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Article

Teachers' Professional Training through Augmented Reality: A Literature Review †

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Abstract: The Practicum is regarded as a fundamental aspect of the training of prospective teachers. In addition, digital tools are increasingly used to enrich a traditional face-to-face experience. However, the technological exploitation of augmented reality (AR) by undergraduate students studying early child-hood and primary education is low. A Systematic Literature Review (SLR) on the use of augmented reality (AR) in teacher training was conducted. Based on the overarching objectives of the ERASMUS+ project, entitled Digital Practicum 3.0 Exploring Augmented Reality, Remote Classrooms and Virtual Learning to Enrich and Expand Preservice Teacher Education Preparation (2020-1-ES01-KA226-HE- 096120), the ultimate purpose of this study was to assess whether the use of this resource favours learning and expertise. Two main results are prominent. First, it is noteworthy how the use of this digital technology is limited, given the scarcity of studies. Second, the research studies available focus largely on the benefits of the use of AR in teacher education at a theoretical level. Thus, future research needs to further explore the use of AR in teacher training specially focused on the student teachers' learning processes.

Keywords: Augmented reality; Teacher Education; SLR; Digital technologies for education

1. Introduction

The Practicum subject plays a fundamental role to train prospective teachers [1]. However, there are few technological initiatives for undergraduate students in Early Childhood and Primary Education that favours such learning [2].

Looking backwards, only a decade ago from now, great transformations have been occurred impacting society, economics, politics, and, also, education. One of the most significant transformations has been the digitalization of almost every representation (e.g., objects, images, sounds, documents, etc.) giving rise to the arrival of the so-called In-formation and Communication Technologies (ICT) society, a revolution that has pro-moted a different way of understanding our world and the rise of new types of learning that necessarily promote interactive and innovative processes [3]. This revolution was accelerated by the recent COVID-19 outbreak, that force professionals around the world to urgently adapt to digital formats [4].

Confronted with these changes, educational institutions have to adapt rapidly to let their learners to acquire and develop skills in, with, and for digital technologies that are necessary for the new societal challenges [5]. Consequently, many schools at all levels have been prompted to include a number of technological resources that endorse the teaching-learning process through the use of innovative pedagogical approaches. It is commonplace that, nowadays, students do not learn in the same way as years before. Therefore, it has been necessary to find effective and engaging pedagogical approaches to implement technologies and adapt the curriculum contents [6,7].

One of the current and future trends in education is the use of Augmented Reality (AR), an immersive technology that uses virtual elements on real scenarios and that teachers could make use of [8,9].

However, it is noteworthy that in the last five years, few systematic reviews have been published in the literature (as indexed in Scopus and Web of Science) that are related to the use of AR in teacher training. As Chang et al. [10] reported there is a need for experimental studies to test the effectiveness of the use of AR in education. The available systematic reviews approach thorough bibliometric analysis of scientific production but fail to characterize the bibliometric indicators associated with the studies that analyse the use of AR in the specific domain of teacher training. Most of the studies analyse the scientific production of the use of augmented reality and artificial intelligence in a general sense [11] and within specific contexts such as:

- Science Education [12–17]
- Language Learning [18],
- Student Training Through M-learning [19]
- Teaching Didactic Planning [20]
- Development of Emotions [21]
- Motivation and School Performance [22]
- The Use of Augmented Reality in Informal Learning Environments [23]

In the present study, a Systematic Literature Review (SLR) was conducted to identify published research papers related to the use of AR in teacher education. Based on the main objectives of the ERASMUS+ project entitled Digital Practicum 3.0 Exploring Augmented Reality, Remote Classrooms, and Virtual Learning to Enrich and Expand Pre-service Teacher Education Preparation (2020-1-ES01-KA226-HE-096120), the ultimate goal is to examine whether the use of this resource favours student teachers' and schools' teachers learning and expertise.

Theoretical Framework

Technology-enhanced learning constitutes a crucial aspect of today's educational pro-grams [24]. The use of technologies combined with active methods triggers quality teaching as they facilitate attending students' needs and pace of learning [25,26].

AR is defined as a part of the mixed reality within the reality-virtuality continuum that improves real environments through the use of digital information projected on them. AR uses technological applications "[…]to enrich users' perceived physical environment with interactive virtual objects and information in real time" (p. 2) [15]. The immersive nature of this technology makes it adaptable across any educational level and subject [27].

