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Emerging Technologies for a Digital Education Project: A Systematic Review on Augmented Reality and Cultural-Historical Heritage

Tecnologías emergentes para el proyecto de educación digital: Una revisión sistemática sobre realidad aumentada y patrimonio histórico-cultural

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ABSTRACT

The popularity of Augmented Reality in recent years has not gone unnoticed by the Digital Humanities and cultural institutions. It constitutes an alternative and innovative way of bringing knowledge closer and developing meaningful, interactive, and contextualized learning about our heritage. In the educational field, an increasing interest in AR is identified as a future resource in Digital Education Projects. This paper reflects on the educational scope of AR in the processes of teaching and learning of historical and cultural heritage. As a methodological proposal, a Systematic Review of the Literature has been carried out, composed between the years 2016 and 2021. Regarding the PRISMA 2020 protocol, 35 academic articles have been analyzed, all collected from the Web of Science and Scopus databases. Existing lines of research, application contexts, implementation techniques, participant profiles, and socio-educational contributions in this field of knowledge have been analyzed. In conclusion, the didactic and informative potential of AR in learning cultural, historical, and material heritage is reaffirmed.

RESUMEN

La popularidad de la Realidad Aumentada en los últimos años no ha pasado inadvertida por parte de las Humanidades Digitales e instituciones culturales. Constituye un medio alternativo e innovador para acercar el conocimiento, desarrollando un aprendizaje significativo, interactivo y contextualizado sobre el patrimonio. En el ámbito educativo, se identifica cada vez un interés mayor, situándolo como uno de los recursos de futuro en los Proyectos de Educación Digital de los centros. El presente trabajo reflexiona acerca del alcance educativo de la Realidad Aumentada en los procesos de enseñanza y aprendizaje del patrimonio histórico-cultural. Como propuesta metodológica se ha realizado una Revisión Sistematizada de la Literatura comprendida entre los años 2016 y 2021. Tomando como referencia el protocolo PRISMA 2020, acompañado del marco metodológico SALSA, han sido analizados un total de 35 artículos académicos recopilados de las bases de datos Web of Science y Scopus. Se han analizado las líneas de investigación existentes, los contextos de aplicación y técnicas de implementación, los perfiles participantes y las contribuciones socioeducativa en este campo de conocimiento. Como conclusión, se reafirma el potencial didáctico y divulgativo del uso de la Realidad Aumentada en el aprendizaje del patrimonio a nivel cultural, histórico y material.

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1. Introduction

The success of Augmented Reality (AR) can be explained by the sophistication of technological advances in recent decades. While the earliest antecedents date back to the 1960s, the term was first formulated in 1992 by Thomas P. Claudell and David Mizell as "that technology used to augment the user's field of view with the necessary information, allowing several tasks to be performed simultaneously" (1992, p. 667).

Over time, the significance of AR has expanded to the point of being considered a medium rather than a technology (Craig, 2013). This is due to its ability to interact with and between people, creating individual and collective experiences that transcend technological barriers. The participation is much more enriching by arousing emotions and creating experiences that connect with the most human.

Augmented Reality has recently exploded thanks to its active use in smartphones. Through an intuitive interface and appropriate dissemination, applications such as Pokémon Go© have managed to unleash a global phenomenon of considerable magnitude and attract the general interest of the public (Bueno et al., 2020).

Away from the entertainment industry, AR has managed to enter other much more diverse fields. A clear example of this is its application within culture. Just like Augmented Reality, museums are experiencing a considerable boom thanks to their broad tourist appeal, resulting in a considerable increase in ever more diverse visitors (Choi et al., 2020; Luo et al., 2019; Shalina, 2015). This human and economic influx has also necessitated considerable reinvention in recent decades. First and foremost, these interpretation centers are spaces for cultural and historical dissemination, inviting visits to the past, reflection on the present and consideration of the future. This poses new opportunities to foster an intergenerational audience's intellectual, aesthetic, emotional, cognitive, and social development (Günay, 2012). The versatility of these centers has been recognized by the OECD (2017), positioning cultural institutions as partners in the enrichment of teaching-learning environments within the ILE (Integrated Learning Environment) framework.

Within this promising context, Digital Humanities have offered a glimpse of their educational potential, placing themselves in line with *art thinking*. *Art thinking* is a disruptive thought proposal that fosters the development of critical thinking and social and civic competencies, essential in a global citizenship (Facal et al., 2017; Santamarina et al., 2020). Therefore, the theoretical links within educational innovation are more than clear.

These circumstances have allowed the exploration of AR's educational possibilities and the study of heritage wealth together. The research community values the non-invasive character of AR, the possibilities for reconstruction and visualization of our heritage from different perspectives, reflecting on its value and preservation, in line with the objectives of UNESCO's agenda (2019).

