USING AUGMENTED REALITY (AR) AS AN AUTHORING TOOL IN EFL THROUGH MOBILE COMPUTER-SUPPORTED COLLABORATIVE LEARNING

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Abstract

Several studies have been published to date about the use of Augmented Reality (AR) as a breakthrough technology in education, but most of them focused on the impact of using prepackaged information on student motivation and engagement. This paper analyzes the affordances and limitations of AR in second language learning, emphasizing its potential as transformative rather than delivery technology in teacher training programs. The novelty of this research is that it examines the attitudes and creative skills of pre-service teachers to meaningfully integrate AR-based projects aimed at teaching English from a Computer-Supported Collaborative Learning model. The sample size was 229 Education students from the University of Alicante (Spain), who created 47 vision-based and location-based projects through different authoring tools, and utilized them to teach English to children. Quantitative and qualitative data were gathered through a pre-post-test, teaching experience videos and class debates.

The research findings revealed that the teacher candidates lack practical training in AR content creation and implementation from a technological and pedagogical perspective, but their attitudes towards AR integration as transformative technology were very positive, particularly regarding student attention, collaboration and shared enjoyment. Spearman's Rho correlation coefficient also demonstrated a relationship between positive attitudes towards AR integration in EFL and the level of difficulty perceived by participants.

Keywords: Augmented Reality; attitudes; creative skills; collaboration; language learning

1. Introduction

The implementation of Augmented Reality (AR) has been steadily growing in different areas such as business, architecture or entertainment over the last two decades, thanks to the emergence of free or low-cost web-based programs and mobile applications. AR appeared in 1968 when it was first used by Ivan Sutherland in his development of the first head-mounted display system, but the term, originally associated with the aerospace and military industries, was not coined until 1990 by Boeing researcher Tom Caudell. Three decades later, as a result of AR software advances and the worldwide penetration of smartphones, this cutting-edge technology has been integrated in several fields such as sports, marketing or education since it provides a digital interactive experience based on a real-world environment. The myriad of AR development tools available today, such as Augment, Blippar, Layar SDK, Metaverse, Roar or ZapWorks, to name but a few, have facilitated the increasing use of this technology. In fact, a good amount of international companies such as Google, Microsoft, HP, Pokémon or IKEA have launched different gadgets and AR wearables, for example smart glasses and jackets, head-worn and wrist-worn devices, while others such as Facebook are currently developing their own AR products.

Although the adoption of AR in education is still in its infancy, several research works have come out to light over the last ten years, but most of them focused on examining the impact of using prepackaged information through AR tools on student motivation and engagement. The novelty of this study is that it evaluates the digital skills and attitudes of teacher candidates to develop their own AR-based projects and use them in the EFL classroom from a Mobile Computer Supported Collaborative Learning model.

2. Literature review

2.1. AR definition

Following Azuma's original definition (1997, 2016), AR is conventionally described as a system including three key elements: a combination of real and virtual content, the interaction in real time and the registration in 3D. Traditionally, AR has been closely associated with Virtual Reality (VR) as part of a mixed reality continuum, but AR uses the real world to provide digital information, enhancing the user immersive experience, while VR is an artificial "environment created by a computer system that simulates a real situation" (Fernández, 2017, p. 2). In other words, VR provides a fully simulated experience whereas AR is closer to the real environment.

Depending on the AR technology, there are different categorizations. Wojciechowski and Cellary (2013) identified three main types: first, marker-based AR, using a static image to trigger a visual overlay as superimposed additional content (3D, video, animation, etc.); second, markerless AR, allowing real objects to be used as triggers by scanning the surrounding environment; third, location-based AR, also known as GPS-based AR, in which interactive digital content is attached to a geographical location. Nevertheless, some authors include location-based AR within the markerless type, thus reducing the categories to just two, markerless and marker-based (Khoshnevisan & Len, 2018; Khoshnevisan, 2019), while others refer to them as location-aware and vision-based (Dunleavy & Dede, 2014). Alternatively, Azuma et al. (2001) provided a different AR typology based on delivery technology used for viewing the virtual and real environments: head-worn displays, handheld displays such as smartphones, and projection displays. Today AR is considered a state-of-the-art technology that no longer requires any specialized equipment to be used in the classroom, apart from a portable electronic device such as a tablet or a smartphone.

AR technology has been recently integrated at all levels of education, from preschool to college, as illustrated in several systematic reviews (Chen et al., 2017; Li et al., 2017; Sirakaya & Alsancak Sirakaya, 2018; Garzón et al., 2019). Although AR can be used in a wide range of scenarios, Yuen et al. (2011) summarized them into five: discovery-based learning, object modeling, skills training, AR books and AR gaming. The last two have been particularly prolific (Vate-U-Lan, 2012; Hockly, 2019), for example, 3D pop-up books have become quite popular among children, as they include printed triggers (e.g., images or QR codes) that activate a virtual overlay in the form of text, image, audio, or video, thus offering a more immersive experience to young learners. However, AR gaming is probably the area with more significant advances due to its global expansion and economic potential, as demonstrated by the constant emergence of new games such as ARSoccer, Live Butterflies, Alien Attack or the worldwide successful Pokémon Go.