Even though AR and Virtual Reality (VR) are considered as part of the same spectrum (e.g., mixed reality), if they are confronted, it is noticeable that their relationship with the real-world changes, which leads to different learning experiences when presenting the subject contents to the students. Virtual reality takes the users to a world that does not exist and AR allows us to be in the real world by adding a new perspective in which additional information is included through the superimposition of virtual elements in three dimensions [28]. The main characteristics of AR can be summarized as follows [29]:

- It is a mixed reality that allows a view of the physical environment accompanied by visualization of interrelated digital components.
- The input is integrated and occurs in real time, i.e., both real and virtual information are delivered in parallel.
- It offers a variety of layers of digital information, allowing the interleaving of different digital elements, such as text, graphics, audio, video, web pages, 3D objects, etc.
- It allows interaction, which means the result of the digital information allows the user to interact with it; for example, 3D objects allow for a variety of options such as the objects being rotated or enlarged, where the animation can even be activated or deactivated. It can improve or change the parts of reality when using techno-logical devices that display additional information seen through the screen. It then requires the users' mediation for it to take place.

Types of Augmented Reality (AR)

Depending on the physical component or marker that activates the digital information, different types of AR can be differentiated. The levels are understood as a type of measurement, which indicates the complexity of the technologies that are involved in developing augmented reality systems. Thus, the more levels there are, the greater the possibilities the applications can provide. Table 1 shows all the levels that currently exist, taking into account their physical and virtual components, as well as their functionality [30–34].

Table 1. Levels of Augmented Reality.

Based on its physical component	**Based on its virtual component**	**Based on functionality**	
		Functionality: increased perception	**Functionality: the creation of an artificial environment**
Level 1: black and white pattern (QR codes)	Image	Documented reality and virtuality	To imagine the reality that could be in the future, associating the real with the virtual
Level 2: image	3D	Reality with augmented perception or comprehension	
Level 3: 3D entity	Video	Perceptual association of the real and the virtual	To imagine the reality that was in the past, associating the real with the virtual
Level 4: a point on the planet determined by GPS coordinates	Audio	Behavioral association of the real and the virtual	
Level 5: thermal footprint	Multimedia	Substitution of the real by the virtual or virtualized reality	To imagine an impossible reality

As shown in Table 1, the AR levels are based on technological criteria. However, the classification based on functionality: *increased perception*, could be better suited for educational approaches as the different virtual projections can evoke particular learning patterns in the students.

2. Materials and Methods

A systematic review is a type of study that analyses the scientific literature production in a given range and area of knowledge [35]. For this reason, the PRISMA protocol and its extension PRISMA-S were used, in addition to a meta-analysis of quantitative studies [36]. The PRISMA protocol consists of four steps to direct the design and implementation of systematic reviews: Step 1. Main goal; Step 2. Review protocol; Step 3: Data mining; Step 4: Data analysis.

Step 1: The main goal of the present systematic review is to analyze research related to the use of AR in teacher training. To meet this goal, the following research questions were posed:

Q1. What are the main bibliometric indicators of scientific production in terms of publication sources of a regional and institutional origin?

Q2. What are the most representative keywords used by the authors?

Q3. What types of studies are most common in the scientific literature?

Q4. Which studies state the reliability and validity obtained in the design and application of the instruments applied?

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Q5. Which augmented reality components are used depending on the user's virtual component? At which stage of teacher training were they applied?

2.1. Validity

Step 2: Review protocol.

Three types of validity were measured in this SLR:

- Internal validity: the analysis of each study included the analysis of the keywords, abstract, article content, methodological approach, and type of research.
- External validity: the studies that lacked validation and discussion of the results were excluded.
- Conclusion validity: the Joanna Briggs Institute evaluation criteria for systematic literature reviews were applied37 in relation to transparency, replicability, quality, and meta-aggregation.

2.2. Inclusion and Exclusion Criteria

The Keywording technique and the Mendeley manager were used to manage keywords 38. The following criteria were applied:

- Inclusion criteria: (a) publication period from 2012 to October 2022; (b) articles indexed in Scopus; (c) articles in English; (b) studies related to teacher training for the didactic use of augmented reality (Please refer to Supplementary Information).
- Exclusion criteria: date of publication, type of research (tutorials, essays), and relation to the object of study and the aim of the research.