Thus, Augmented Reality has proven its potential pedagogical function in museums and interpretation centers, standing out as one of the most avant-garde resources. Its implementation evidences a rupture in the way of conceiving space, changing the design of the facilities themselves (Muñoz & Martí, 2018), as is the case with the new educational approaches of the classrooms of the future. In this sense, its advantages could be in the following areas: 1. The possibilities of interaction, positive in situational learning and its degree of empathy with the space (context-aware learning) (Wen & Looi, 2019); 2. A considerable improvement in inductive reasoning and problem-solving, among other skills, from the educational theory of "Learning by doing" or Learning-by doing (Lesgold, 2001); 3. Immersion capacity within the real environment, achieving a more complete experience. In this, aspects such as narrative (storytelling), interactivity, and socialization are key (Dede, 2009; Dede et al., 2017); 4. The direct association between entertainment and the assimilation of theoretical and practical knowledge (edutainment) (Makarius, 2017; Ruiz-Torres, 2011). As can be seen, all the advantages are oriented to the use of active methodologies that accompany the implementation of AR, in line with current trends related to educational innovation and the development of Digital Education Projects in educational centers.

With this context in mind, we ask: What emerging trends are perceived for augmented reality and historical-cultural heritage? What methodological proposals are applied in classrooms? What assessments are valued for the educational potential of AR, and what is the general public perception?
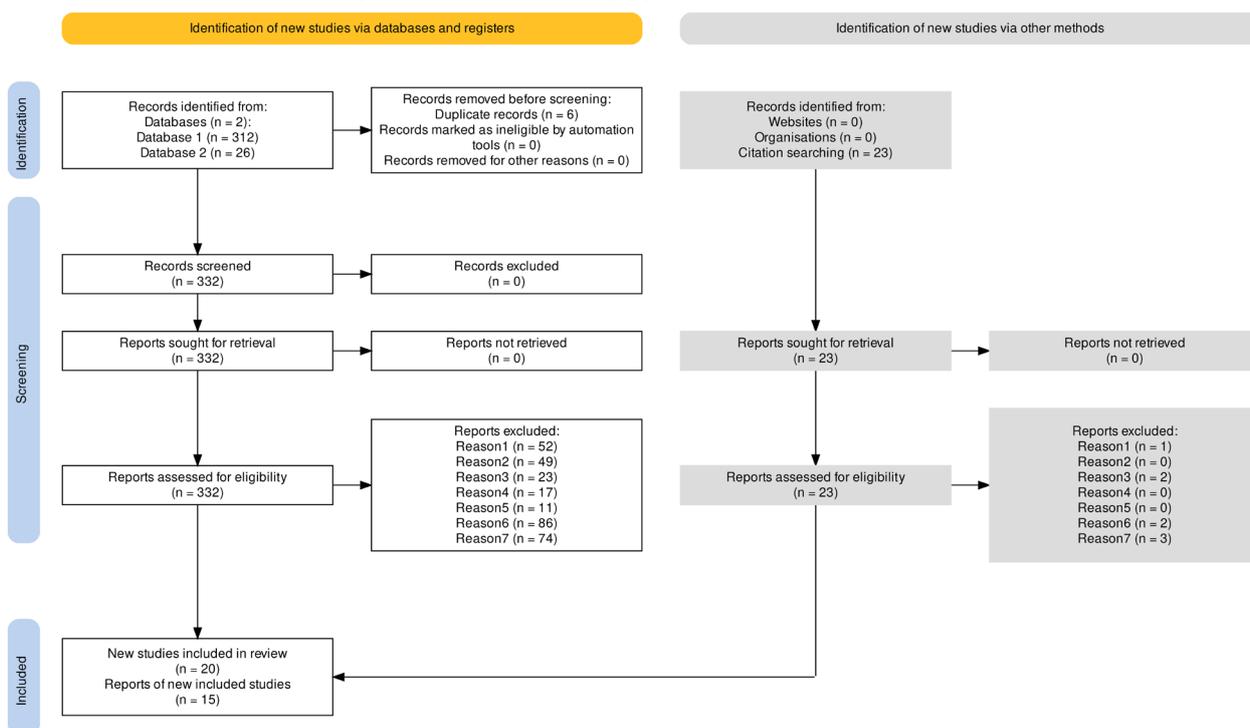
2. Methodology

The methodological perspective adopted was that of a Systematic Literature Review (SLR), which is characterized by its organized and reproducible nature. The research objectives were:

- OE1. Identify emerging lines of research on Augmented Reality and its future prospects within Digital Humanities and Education.

- OE2. Distinguish the contexts of application with patrimonial value where Augmented Reality is used and its historical periodization.
- OE3. Describe the most relevant technical and methodological proposals of Augmented Reality concerning historical and cultural heritage.
- OE4. Present the data collection techniques and the characteristics of the participating profiles.
- OE5. Reflect on the socio-educational scope of AR in the study and dissemination of Historical Heritage.

PRISMA 2020 (Page et al., 2021) (Figure 1) standards have been applied to conduct this review, identifying eligibility criteria, information sources, search strategy, selection process, data collection process and data list.

Figure 1. Process of identifying studies (PRISMA Protocol)

Note. Own elaboration.

The SALSA (Search-AppraisaL-Synthesis-Analysis) (Grant & Booth, 2009; Booth et al., 2016; García-Peñalvo, 2022) framework was chosen from the possible methodological approaches to SLR. In the first search phase (Search), the chronological search period, databases and keywords were defined. In this study, the chronological reference period runs between 2016 and 2021. Web of Science and Scopus were consulted as reference databases for this work. The multidisciplinary nature of the two has managed to delimit our topic of study with the nuances that it presents, touching on.

Education, Humanities and Technology. Boolean logic was used in the search criteria to ensure greater order and thoroughness. Due to the high number of results obtained and their thematic disparity, it was decided to narrow the search criteria by entering the keywords both by title and by theme (Table 1).

