apps de realidad aumentada para aprender [en línea]. Guadalinfo. https://blog.guadalinfo.es/apps-de-realidad-aumentada-para-aprender/

Ruiz, F., & Belmonte, A. (2014). Los jóvenes como usuarios de aplicaciones de marca en dispositivos móviles. *Comunicar*, 43, 73-81. https://doi.org/10.3916/C43-2014-07

Sáez-López, J., Sevillano-García, M.L., & Pascual-Sevillano, M.l. (2019). Application of the ubiquitous game with augmented reality in Primary Education. [Aplicación del juego ubicuo con realidad aumentada en Educación Primaria]. *Comunicar*, 61, 71-82. https://doi.org/10.3916/C61-2019-06

Toledo, P., & Sánchez, J. M. (2017). Realidad Aumentada en Educación Primaria: efectos sobre el aprendizaje [Augmented Reality in Primary Education: effects on learning]. *RELATEC, Revista Latinoamericana de Tecnología Educativa, 16*(1), 1-14. http://dx.medra.org/10.17398/1695-288X.16.1.79

Wei, X., Weng, D., Liu, Y., & Wang, Y. (2015). Teaching based on augmented reality for a technical creative design course. *Computers & Education, 81,* 221-234. https://doi.org/10.1016/10.1016/j.compedu.2014.10.017

Wu, H.S., Wen-Yu, S., Chang, H.Y., & Liang, J. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, 62, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024