2.3. Search Indicators

The Scopus database was used for article selection, which was limited to the last 10 years (2012-October 2022). Combinations between AND/OR logical operators were used and the keywords were: practicum, teachers, training, initial teacher education (ITE), pre-service, candidate, student, and augmented reality. Several terms established in the se-mantic framework of teacher training were used such as teachers, professors, initial, pre-service, and candidate.

The search string used was the following: (KEY (practicum) OR KEY (teachers AND training) OR KEY (initial AND training) OR KEY (preservice AND teachers) OR KEY (candidate AND teachers) OR KEY (student AND teachers) AND KEY (augmented AND reality)) AND PUBYEAR > 2011 AND PUBYEAR < 2023 AND PUBYEAR > 2012 AND PUBYEAR < 2023.

2.4. Data Analysis.

Step 3: Data mining.

A data matrix was used to analyses each study in depth and to achieve the analysis, synthesis, and grouping of the information [36] which included authors, studies, publication sources, type of research, stage of teacher training, reliability and validity of the instruments, and the components of augmented reality according to the user's virtual component used in the studies. The three researchers rated each component from 1 (lowest score) to 5 (highest score) The process followed the established PRISMA method stages: grouping of variables, trend analysis, and statistics (see Figure 1). Cohen's Kappa reliability coefficient (k=0.826) was applied to the observations, achieving 96% and adequate co-incidence [39].

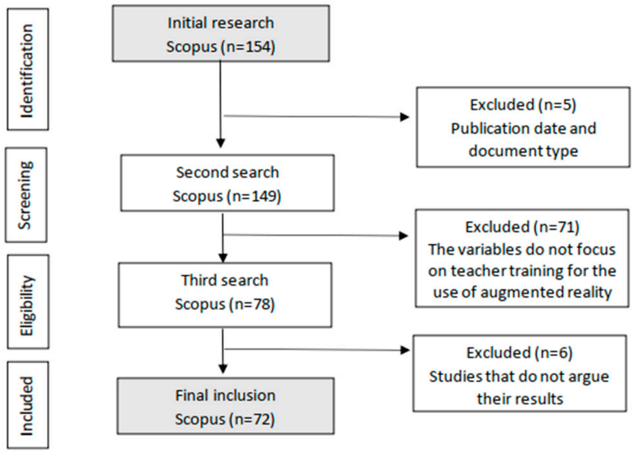

Figure 1. (PRISMA flowchart) summarizes the procedure followed.

2.5. Information Selection and Representation

Step 4: Data analysis.

Functions of the VOSViewer were employed to determine the most common terms used from among the authors' keywords using the co-occurrence of keywords and the networks they formed. In this regard, the functions were applied to the clusters and subclusters. This software is used because it allows the construction and visualization of networks based on clustering techniques [40].

3. Results

Q1. What are the main bibliometric indicators of scientific production in terms of publi-cation sources of a regional and institutional origin?

A total of 72 documents were selected from the SCOPUS (meta)database, in-cluding 50 articles and 22 conference proceedings. The years with the highest scholarly production (Figure 2) were 2013, 2019, and 2020.

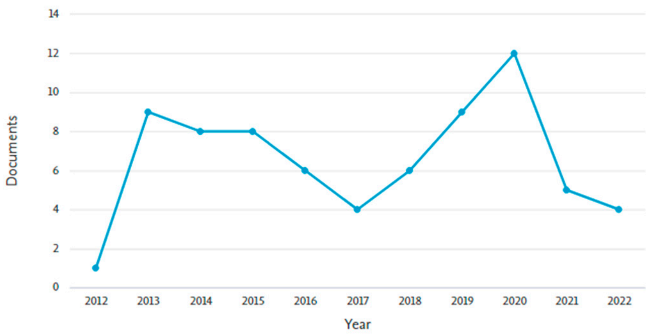

Figure 2. Document Per Years.