Table 1. Proposed boolean searches

Boolean search and filters
museum AND augmented reality OR AR (tema: heritage OR education)
heritage AND augmented reality OR AR (tema: heritage OR education)
Histor* AND augmented reality OR AR (tema: education)
Art* AND augmented reality OR AR (tema: education OR museum)

Note. Own elaboration.

During the evaluation phase (AppraisaL), the results obtained were evaluated according to previously defined inclusion criteria (IC) and those publications with the highest degree of affinity were selected. In this way, a total of seven publications were selected:

- CI1: They must meet most of the proposed objectives.
- CI2: The publications should go deep into the application of augmented reality in the museum world and about historical-cultural heritage. Their content should include an educational dimension with the application of AR.
- CI3: Free access in databases or, failing that, available online in repositories and social networks (Academia.edu, Researchgate).
- CI4: They must fall within the 2016 to 2021 timeframe.
- CI5: Publications must be in English.
- CI6: Only research articles will be sought, discarding conference papers, book chapters, books, and doctoral theses.
- CI7: They must be empirical in nature, implicitly or explicitly following the formal IMR&D structure (Introduction, Methods, Results and Discussion).

After searching, 20 articles met all the inclusive criteria. However, due to the small number of results, a second selection process was established using the "snowball" technique. This involved consulting all the publications referenced in the bibliography of the previously selected articles and applying the inclusion criteria. As a result, 15 more articles were collected, bringing the total number of articles to 35 (Table 2).

Table 2. Selected articles

Papers	Web of Science	Scopus	Snowballing
(Andrade & Dias, 2020)	X		
(Azhar et al., 2019)			X
(Baker et al., 2020)	X	X	
(Barrado-Timón & Hidalgo-Giralt, 2019)	X		
(Bernarduzzi et al., 2021)	X		
(Bhaskara & Sugiarti, 2019)			X
(Blanco-Pons et al., 2019)	X	X	
(Boboc et al., 2019)			X
(Chang et al., 2019)	X		
(Gherardini et al., 2019)		X	
(Ghouaiel et al., 2017)			X
(Hammady et al., 2020)			X
(Han et al., 2019)			X
(Higgett et al., 2016)			X
(Ibáñez-Exteberría et al., 2020)	X	X	
(Jones et al., 2019)			X
(K. Jung et al., 2020)		X	
(T. Jung et al., 2020)	X		
(Kasapakis et al., 2016)			X
(Marto et al., 2020)	X		
(Marto & Gonçalves, 2019)	X		
(Mendoza-Garrido et al., 2021)	X	X	

Papers	Web of Science	Scopus	Snowballing
(Moorhouse et al., 2019)	X	X	
(Morganti & Bartolomei, 2018)			X
(Petrucco & Agostini, 2016)			X
(Poce et al., 2019)	X	X	
(Qian et al., 2021)	X		
(Sardo et al., 2018)			X
(Schaper et. al, 2018)	X		
(Shih et al., 2019)	X		
(Shih et al., 2020)	X		
(Supriyono et al., 2020)		X	
(Tom Dieck et al., 2018)			X
(Tom Dieck & Jung, 2017)			X
(Vera et al., 2016)			X

Note. Own elaboration.

The third phase corresponds to the synthesis phase. In this phase, all the information collected from each article is extracted in a standardized registry protocol (Sánchez-Meca, 2010, p. 57). This record allows for synthesizing and extracting data related to the objectives and other variables of analysis to establish a descriptive exploration from the qualitative paradigm (Table 3).

With all this, the purpose of the last analysis phase is to consult and interrelate the extracted information globally. This process allows us to have a general overview that brings us closer to the context studied with greater clarity under the limits and purposes of the work.

Table 3. Registry protocol

| Registry protocol |
|---|
| Published country: |
| Published year: |
| Keywords: |
| Academic Journal: |
| Affinity with research objectives: |
| SO1. Research line. |
| SO2. Implementation context and its heritage value. |
| SO3. Technical and methodological proposals of Augmented Reality. |
| SO4. Participant profiles. |
| OE5. Socio-educational outreach. |
| Features of Augmented Reality: |
| Historical period: |
| Location: indoor, outdoor, mixed, unmentioned, or non-specific |
| Assessment on the effectiveness of Augmented Reality: positive, neutral, or negative. |

Note. Own elaboration.

3. Results

In addressing this section, some quantitative data such as countries, years of publication, academic journals and keywords have been explored. On the one hand, those countries traditionally known as tourist destinations with a rich heritage value are the most prominent, followed by Asian countries. The latter is important because they are technological development centers and tourist attractions. However, the largest number of publications are registered in the United Kingdom, most of them corresponding to the AR & VR Hub research group at Manchester Metropolitan University.

We can see major differences if we focus on the number of publications and their evolution over the last five years (Figure 2).