2.2. AR in education

The studies about the educational use of AR have been mostly framed within two theoretical models (Dunleavy & Dede, 2014): the Constructivist approach and the Situated Learning theory. On the one hand, the Constructivist approach implies that learners assimilate new knowledge and information thanks to an active process based on learning by doing and performing authentic tasks through the interaction with each other and the surrounding environment. On the other, the Situated Learning theory postulates that all learning takes place within a community of practice, and it is the result of the interaction between the learner and the elements of the environment in which they live (context, content, communication and participation). In this sense, AR fits into both theoretical models, as it provides a student-centered immersive experience based on experiential learning and building on understanding.

However, most learning theories used today by in-service teachers were created before the digital age. Thus, some authors stressed the need to update and (re)design new theoretical approaches and pedagogical methods, in which technology is used in a transformative manner, and to (re)educate pre- and in-service teachers in the meaningful integration of AR through new models such as mobile Computer-Supported Collaborative Learning (Song, 2014) or Connectivism (Zhang et al., 2020). MCSCL, short for mobile Computer-Supported Collaborative Learning, is a pedagogical method concerned with how students can learn together through mobile devices and shared spaces by combining different principles such as mobility, context, interaction and collaborative learning. This is all possible thanks to the adoption of mobile devices and other wirelessly networked handheld computers, which can be used by teachers and students in the classroom without losing face-to-face contact. In contrast with cooperative work, where students work separately in common assignments, collaborative work involves "joint and symmetrical engagement of participants toward shared learning and problem-solving goals" (Jeong & Hmelo-Silver, 2016, p. 247). Different authors highlighted the positive impact of MCSCL on student communication, engagement and motivation as it enhances context-rich learning, collaboration and mobility (Yaslam & Iahad, 2013; Hsu & Ching, 2013).

Regarding the benefits of integrating AR in education, some authors emphasized that it promotes critical thinking, enhanced spatial learning, decreased cognitive load, increased motivation, better representation of abstract concepts and higher achievement (Dunleavy et al., 2009; Norlund et al., 2016; Sirakaya & Alsancak Sirakaya, 2018). All these affordances can be summarized in four key concepts: immersion, representation, problem-solving and gamification.

However, the challenges for a meaningful integration of AR in the classroom can be twofold: technological and pedagogical (Alkhattabi, 2017; Khoshnevisan & Le, 2018; Hockly, 2019). Among the technical constraints, authors usually refer to the small number of AR apps or connected devices available in real-life classroom settings, the cost of its implementation in most cases, and the technical problems experienced about GPS and marker-based AR technology (image recognition, limited processing power, storage capacity, connectivity, etc.). In relation to the pedagogical drawbacks, some studies indicated the lack of IT skills and AR preparation among in- and pre-service teachers, inappropriate technological pedagogical models, and a certain concern about the usability of AR technology among educators. Other reported limitations were lack of privacy, information overload and student distraction. Figure 1 summarizes the main affordances and limitations of AR integration as described in different studies.

Affordances	Immersion	context interaction, experiential learning, building on understanding.
	Representation	reduced cognitive load (spatial and abstract concepts), multitasking & ubiquituous learning
	Problem-solving	enhanced cognitive and higher-order thinking skills, self-learning capabilities & confidence
	Gamification	increased interest and enjoyment, engagement & motivation, satisfaction
Limitations	Technical	lack of availability of AR educational tools (free or low-cost)
		lack of electronic devices in some educational settings
		technological problems (connectivity, image recognition, etc)
	Pedagogical	lack of digital skills and adequate training of educators (concern, negative attitude, etc.)
		lack of adequate pedagogical models for AR integration in the classroom
		lack of academic and tecnical support

Figure 1. Summary of AR affordances and limitations in education

2.3. AR in language learning

The implementation of AR in language learning is constantly increasing, as attested by the number of works published over the last five years (Khoshnevisan & Le, 2018; Parmaxi & Demetriou, 2020). Although most of them concentrated on adult learners, some articles explored the impact of using AR with children in the EFL classroom (Dalim et al., 2016), and a few studies focused specifically on certain language areas and skills, for example, learning vocabulary through place-based mobile games (Godwin-Jones, 2016), or learning case grammar by dynamically creating quizzes based on real-life objects (Draxler et al., 2020).

Using mobile AR gaming in language learning has lately created great interest (Taksiran, 2019; Wu, 2019). In fact, new areas have emerged such as location-based mobile games for language learning (LBMGs), which "combine place-based experiences with multimedia content and make use of game-design principles and scenarios to create real-world contexts for learning" (Richardson, 2016, p. 36). The idea underlying these studies is that AR can provide an immersive real-time gaming environment with a focus on language, thus promoting ubiquitous, formal and informal learning.