The research papers were published in the following journals (Figure 3): Computers and Education (23), Procedia Computer Science (19), Computers in Human Behavior (6), Heliyon (2), International Journal of Human-Computer Studies (2) and, Teaching and Teacher Education (2). It was observed that for subject matter, the conference proceedings presented in Procedia Computer Science had a great influence. Therefore, the indexing categories related to Education and General Computer Science were the most representative, which reaffirms the interdisciplinary nature of the educational technology domain.

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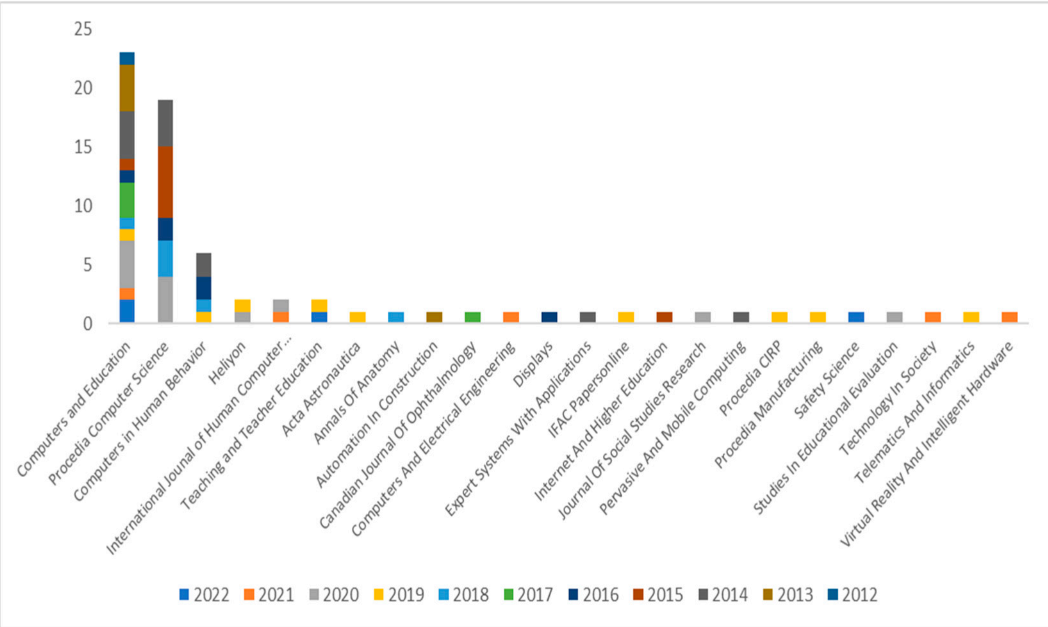

Figure 3. Relationship Between Publication Resources and Years.

Q2. What are the most representative keywords used by the authors?

The most frequently used keywords were found to be (Table 2): Augmented reality (59), Students (34), Education (26), Computer-aided instruction (21), Teaching (21), E-learning (17), Engineering education (15), Virtual reality (14), Interactive learning environment (12) and, Learning systems (11).

Table 2. Keywords (number in brackets) vs. Top Articles.

Keywords	Articles with at least 100 citations
Augmented reality (59)	[41–57] (Chen and Tsai 2012, Kamarainen *et al.* 2013, Lin *et al.* 2013, Wojciechowski and Cellary 2013, Di Serio *et al.* 2013, Cai *et al.* 2014, Sommerauer and Müller 2014, Zhang *et al.* 2014, Chiang *et al.* 2014, Fonseca *et al.* 2014, Ibáñez *et al.* 2014, Akçayir *et al.* 2016, Yilmaz 2016, Huang *et al.* 2016, Hsu 2017b, Chang and Hwang 2018, Sahin and Yilmaz 2020)
Students (32)	[41–43,45–49,51,52,54,55,57] (Chen and Tsai 2012, Lin *et al.* 2013, Di Serio *et al.* 2013, Kamarainen *et al.* 2013, Zhang *et al.* 2014, Chiang *et al.* 2014, Fonseca *et al.* 2014, Ibáñez *et al.* 2014, Akçayir *et al.* 2016, Huang *et al.* 2016, Hsu 2017b, Chang and Hwang 2018, Sahin and Yilmaz 2020)
Education (26)	[47,51,52,54] (Kamarainen *et al.* 2013, Akçayir *et al.* 2016, Huang *et al.* 2016, Hsu 2017b)
Computer-aided instruction (21)	[41–43,46–48,50,54–57] (Chen and Tsai 2012, Di Serio *et al.* 2013, Lin *et al.* 2013,