Figure 2. AR Experiences per Year
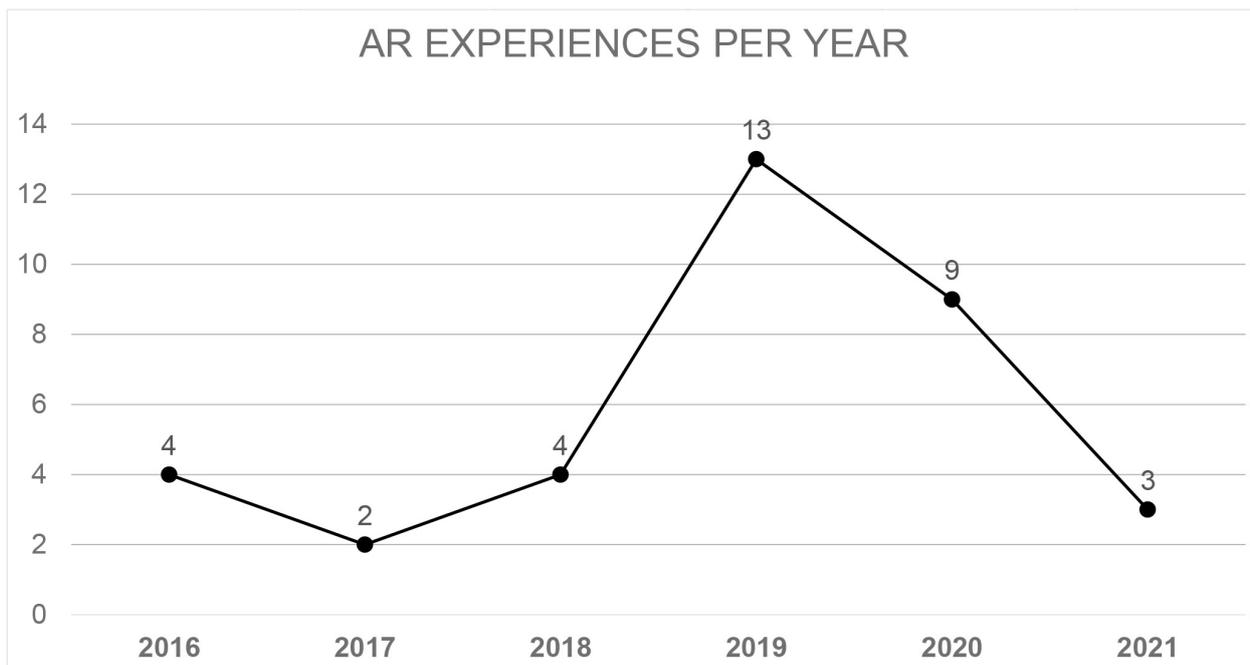
Note. Own elaboration.

The year 2016 is marked by the popularity of Augmented Reality and its recreational component. This is manifested in the interest in the possibilities of AR and how to exploit them in the heritage and socio-educational field. The years 2017 and 2018 are characterized by a more practical analysis of the visitor experience. All this led to a higher number of publications in 2019. By far, the highest number of publications was recorded in 2019. Some possible reasons for such a peak could be attributed to the records seen in tourism and the increasingly strong commitment to the inclusion of AR in the educational field. Further ahead, the years 2020 and 2021 show very good data due to a general evolution. In addition, the first works refer to the problems of the health crisis and the tourism sector and the possibilities of e-learning and b-learning as alternatives to new scenarios (K. Jung et al., 2020; Shih et al., 2020).

Considering the characteristics of the publication journals (Figure 3), the use of interdisciplinary databases and search filters yielded a greater number of journals based on Science and Technology. This fact responds considerably to the thematic complexity involved in the development of Augmented Reality applications for educational purposes.

Lines of research in the application of Augmented Reality (OE1)

Considering the thematic diversity of the publications, a total of 10 lines of research are presented below:

1. Pedagogical strategies in educational levels. Different studies have tried to adapt digital resources, pedagogical theories, and age ranges to heritage and AR integration. This is valued favorably as a

Figure 3. Journal´s main research fields

JOURNALS' MAIN RESEARCH FIELDS

KEY

■ Science and Technology (16)
■ Education (3)
■ History and Heritage (4)
■ Interdisciplinary (3)
■ Tourism (3)
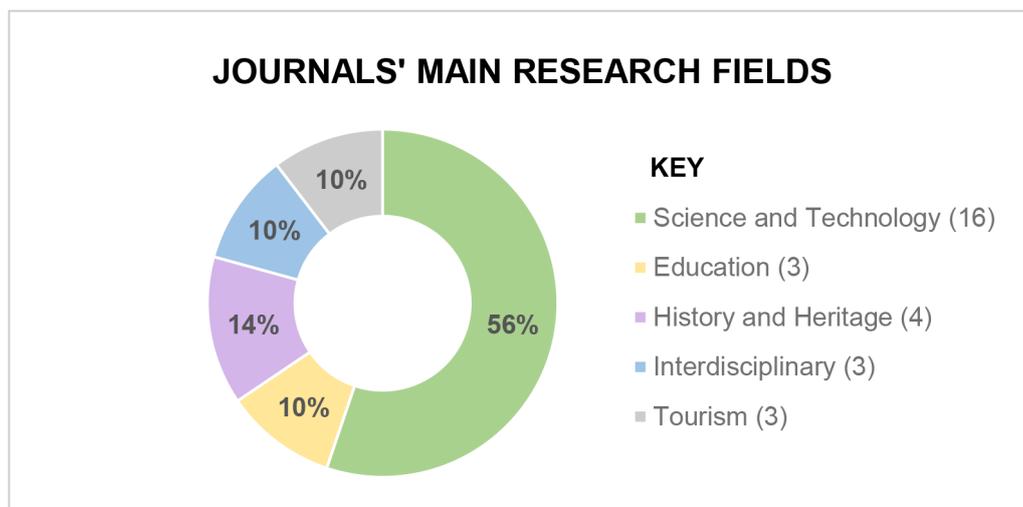
Note. Own elaboration.