Although the integration of AR in language learning is emerging, and has been sometimes criticized for lacking "strong theoretical support such as frameworks and models" (Zhang et al., 2020, p. 217), different authors have demonstrated that its implementation may be well grounded in the theoretical foundation of Constructivism and Situated language learning, since "all learning takes place within a specific context and the quality of the learning is a result of interactions among the people, places, objects, processes, and culture within and relative to that given context" (Dunleavy & Dede, 2014, p. 736). Based on these perspectives, the reader response theory emphasizes the role of meaning created by readers. This approach is then considered applicable in language learning, particularly in engaging students to read (Gonzales & Courtland, 2009; Mizuno, 2015). By using a reader response theory, students do not only analyze the writers' purposes in creating the text, but also create meaning by using their background knowledge when interacting with the text (Rosenblatt, 1990). In this case, through reader-response based activities, readers are encouraged to play an active role in interpreting the meaning of the texts.

Studies have elaborated some benefits of the reader response theory in the classroom. Carlisle (2000) found out that the implementation of the reader response theory does not only help students learn the semantic domains of the texts, but it also encourages them to explore the text and give critical responses. In line with the previous findings, Gonzales and Courtland's study (2009) highlights the link among reader response, readers' interests and critical thinking. Mizuno (2015) strengthens this argument by proposing that responding to reading materials gives "a positive impact on the cognitive process of reading" (p. 18). Laboid (2016) suggests that the implementation of reader response journals in class helps students know themselves and gain "a sense of ownership of their learning experiences and to gain confidence and self-efficacy which are likely to affect positively their reading and writing attainments" (p. 111). He further suggests some reader-response activities that are in line with the teaching of reading strategies, such as outlining, paraphrasing, referential questioning and applying ideas to the real world. However, a recent study by Biglari (2017) shows that although there is no straightforward relationship between reader responses and students' comprehension, classroom practice based on reader responses decreases learners' anxiety.

Considering the positive relationship between reader-response approach and language learning, this research focuses on elaborating the implementation of digital reader response theory in technology-enhanced EFL reading class.

2.4. AR in teacher training programs

Teacher training programs have incorporated AR with different levels of success, the first problem being that in-service teachers are mostly unfamiliar with this breakthrough technology (Khoshnevisan, 2019). For this reason, Yang (2018) developed a model to assess pre-service EFL teachers' attitudes toward AR integration, due to the paucity of empirical research in this area, while Osuna et al. (2019) reported some obstacles at the university level, such as lack of proper teacher training and lack of conceptual foundation.

The second problem is that these training programs usually focus on learners merely as AR recipients rather than content designers and creators, which puts them in a passive position. Ke and Hsu (2015) pointed out that studies of vision-based mobile AR are relatively few and mostly based on learners' use of already existing lessons in which learning content is simply delivered. However, AR may also be used to enhance higher-order thinking skills among teacher candidates (Bower et al., 2014). In fact, using technology in a transformative manner would help future educators build their own confidence and competence, "yet teacher training often does not help future or current teachers develop these skills" (Stickler et al., 2020, p. 137).

In a pioneer study, Ke & Hsu (2015) investigated the effectiveness of smartphone-based, AR artifact creation in reinforcing the technological pedagogical content knowledge (TPACK) of teacher candidates, concluding that "mobile AR artifact design tend to better promote integrative competencies that connect technology, pedagogy, and/or content knowledge" (p. 22). Similarly, Sirakaya & Alsancak Sirakaya (2018) emphasized the need to include teachers as the implementers of the AR system while Sáez-López et al. (2020) advocated for initial teacher training in order to be able to design and apply AR-based practices in the classroom. In this sense, Zhang et al. (2020) reinforced the idea of instructors playing a dual role as a teacher and AR designer so that they "can better evaluate their students' needs and customize the technology in their teaching" (p. 230).

3. The study

3.1. Objectives

This study seeks to analyze the digital skills of teacher candidates in order to develop AR-based projects aimed at teaching English to children and young learners, and to assess the impact on their attitudes towards AR integration. Specifically, the three research questions are as follows:

- Can teacher candidates develop their own AR-based projects from a MCSCL model?

- Can teacher candidates meaningfully implement their own AR projects with children in a real language classroom setting?
- What are the participants' attitudes towards AR integration in the EFL classroom at the end of the experiment?

A mixed-method research design was adopted, in which participants were provided with a set of instructions as summarized in Figure 2.