	Wojciechowski and Cellary 2013, Zhang *et al.* 2014, Chiang *et al.* 2014, Ibáñez *et al.* 2014, Sommerauer and Müller 2014, Huang *et al.* 2016, Hsu 2017b, Chang and Hwang 2018)
Teaching (21)	[44,46,48,51,58] (Kamarainen *et al.* 2013, Chiang *et al.* 2014, Zhang *et al.* 2014, Yilmaz 2016, Chang *et al.* 2018)
E-Learning (17)	[55,56] (Chen and Tsai 2012, Sommerauer and Müller 2014)
Engineering education (15)	[52,54] (Akçayir *et al.* 2016, Huang *et al.* 2016)
Virtual reality (14)	[49,55,57] (Chen and Tsai 2012, Lin *et al.* 2013, Sahin and Yilmaz 2020)
Interactive learning environments (12)	[42,43,46,48,50,54,55,57,59] (Chen and Tsai 2012, Lin *et al.* 2013, Wojciechowski and Cellary 2013, Chiang *et al.* 2014, Ibáñez *et al.* 2014, Zhang *et al.* 2014, Huang *et al.* 2016, Hsu 2017a, Chang and Hwang 2018)
Learning systems (11)	42,43,46,50,54,55,57] (Chen and Tsai 2012, Lin *et al.* 2013, Wojciechowski and Cellary 2013, Chiang *et al.* 2014, Ibáñez *et al.* 2014, Huang *et al.* 2016, Chang and Hwang 2018)

Concerning the keywords used by the authors (Figure 4), a total of 211 were found in the sample, of which 36 had appeared at least twice, with the most frequent being: Augmented Reality (39), Interactive learning environments (12), Virtual Reality (9), Education (8), Applications in subjects' areas (6) and Mobile learning (6).

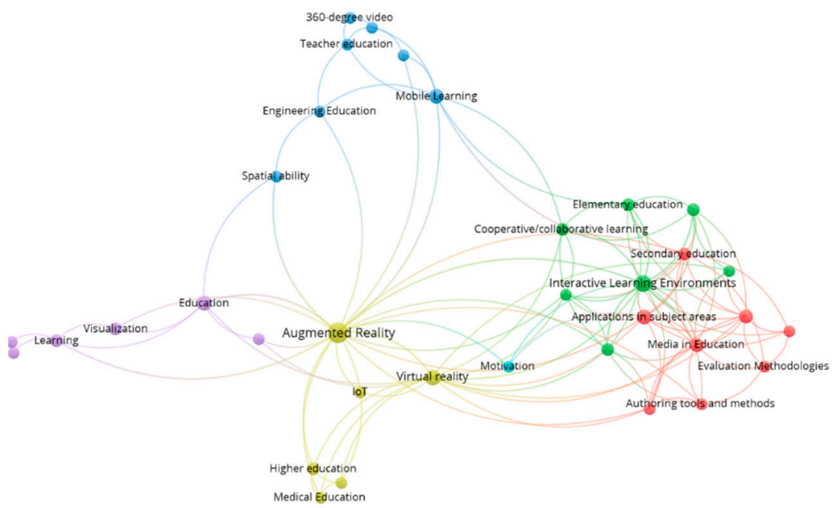

Figure 4. Keyword Network.

In the first and second clusters (Figure 5), the nodes for Applications in subject areas and Interactive learning environments stand out, respectively, and are interconnected through the nodes for Teaching/Learning strategies, Simulations, and Interactive learning environments.