reinforcement of knowledge acquisition, motivation for learning in museums, and learning styles (Moorhouse et al., 2019; Qian et al., 2021). Other valued topics are in situ learning, collaborative heritage learning, reflection, and critical reconstruction of the past (Schaper et al., 2018) or smart textbooks with AR (Azhar et al., 2019). Moreover, within the most explored educational levels, AR's implementation in university museums stands out (Bernarduzzi et al., 2021; Poce et al., 2019).

2. Learning-by-doing: Interaction and content search. In open spaces, heritage conservation has been considerably studied (Chang et al., 2019), exploring the urban environment and the possibility of discovering more about its history from discovery through serendipity (Jones et al., 2019). In interiors, Ghouaiel et al. (2017) analyzed the impact of Augmented Reality in museums and its impact on the learning experience from a customizable guide that considers the visitor's preferences. In this sense, the Contextual Design technique is fundamental for a favorable experience (Vera et al., 2016).

3. Reconstruction of exterior spaces and techniques. The publications by Bhaskara and Sugiarti (2019), Morganti and Bartolomei (2018), and Blanco-Pons et al. (2019) manifest a special interest in the augmented superimposition of old photos together with information in the real environment. Photogrammetry was the main technique used to assess the buildings' geometric characteristics and the existing light changes.

4. Multisensory experiences. These are based on enhancing the use of the five senses in visitors. Studies have tried to prove their influence on the quality of the users' experience, enjoyment, and learning (Marto et al., 2020; Marto & Gonçalves, 2019). The visual and auditory components were the most influential in the immersive sensation, although the smell is also favorably recognized. On the other hand, developing a multisensory prototype linked to a smartphone via Bluetooth stands out (Sardo et al., 2018).

5. Storytelling. Despite being a cross-cutting theme in several publications, some give it maximum prominence, delving into the use of historical figures to identify the theme and arouse the interest of users, as well as user behavior patterns, needs, and accessibility for a more customizable gamified experience (Andrade & Dias, 2020; Boboc et al., 2019; Hammady et al., 2020).

6. 3D object reconstruction and contextualization. The dispersion of archaeological sites or the fragmentation of objects is a handicap when interpreting and assessing material heritage. In this sense, the recreation of artifacts partially or completely is possible thanks to the use of 3D (Gherardini et al., 2019; Supriyono et al., 2020). For outdoor cases, several publications are characterized by accurately placing 3D historical buildings in an urban environment (Higgett et al., 2016; Shih et al., 2019).

7. RSLs and other qualitative studies of interest. These studies value the capacity of AR in the documentation, intervention, representation, and dissemination of History (Barrado-Timón & Hidalgo-Giralt, 2019). In addition, AR's economic advantage over the cost of guided tours is appreciated. Moreover,

the implementation of AR has been valued as an identifying feature or branding by cultural institutions (Tom Dieck & Jung, 2017). However, some researchers point out that the educational quality of its applications is an aspect to be studied in greater depth (Ibañez-Etxeberria et al., 2020).

8. Wearable technology. This type of technology encompasses all those electronic or sensory devices used in clothing or on the body. Publications assessed users' attitudes and enjoyment, creativity, and educational value (Han et al., 2019; Tom Dieck et al., 2018). This has led to considering users' perceptions and assessing users' subjective norms, intentions, and attitudes, such as resistance or interest in these devices (T. Jung et al., 2020).

9. COVID-19 and Heritage. Research groups were not oblivious to the circumstances generated during the healthcare crisis. Taking this context into consideration, K. Jung et al. (2020) and Shih et al. (2020) put forward as disruptive proposals: the integration of VR and AR in the development of apps and being able to learn and enjoy remotely. This double option would maintain tourism sustainability, health safety and quality of heritage learning.

10. Accessibility. Another point of appreciation has been the attention to diversity, with special emphasis on hearing impairment. For the promotion of inclusive experiences, the importance of aesthetic components, motivation, satisfaction, and interactivity was considered important (Baker et al., 2020).

Contexts of application and their heritage value (OE2)

The location of experiences collected in the different studies indicates a predominance of AR outdoors (17). Indoor development remains second with 35% (12) (Figure 4).

In terms of information, there are major gaps. Hardly any data contextualizes where AR will be experimented with versus how it will be experimented with. However, there are exceptions where we see such references: Bienes de Interés Cultural (Schaper et al., 2018) or World Heritage Sites by UNESCO (Andrade & Dias, 2020; Kasapakis et al., 2016; Petrucco & Agostini, 2016).

Finally, the historical periods of greatest interest are the Contemporary Age (31%) and Ancient Age (20%) in contrast to Prehistory or the Middle Ages (0 results) (Table 4). However, the latter tend to find a place in those studies encompassing several periods (26%).