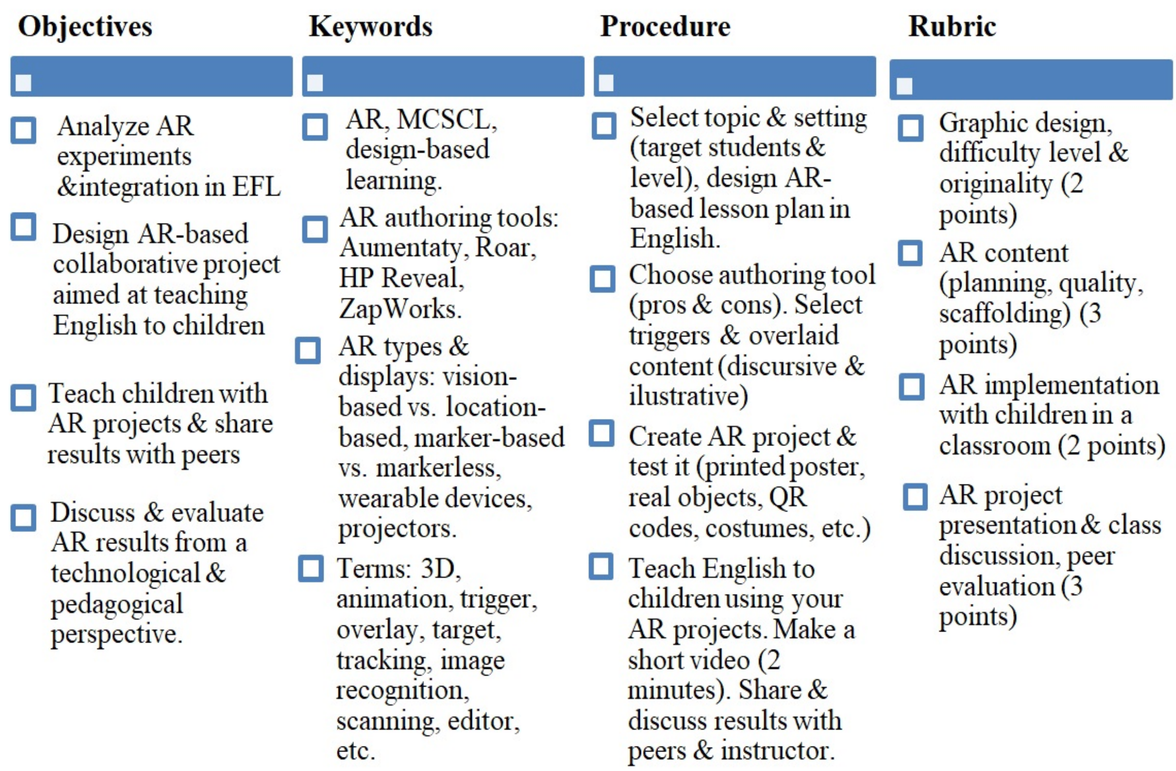

Figure 2. Summary of AR instructions provided to participants

3.2.. Participants and study context

A total of 229 teacher candidates from the College of Education took part in this experiment, with 84% being female students and 21 years old on average. All participants were enrolled in the subject 'Integrating Skills in English' at the University of Alicante, a medium-sized university located on the southeastern coast of Spain. This is an elective class offered daily throughout two consecutive months to third-year Education students who are willing to become preschool and elementary teachers, where they learn how to use effectively different methods and resources to teach English to children. The methodology is based on a combination of MCSCL and project-based learning, in which in-class activities are strategically reserved to project development and student interaction through face-to-face exercises and the use of personal electronic devices. Thus, wireless interconnected handhelds such as laptops, tablets and smartphones are used to promote collaborative learning and peer evaluation. The two-hour daily lessons take place in large classrooms where students can easily move around in order to collaborate, share and discuss the results with their peers and instructors. For the project implementation in a real classroom setting, the Education students obtained informed consent from school administrators and in-service teachers located in the area to utilize their AR-based projects to teach English to children.

3.3. Procedure and instruments

The AR experiment was carried out during twelve two-hour sessions, comprising seven different stages as shown in Figure 3. First, teacher candidates were provided with an overview of the AR project and became introduced to different AR types (location-aware and vision-based). Next, all participants were randomly assigned to teams of four to five members in order to plan an English lesson on a topic they selected, including target students, language level and types of activities. The third and fourth stages consisted of three training sessions on different authoring tools, requiring each team to select one based on their learning goals and project needs. Then, they had to create or find different images or objects (triggers) and multimedia content (overlays) for their educational projects, including discursive and illustrative representations, and organize them in a scaffold manner. The development stage comprised three two-hour sessions, in which the instructor had to assist participants in some technical as well as pedagogical issues such as content creation and format, tool limitations and possible obstacles. In the following stage, each team had to implement their AR project with children in a real classroom, and prepare a two-minute video about their teaching experience. In the last stage, all participants presented simultaneously the AR projects to their peers in 10-minute rotations and evaluated them through clickers, after discussing their results and teaching experience.