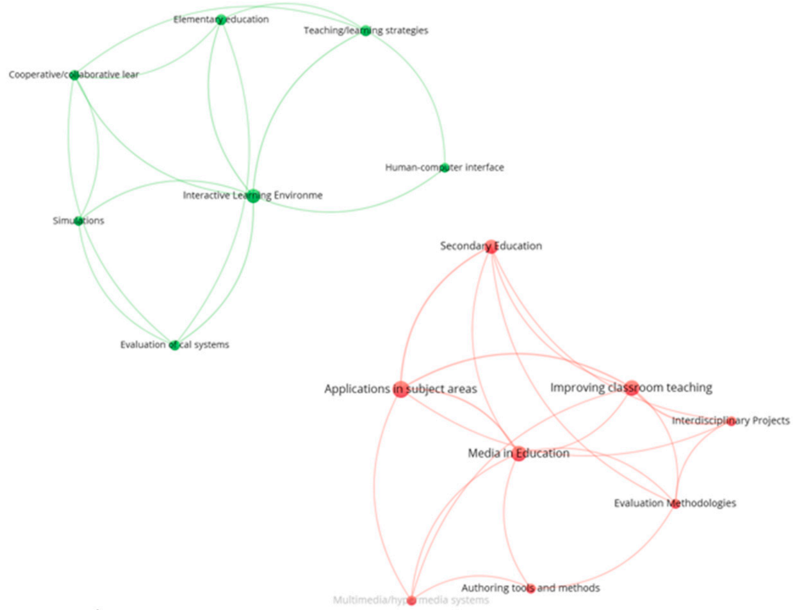

Figure 5. First and Second Clusters (Left to Right).

In the third cluster, the nodes for Mobile learning and Engineering education were prominent, while in the fourth cluster, Augmented Reality and Virtual Reality stand out. Both clusters are interconnected through Augmented reality, which highlights the strong relationships among User experience, Mobile learning, and Spatial ability (Figure 6).

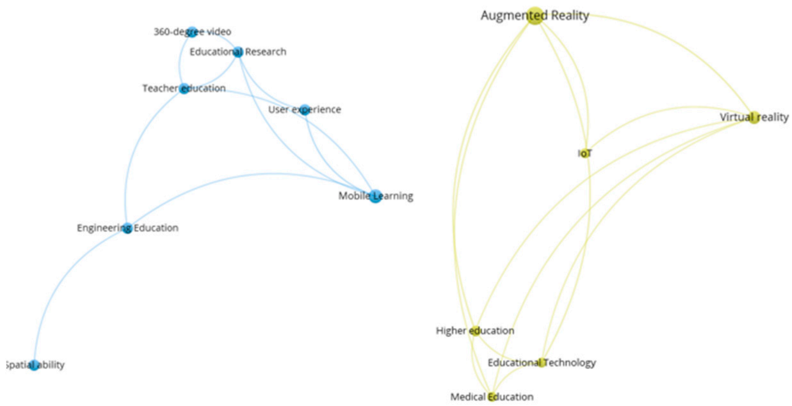

Figure 6. Third and Fourth Clusters (Left to Right).

In the fifth cluster (Figure 5), the nodes for Education and Mixed reality stand out, while the sixth cluster only contains the node for Motivation. In addition, the fifth cluster shows a relationship with the third through the nodes associated with AR and Virtual reality. For the sixth cluster, there is a strong interaction with the first three clusters through the terms Applications in subject areas, Interactive learning environments, and, Augmented reality, respectively (Figure 7).

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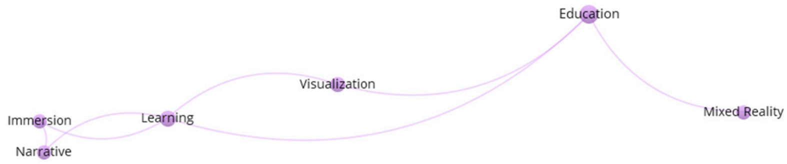

Figure 7. Fifth Cluster.

Thirty-six countries were identified of which Spain, Taiwan and Turkey were the most notable (Figure 8). Out of the total, 17 countries accounted two published papers on the topic but only five of them were specifically related to the use of AR in the classroom and they come from Spain, Venezuela, and Portugal.