Figure 4. Location of AR Experiences
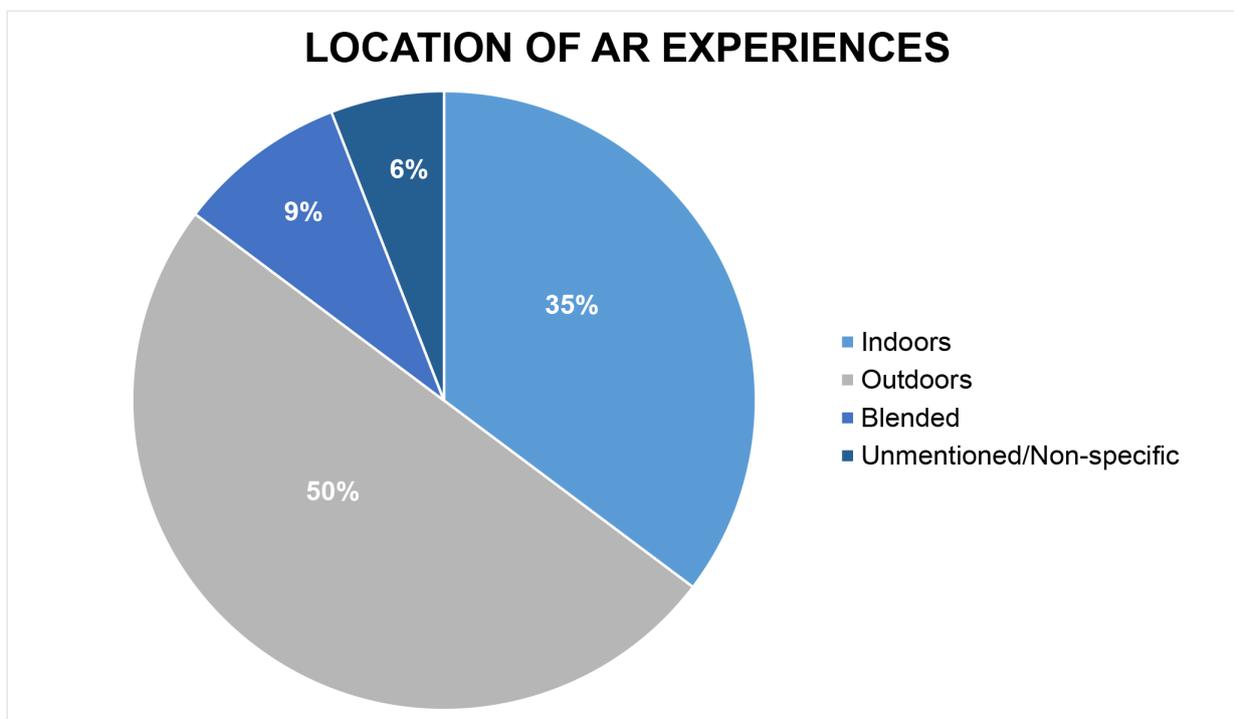
Note. Own elaboration.

Table 4. Effectiveness of Augmented Reality

Overall appraisal	Total publications	%
Positive	30	86
Negative	0	0
Mixed	5	14

Note. Own elaboration.

Technical and methodological proposals for Augmented Reality (OE3)

Broadly speaking, the articles that present AR self-development do so through applications for smartphones and tablets. These apps are mostly multiplatform (Android and iOS), and some consider the importance of multilanguage (Andrade & Dias, 2020; Bernarduzzi et al., 2021; Bhaskara & Sugiarti, 2019). In this sense, the most widespread forms of AR are: a) based on markers with geolocation (Andrade & Dias, 2020; Bhaskara & Sugiarti, 2019). In case location is not required, there is usually the overlay of 3D objects using QR code (Poce et al., 2019; Supriyono et al., 2020) or as detectable icons within a printed map (K. Jung et al., 2020); b) without markers of geolocation (Higgett et al., 2016; Jones et al., 2019; Mendoza-Garrido et al., 2021; Petrucco & Agostini, 2016; Shih et al., 2019).

Regarding software, Unity is the most widespread for application design (15 publications). It is usually combined with Augmented Reality platforms such as Vuforia SDK. However, there are other alternatives such as Augment, EasyAR and ARCore. Blender is usually used for 3D modelling, while SLAM (Simultaneous Localization and Mapping) technology is used for geolocation.

Despite the positive ratings on AR (Table 5), some problems are centered around physical and technological barriers. These include connectivity, spatial limitations, and lack of lighting in some spaces. Outdoors, these appreciations are of particular concern, resorting to photogrammetry or geolocated ray emission technique to solve object occlusion problems (Kasapakis et al., 2016). Other drawbacks noted are inaccurate GPS tracking, small screen or displayed information size, and failures during use (Bhaskara & Sugiarti, 2019; Petrucco & Agostini, 2016).

Table 5. Application of AR in different historical periods

Historical periods	Total publications	%
Prehistory	1	3
Ancient Age	7	20
Modern period	3	9
Contemporary age	10	29
Several periods	9	26
Not applicable / Not specified	5	14

Nota. Own elaboration.

Participant profiles (OE4)

In addition to the technology employed, one of the most decisive processes in this research is its implementation among users. The participants chosen may vary according to the objectives pursued and selection strategies (sample number and socio-demographic profiles). In some cases, testing is reserved for members of the research team because it is a prototype, although the most common is the introduction of AR to visitors. Thus, the researchers focused on non-participant observation and data collection during the experience.