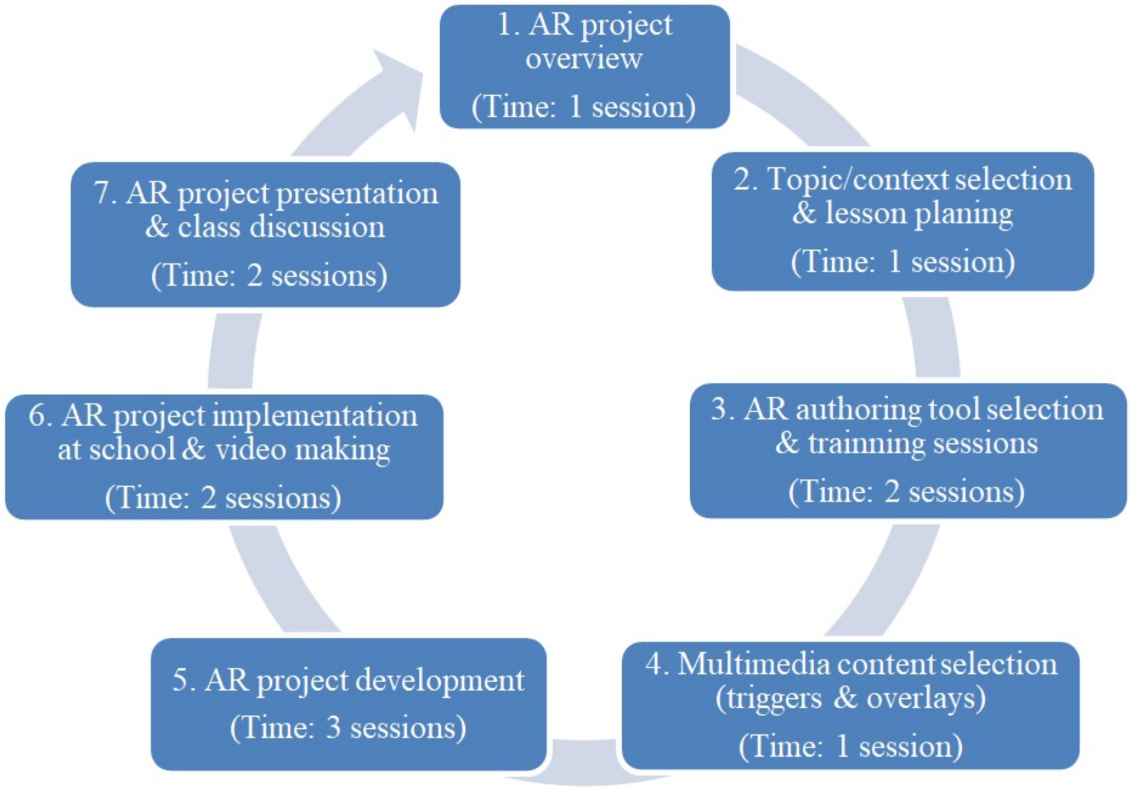

Figure 3. Stages of the AR project experiment (12 two-hour sessions)

Quantitative and qualitative data were gathered through different research instruments: a pre-post-test, AR projects, teaching videos and class discussion. The pre-post-test administered on-line included different sections, one specifically aimed at measuring the participants' attitudes towards AR, which was partly based on Küçük et al. (2014), on completion of the experiment. For the AR projects, students were free to choose any authoring tool that best fitted their technical and pedagogical needs, but the corresponding images and video links needed to be posted in their blogs. The class discussion consisted of semi-structured debates, in which students were asked about their teaching experience with children as well as their self-perceived learning outcomes.

4. Findings and discussion

4.1. AR project samples

A total of 47 AR projects addressed to different educational levels were created on a wide range of topics such as the human body, the solar system, colors and shapes, musical instruments, feelings and emotions, recycling, etc. The number of vision-based projects was considerably higher than the location-based ones since most teams planned to implement their projects with children inside the classroom. As regards the authoring tools, the three most widely used were Aumentaty, Roar and HP Reveal, all of them offering free sign-up options with limitations. Aumentaty provides free access to educators, who can publish their projects at no cost and enjoy certain options such as (re)editing and analytics capabilities, but the AR projects created expire after a certain period of time, and this tool requires participants to download the Creator program to develop their projects and the Scope app to view them. Roar is a business-oriented tool with different pricing options, but users can sign up for free with a limitation of 20 views and 4 ARs. HP Reveal, formerly known as Aurasma, was initially a very popular tool among participants for its intuitive interface, free access, unlimited scans and social networking options, but it was discontinued for a while and later redesigned and renamed as LinkReader with different features.

The AR projects developed by the teacher candidates used three types of trigger elements, which needed to be closely related with the main topic of their English lesson: posters or murals, costumes and real-world objects, as illustrated in Figure 4.

Figure 4. AR projects. From top left to bottom right: Art and museums (poster), The Digestive System (costume), AR project presentations (Ocean poster), AR project implementation with children (Farm animals mural).

Each project was required to include a minimum of ten multimedia activities, which needed to be diverse and sequentially organized for the target students, depending on their time to completion and difficulty level. These activities could be based on information and exercises previously created by the participants or linked to already existing web-based materials. Following Ke and Hsu (2015), the overlaid content included was classified into discursive representations, such as text-based and voiceover explanations, and illustrative representations, for example 3D images, songs, short video lessons, etc. The activities were aimed at strengthening different language and reasoning skills among children, such as listening and reading comprehension or vocabulary retention, and they were linked to a wide range of on-line games, for example painting, flash cards, crosswords, word match or jigsaw puzzles, as shown in Figure 5.