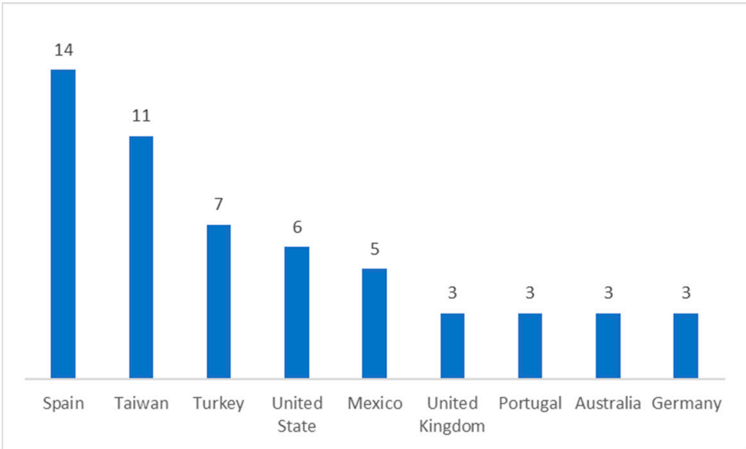

Figure 8. Countries with the Highest Scientific Production.

Among these countries, the higher education institutions with the largest scientific production in the selected sample are the National Taiwan University of Science and Technology (Taiwan), Ataturk University (Turkey), Carlos III University (Spain), University of La Laguna (Spain), Tecnologico de Monterrey (Mexico), and the University of Aveiro (Portugal), all of them accounting at least three publications.

Q3. What types of studies are the most common in the scientific literature?

As shown in Table 3, exploratory and quasi-experimental studies are the most common.

Table 3. List of study types (n=72).

Quantitative studies			Qualitative studies		Mixed Method	
Exploratory	Descriptive	Quasi-experimental	Exploratory	Descriptive	Quasi-experimental	Exploratory
[50,55,60–82]	[41,83,84]	[43,45–49,52,54,56,57,85–104]	[51,105–112]	[51,53]	[44,113]	[42,114]

As shown in Table 3, a number of 27 (41.5%) studies implemented quasi-experimental designs and 23 studies (35.3%) were exploratory, making the quantitative analysis approach the predominant type of research (76.8%). Another group of 11 studies (16.9%) were found to be of qualitative nature and just four (6.1%) were mixed methods.

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Q4. Which studies state the reliability and validity obtained in the design and application of the instruments applied?

Reliability indicates the degree to which repeated application of the instrument to the same subject will produce the same results, and validity refers to the degree to which a given instrument measures what it is supposed to measure [115]. Of the 72 documents, only 27 explicitly state reliability [41,47,49,51,52,72,77,89,99] and nine the validity of the instruments applied [42–44,46,57,87,88,105,106], which provides evidence of the limited transparency in data sharing.

In turn, only eight studies show the reliability and validity obtained in the design and application of the instruments [48,53,63,68,97,100,112,114].

Q5. Which AR components are mainly used by teachers? At which stage of teacher training were they applied?

The answers to these two questions can be found in Table 4 based on the following three legends.

Legend 1: Research topic (related to AR)

(1) Use of 360º videos in AR. Studies based on the use of immersive videos in aug-mented reality

(2) Virtual environments embedded in AR. Studies based on virtual learning envi-ronments and their integration with augmented reality technology

(3) Teacher Digital Competencies. Studies focused on the development of digital teaching skills through the use of augmented reality

(4) Learning Applications for AR. Studies focused on the use of various gaming ap-plications and learning environments, for example, Mobile learning, ubiquitous games

(5) Development or adaptation of new augmented reality technologies. For example, the plugin development (COPIE-STEM protocol)

Legend 2: Augmented Reality component.

(1) With markers (e.g., Images, QR, Printed Images)

(2) Without markers

(3) Projection-based

(4) Superimposition-based

Legend 3: Teacher training Phase

(1) Expert (teachers with teaching experience)

(2) Beginner (teachers new to teaching)

(3) Pre-service (teacher training students)

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Table 4. List of Study Types (n=72).

Classification		Augmented Reality Component (Virtual User Component)	Stage of Teacher Training Subject
Subject of study	Studies (reference)		
1	[75]	2	3
	[63]	2	3
	[114]	1	3
2	[106]	1	1,2,3
	[73]	1	3
	[69]	1	1,3
	[105]	1	1
	[113]	1	3
	[108]	1	3
	[101]	3	3
	[102]	2	3
3	[91]	1	1,3
	[111]	1	3
	[68]	-	1
4	[49]	1	3
	[83]	1	3
	[44]	1	1,3
	[51]	1	3
	[70]	1	3
	[107]	1	3
	[85]	1	3
	[76]	1	1,3
	[86]	1	3
	[43]	1	3
	[77]	1	3
	[87]	1	3
	[110]	1	3
	[109]	1	3
	[78]	1	3
	[79]	1	3
	[80]	1	3
	[88]	1	3
	[89]	1	3
	[81]	1	3
	[90]	1	3
	[91]	1	3
	[92]	1	3
	[41]	2	3
	[93]	3	3
	[84]	1	3
	[48]	2	3
	[94]	1	3
	[82]	4	3

Table 4. List of Study Types (continued).