In view of the above, the question arises as to what information is most sought after. Here, the most studied sociodemographic data were age and gender. The open nature of the museums translates into very open results at the audience level. The intergenerational richness of the exhibitions has posed an additional problem: how to classify visitors by age group. On the other hand, if the studies are oriented toward studying the student body, the ages and educational levels are much more specific. In the latter case, the students with the greatest prominence are those at the university level. When addressing the question of gender, there is considerable equality, although some people choose not to specify their gender (Higgett et al., 2016; Jones et al., 2019; T. Jung et al.,

2020; Poce et al., 2019). Other data of interest from the publications were languages, nationality, and purchasing power.

The timing of the research is subject to the number of visitors, the environment, and the planning of the research team. The most common method is to develop the whole experience during the same day, although there are cases where it is developed in several sessions.

When referring to data collection instruments, the most chosen is the questionnaire based on a Likert scale. In this way, the questions are usually formulated according to technical and propaedeutic aspects (usefulness, satisfaction, handling, and ease of learning) on a scale of 5 or more points. To achieve more qualitative results, some articles have proposed the introduction of open-ended questions, either partially (Poce et al., 2019) or completely (Jones et al., 2019).

Some studies conduct pre-test and post-test questionnaires to participants (Marto et al., 2020). The main purpose is to explore prior perceptions and knowledge, as well as subsequent impressions with AR. Most often, the elaboration takes place on-site after the experience, although there are also cases where they have been conducted online (Chang et al., 2019; T. Jung et al., 2020).

The second, more occasional method corresponds to semi-structured interviews. These are an enriching complement to closed-ended questionnaires. Some researchers propose elaborating interviews with groups of experts related to heritage, application development (Andrade & Dias, 2020; Tom Dieck & Jung, 2017), and even attention to diversity (Baker et al., 2020). When working with non-university students, teachers are often interviewed (Hammady et al., 2020; Petrucco & Agostini, 2016).

Another issue addressed in the experiences is the distribution of participants. The preferred typology by researchers is individual interaction with the device, although if we refer to the student body, the most frequent is to form groups to explore communication and collaborative learning capabilities (Kasapakis et al., 2016; Moorhouse et al., 2019).

Finally, it is worth mentioning the interaction or exposure time. This ranges from unlimited time (Hammady et al., 2020) to those five minutes (Marto et al., 2020; Marto & Gonçalves, 2019). In general, the average experience is usually between 20-30 minutes.

Socio-educational outreach (OE5)

The publications manifest a positive value on *serious games*, which are characterized by providing formal knowledge through gamification and entertainment (edutainment) (Barrado-Timón & Hidalgo-Giralt, 2019; Qian et al., 2021). To achieve the combination of fun and learning, narrative constitutes a key element for two reasons:

1. It encourages the use of correct terminology, implying a better level of knowledge (Bernarduzzi et al., 2021).
2. It enriches the capacity for historical interpretation and its relation to the present through emotional involvement. The psychological background promotes a greater immersive capacity, improving the understanding of people, places, and events, thus, awakening a greater cultural awareness (Supriyono et al., 2020).

Thus, the fact that narrative and immersion are associated is not accidental: when gameplay is invited, it is necessary to feel motivated to participate and discover. Therefore, predisposition and mood influence the interactions between the virtual and real worlds (Jones et al., 2019). This aspect is especially sensitive at early ages.

The use of AR facilitates the acquisition of new knowledge and skills complementary to curricular content, maintaining motivation and personal fulfillment. The literature shows positive recognition of field visits regardless of educational level (Hammady et al., 2020; Moorhouse et al., 2019). Likewise, a change in the opinions of participating teachers is appreciated after the experiences with AR. Above all, teachers value its interactive and immediate capacity, being an ideal complement for the introduction of active methodologies such as the Inverted Classroom (Mendoza-Garrido et al., 2021) or Project Based Learning (Kasapakis et al., 2016; Petrucco & Agostini, 2016).

The educational results have been beneficial when it comes to the alternative use of AR with wearable or multisensory technology. Participants were infected by the enthusiasm of taking part in an innovative activity. In general terms, they could better perceive the objects in the exhibits. As opposed to seeing them as isolated artifacts, they could find, through AR, a much more unified thematic approach compared to people who made the traditional visit (Tom Dieck et al., 2018). However, some resistance is still perceived at the social level.

For example, in the form of embarrassment. As such, museums or enclosed spaces are considered the most suitable implementation environments for the time being (Han et al., 2019; K. Jung et al., 2020).

Regarding multisensory studies, it is found that the information conveyed is better perceived when more information channels are used (Sardo et al., 2018). The visual and auditory components were the most influential in the immersive sensation, although smell is also favorably recognized. The comments made by the participants demonstrated a deeper understanding of the archaeological site in terms of History and Art (Marto et al., 2020; Marto & Gonçalves, 2019). Thus, participating in experiences through movement and the senses is manifested as an essential part of learning and cognitive development (Moorhouse et al., 2019).

Finally, the combination of Augmented and Virtual Reality offers undeniable advantages. According to the study by Shih et al. (2020), AR enables learning in a heritage environment, while VR offers the possibility of learning and interacting remotely.