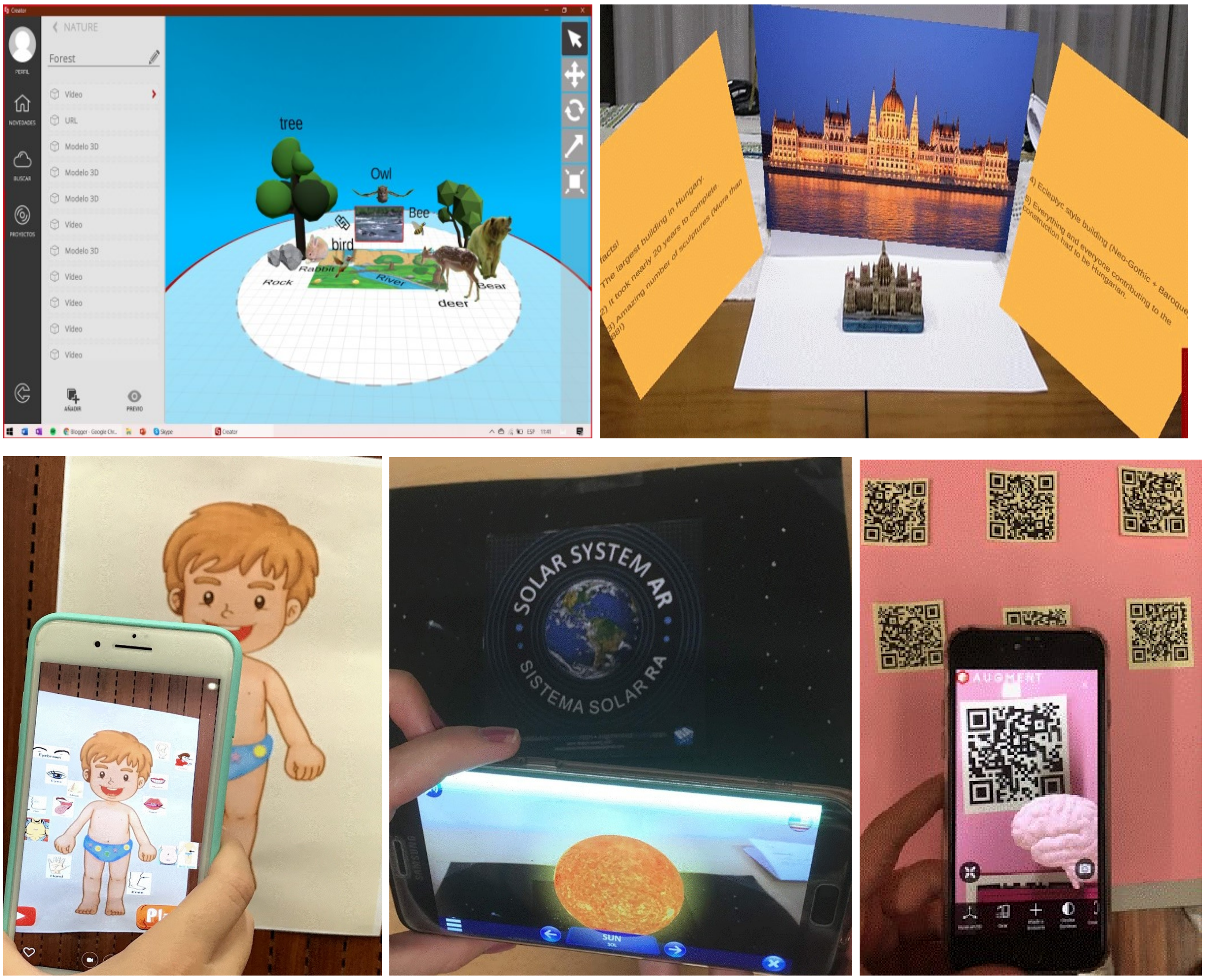

Figure 5. AR multimedia activities. From top left to bottom right: Creating a project on wild animals (Aumentaty), Reading activity on European monuments, On-line game about the Human body, Solar system 3D image, QR codes and games related with the Human brain.

4.2. Data results and discussion

According to the pretest results, nearly all the teacher candidates had previously received theoretical instruction about AR in education, but only 48% of them had actually experienced it as real users and just 11% had created an AR project in the past. In the section about AR-related terminology, only three terms were widely recognized by participants (3D, scan, link), while the other seven (marker, trigger, overlay, tracking, extended tracking, hotspots, image target) were unknown before the experiment.

The post-test results indicated that the technical aspects (Items 3-7) were perceived as more difficult than the pedagogical ones (1, 2 & 8), as shown in Table 1. Due to the lack of expertise in AR creation, selecting an authoring tool and learning how to use it became a complex task since they had previously to reflect on issues such as mobile availability, software compatibility, interface design, user-friendly implementation and pricing options. Some hindrances reported in the development stage were limitations to content creation and number of views as well as project editing and publishing options. Regarding the implementation in a real classroom, costumes and real-world objects were highly praised, as they were said to provide a more engaging and immersive experience. Similarly, tablets were preferred over smartphones thanks to their enlarged field of view (FOV).

Participants were trained in different AR software development kits (SDK) in the third stage of the experiment, but they were encouraged to explore and watch some video tutorials before selecting the authoring tool that best fitted their own needs. The three most popular were HP Reveal, Aumentaty and Roar. HP Reveal, formerly known as Aurasma, was a free extended reality platform, which allowed them to easily create AR content or new Auras through the HP Reveal studio website, but the platform was shut down in 2020, and was later renamed as Linkreader, with different and somewhat limited options. Aumentaty is a free AR development tool for Windows, specifically designed for education. The teacher candidates needed to download the Creator software from the website to develop the project, and the Scope app to view it on their tablets and smartphones (Android and iOS). It was praised because of its intuitive interface (see first image in Figure 5) and its 3D image gallery, but some participants experienced technical problems when importing 3D objects. The Roar Augmented Reality platform enabled users to overlay real world objects with digital content through image markers and other forms such as detecting surfaces, offering 20 views and 4 AR for free. This tool was praised for its design options and functionalities, though some teacher candidates complained about the very limited number of scans in its free version. Other free or freemium tools used, some with watermarks, were Augment (see Figure 5), ARkit, Metaverse, Vuforia and Wikitude.

Pedagogically, the most common problems observed were lack of proper planning and poor quality of some multimedia content included in the AR projects. Although the instructions provided clearly indicated that the projects should be organized to facilitate scaffolded learning, a few teams prioritized design over content, therefore, some projects became a collection of unconnected activities. However, most of them integrated meaningfully the digital content in a sequential manner by using arrows.

Table 1. Level of difficulty in the AR project development (from very easy (1) to very difficult (5))

Descriptive statistics (N=229) Cronbach's Alpha: .829	**M**	**SD**
#1. Selecting the topic and learning objectives of the AR project	2.34	.809
#2. Selecting the key vocabulary and designing the English language lesson	2.57	.795
#3. Selecting the authoring tool (interface, software compatibility, pricing, etc.)	3.46	.939
#4. Learning how to properly use the selected authoring tool	3.58	.927
#5. Selecting/creating the triggers for the AR project (markers, images, location)	2.67	.961
#6. Selecting/creating the overlaid virtual content (discursive and illustrative)	3.21	.806
#7. Creating the whole AR project	3.44	.860
#8. Using the AR-based project to teach children	2.82	.898

The post-test included a section aimed at measuring the participants' attitudes towards AR, which included negatively-worded statements to avoid the acquiescence bias (Küçük et al., 2014). As Table 2 illustrates, statistical data binning revealed that 93.45% of respondents agreed with the positively worded statements included in items 1-6, 13 & 14 and that 69.44% disagreed with the negatively worded statements in items 7-12 (reverse coding). Consequently, these scores evidenced the positive attitudes towards AR integration in the EFL classroom among participants, particularly regarding the fun factor (M=4.34) and the willingness to learn more about AR programs (M=4.30) and to use them in the future (M=4.30). The lower yet positive values corresponded to self-perceived learning gains (M=3.78) and better concentration (M=3.55). These results clearly indicated that the teacher candidates are open to adopting AR as a transformative technology in their role as students as well as future educators.

Table 2. Participants' attitudes towards AR integration (from (1) completely disagree to (5) completely agree)

Descriptive statistics (N=229) Cronbach's Alpha: .860	**M**	**SD**
#1. I enjoyed all AR-based projects presented and discussed in class.	4.10	.688
#2. Demonstrations of AR lessons in English increased my curiosity.	4.07	.763
#3. I think English classes will be more fun if teachers use sometimes AR lessons.	4.34	.693
#4. AR lessons give a sense of reality in the environment.	4.00	.775
#5. I think I learned more in English thanks to the AR lessons.	3.78	.922
#6. I can concentrate better when a lesson is explained with AR.	3.55	.905
#7. AR lessons do not attract my attention.	1.94	1.247
#8. AR lessons make my learning difficult because I find them confusing.	1.80	1.049
#9. There is no need to use AR in the classroom.	1.84	1.064
#10. Using AR in the classroom causes waste of time.	1.62	.991
#11. It is difficult to use AR programs in English lessons.	2.23	1.053
#12. I get bored while I am using AR applications in class.	1.60	1.066
#13. I want to use AR lessons in the future with my students.	4.27	.921
#14. I want to learn more about AR programs and how to use them in the classroom.	4.30	.927

Additionally, Spearman's Rho correlation coefficient revealed a certain relationship between the level of difficulty perceived by the participants when creating their projects and the attitudes towards AR integration in the classroom. This correlation was weak in the case of negative attitudes ($p=.000 < .01$), and more moderate as regards positive attitudes ($p=.042 < .05$). Therefore, it seems that the participants with positive attitudes found the AR creation project less complex, although some other factors should be taken into account, such as previous experience and motivation. Similarly, a positive correlation was observed between the level of difficulty and the time needed to develop the AR project, as shown in Table 3. Nearly 45% of the teams finished the project in less than 5 hours and 38% did so in 5-10 hours, as opposed to the remaining 17% who needed more than 10 hours to create it.