4. Discussion and conclusions

The thematic diversity of the publications (OE1) allows us to have a much more global vision of the scope and impact of Augmented Reality in heritage education. Among the most innovative examples, we can mention multisensory experiences, wearable technology, and accessibility, which lead to improvements in emotional response, interaction, and inclusion when disseminating heritage in history education.

On the other hand, it is worth highlighting the allusions to the current pandemic in the most recent publications. The outbreak of COVID-19 hurt travel, either due to administrative restrictions or the insecurity of the population itself. One of the main consequences was the significant change in the way of relating to the environment, so the approach of the research teams integrating Augmented Reality with other remote options (VR) shows promise for the future.

If we refer to the contexts of application and their heritage value (OE2), we find a certain disparity in the historical periods, the most recurrent being the Contemporary Age. Perhaps it would be interesting to focus on those periods that are less explored, introducing pedagogical strategies that include the insertion of AR in combination with narrative.

The location of experiences with AR is striking, pointing to a growing interest in the improvement of geolocation systems in outdoor environments. Regardless of whether they are used indoors or outdoors, there is a lack of description and contextualization of the application environment. It would be interesting for future studies to go deeper into aspects such as ownership (public, private, mixed), location within the city or municipality to which a site belongs, local history, the estimated number of visitors and their origin, the organization of room space and the content exhibited. For open spaces, such as the urban center or archaeological sites that can be visited, it would be convenient to refer to the history of the city or site where the experience takes place and its historical, artistic, and cultural value. This scarcity of data could result from the low percentage of publications in journals related to History and Archaeology (10%), where these types of issues are more greatly emphasized than in more distant categories, as is the case for Science and Technology (56%).

Regarding the technical characteristics and methodological proposals of Augmented Reality (OE3), there is a special predilection for using geolocation. Behind this trend is the use of SLAM technology, in parallel with the sophistication of marker-less AR. Within the programs responsible for application development and 3D modeling, there is a commitment to using free and open-source software, which tends to offer multi-platform and multi-language applications. The negative aspects mentioned in the investigations analyzed are technical problems, especially lack of connectivity and geolocation failures. However, these appear to be circumstantial, with the possibility of being resolved in the short term through new updates or improved coverage.

As for the participant profiles (OE4), little information appears in the studies, with experiences aimed at university students being those included in the greatest number. The analysis also showed that the vast majority were based on case studies, focusing on conception, development, and use of AR in contexts of heritage interest. Although these contribute to the experimental application of new proposals, it would be advisable to develop studies at the macro level, with the possibility of resorting to the use of qualitative analysis software.

Finally, analyzing the socio-educational scope (OE5), this medium satisfactorily fulfills the visual, attractive, interactive, and pedagogical character necessary for disseminating historical and cultural heritage. Following UNESCO's approach, AR would cover, in a versatile way, all tangible and intangible cultures. This would include traditions, performing arts, social practices, rituals, or festive events (Boboc et al., 2019; Qian et al., 2021; Shih et al., 2020).

However, every technology comes at a price, and this aspect is not contemplated. By this, we refer to the "reality" of the digital divide, which is greater in developing countries (Mendoza-Garrido et al., 2021; Morganti & Bartolomei, 2018). Some impediments are immediate, detrimentally affecting the satisfaction and development of the experiences (e.g., connectivity problems of the cities themselves or the lack of smartphones by the participants).

In addition, another debate should be considered: the inclusiveness of AR. This topic, linked to heritage education, would be of great value to the academic community if it were to be explored. The generational disconnection of older people is often associated with the younger ones, growing up under the label of "digital natives." For this reason, overestimating the capabilities and experience of students is counterproductive. Frustration and impatience are even more accentuated when dealing with very young ages. According to (Petrucco & Agostini, 2016), such rejection generates a double disconnection: theoretical and technological.

Since Augmented Reality is involved, one must know how to handle digital content correctly. As such, it is paramount to have instructions and a simple interface. This could drastically reduce the proliferation of negative experiences, which could arise regardless of age. Below the umbrella of user satisfaction, another fundamental factor is the call to cater to diversity.

In addition to achieving a greater sense of inclusion, a favorable impact on engagement and performance is also generated (Baker et al., 2020). Therefore, exploring new ways to awaken this type of sensation would guarantee a better-quality heritage education. Linking with heritage education, one of the challenges pursued by history learning, is the creation of a critical citizenship committed to the present. The ability to address past, present, and future is more than feasible through AR.

However, this alone is not enough. The information to be transmitted is the main cog in the wheel. Therefore, aspects such as anachronisms should be avoided to awaken socioemotional links with history in a more reliable way. Decontextualization, whether accidental or justified, is detrimental to those unfamiliar with the content exhibited and its historical framework and can lead to confusion and errors in the future.

Some limitations of the study could be related to the five-year time frame established. Although it covers five years and coincides with recent popularity, conducting studies covering longer periods would be interesting. In this sense, the systematic and reproducible nature of the SLRs makes this purpose much more attainable.

The proposal towards which we are oriented is to stimulate reflection on the topic addressed to promote Digital Humanities towards optics more closely related to Educational Technology. The linking of both could be fundamental in achieving a better approach to the didactics of History and other disciplines by the educational community and the rest of society. This commitment is one of the main tasks to be developed if we want to achieve a committed and critical citizenship, active within the challenges of a globalized world.

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