Table 3. Spearman's rho correlation coefficient between different rank variables.

		Positive Attitudes	Negative attitudes	Time creating AR
Difficulty level	Correlation coefficient	-.134*	.239**	.175**
	Sig. (2-tailed)	.042	.000	.008
	N	229	229	229

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

In a semi-structured debate, following the project presentations in the classroom, the teacher candidates shared their thoughts and beliefs about utilizing AR technology to teach children. Nearly all of them agreed that AR seemed to enhance children's motivation and engagement, thanks to visual interactive games which helped them make connections more easily. In fact, children were observed as exploring, pointing, painting, reading, writing or singing while having fun, so the participants believed AR could effectively provide an immersive experience and a lifelike environment, particularly when using costumes and real-world objects as triggers. They also stressed the fact that AR technology helped children better associate and understand some abstract and spatial concepts, and it was safer to experiment with certain topics in order to avoid harmful consequences given in real life. Furthermore, some in-service teachers who monitored the experience showed a strong interest in such a breakthrough technology while acknowledging the positive impact it had on their students' attention and motivation.

However, some of the obstacles reported were related with usability difficulties, particularly limitations with multiuser interaction since most AR programs are single-user oriented. As the teams were made up of 4-5 members, the teacher candidates could simultaneously utilize their project with several children but class management could become a problem depending on the teacher-student ratio and technological resources available in the classroom. Moreover, the teacher candidates were concerned about how to deal with some learner differences and AR implementation. Regarding technological problems, a few participants complained about feeling frustrated during the teaching experience because of low image sensitivity and recognition, scan limitations, limited hardware and poor connectivity in some spaces. Furthermore, some in-service teachers expressed their concern about the impact of using AR on children, for example, decreased peer-interaction and the socially isolating factor, also known as attention tunneling.

The post-test results revealed that the overall satisfaction with the AR experiment in the EFL classroom was high among the teacher candidates, as 45% of them indicated they were completely satisfied and 38% very satisfied, in contrast with 11% who took a moderate position and the remaining 6% who were not satisfied.

5. Conclusions

This study demonstrated that AR technology can be meaningfully integrated to train teacher candidates in the EFL classroom from a MCSCL model. As suggested by Bower et al. (2014), there is nowadays an overemphasis on lower-order thinking skills in the curriculum, which "constrains the amount of time that can be dedicated to having students think critically and utilize knowledge in creative ways" (p. 12). Although most of the research previously done about AR has focused on the impact of using prepackaged information on student motivation and engagement, the results of this paper show the effectiveness of adopting authoring tools in teacher training programs in order to enhance higher-order thinking skills and create collaborative projects aimed at teaching English to children. The results confirm the first two research objectives related with the participants' skills to create and utilize AR-based projects to teach English to children. Consequently, there is a need to make teacher candidates assume a more active role in transformative technology as content designers and creators, not just recipients.

The novelty of this experiment is that it analyzed the impact of AR implementation on the participants' attitudes by covering all the different stages in the AR development process: from pre-production by teacher candidates to implementation with children in a real classroom setting. Most of the 47 projects created were vision-based, and those using real-world objects and costumes as trigger elements were highly valued since they provided a more immersive experience and feeling of presence. According to the participants' comments, the overlaid content of the AR projects enhanced learning in a real-life context, as it comprised a wide range of interactive multimedia activities, including both discursive and illustrative representations. In line with Sáez-López et al. (2020), the affordances of the integration of AR as a design-based learning tool were increased participation, creativity and greater enthusiasm. As a result, the participants' attitudes towards AR were very positive, particularly regarding shared enjoyment, attention, and willingness to learn more about this technology.

However, several hindrances were observed at different stages of the experiment. Technologically speaking, certain limitations were reported about content creation and publishing options, poor connectivity, low image sensitivity and shortage of resources.

Pedagogically, some projects lacked adequate lesson planning or scaffolding and included poor quality learning activities since they were image- rather than content-oriented, thus they were not purposeful. In this sense, the teacher candidates require better training in both technological as well as pedagogical models in order to know how to meaningfully effectively AR into the EFL classroom. In line with Whyte & Schmid (2019), "clear principles for material design and examples of good practice are needed to help teachers develop an increased awareness of the different types and levels of interactivity and language interaction supported by technology" (p. 351). Furthermore, in-service teachers who monitored the experience were interested in learning more about this cutting-edge technology but expressed some concern about the impact on peer-interaction among children.

From a CSCML model, AR can be effectively employed as a transformative technology with multiple educational purposes, such as facilitating mobility and an immersive environment to young learners, as well as promoting collaborative learning and creative skills among future educators. However, more technological advances are necessary in relation to the availability and affordability of AR applications and authoring tools, and better adaptation to real classroom settings in terms of software adaptability and multiuser interaction. Further research is needed due to the constant emergence of AR apps and wearables and their implementation in different educational areas. Future studies need to delve more deeply into content creation and classroom implementation, and future educators need to be properly trained to integrate AR in and outside the classroom.

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