Classification		Augmented Reality Component (Virtual User Component)	Stage of Teacher Training Subject
Subject of study	Studies (reference)		
	[54]	2	3
	[95]	1	3
	[96]	1	3
	[60]	2	3
	[46]	2	3
	[42]	1	3
	[50]	1	3
	[61]	1	3
	[97]	1	3
	[98]	4	1,3
	[64]	1	3
4	[99]	1	3
	[62]	1	3
	[100]	2	3
	[53]	1	2
	[52]	1	3
	[55]	1,2	3
	[47]	1	3
	[65]	3	3
	[66]	1,3	3
	[45]	1	3
	[57]	1	3
	[67]	1	3
	[56]	1	3
	[103]	1	3
	[71]	1,2	3
	[104]	-	3
	[72]	-	1
5	[112]	1	3

As Table 4 shows, the most frequent research topics in the reviewed articles are Learning Applications for AR (79.19%), Virtual environments embedded in AR (9.72%), and the Use of 360º videos in AR (5.55%). As for the AR component, the physical markers such as QRs or images are the most used in educational research (54; 75%) while other studies (10) research on AR with no markers (13.88%). However, to a lesser extent, five research works focused on a more sophisticated technology: projection-based AR (4; 5.55%) or superimposition AR (1; 1.38%).

Finally, the majority of the studies included in this SLR did research AR within the Pre-service teaching period (66; 91.66%); eight (11.11%) investigated the AR components as used by expert teachers whereas only two (2.77%) tested AR in the teaching induction period (beginning teachers).

4. Discussion

The aim of this research was to conduct a Systematic Literature Review related to the use of AR in teacher education. To this end, five research questions were posed in relation to 1) the analysis of academic production using bibliometric indicators (publication re-sources, author keywords, and countries), 2) methodological analysis, and 3) the analysis of the topics (subjects of study) related to the research topic.

The research production analysed mainly came from three well-known journals in the field of technologies applied to education: Computers and Education (23), Computers in Human Behavior (6), and the conference proceedings published in Procedia Computer Science (19). Our analysis of the papers indicates that technologies in Teacher Education with an emphasis on the use of augmented reality has been increasing over the last ten years (2012-October 2022).

Moreover, the analysis of author keywords highlights the importance of the use of AR in Education and more specifically in teacher education. In this regard, in recent theoretical studies [12,116], and empirical studies carried out at the university [117], primary education [118], and high school [119,120] levels, shed evidence on the pedagogical use of AR as an effective tool to promote students' learning. However, the analysis of the scientific production gathered from Scopus reaffirms a lack of sufficient empirical research related to the importance of AR for the teacher training processes. The scarcity of qualitative and mixed studies carried out in educational research related has had a negative impact on the generalizability of our results [121].

The results of other similar theoretical studies [122] scrutinising the effect of gamification on academic performance have also reaffirmed the need for teacher training not only in the use of serious games based on AR but also in the understanding and pedagogical use of several digital technologies [123–125].

Five clusters were identified from the analysis of the author keywords, which show there is a strong relationship between Augmented reality, Mobile learning, Interactive learning environments, and Motivation.

Concerning Mobile Learning, the effectiveness of augmented reality in improving student engagement and providing a sense of reality is well known, especially in science education [12,13,15,19]. In this context, the concerns related to pedagogical usability [127,128], safety and privacy [19], and pedagogic practice are also important [129,130].

In the studies related to the keywords Augmented reality and Interactive learning environments, the need for educational software to be able to record, interact and visualize objects in 3D is pointed out. However, the design of this software can be done with or without bookmarks. The essence and effectiveness of interactive learning lie in selecting the right environment, instructional design, teacher training, and content management tools. The main tools used in educational studies for visualization are commercial or open-source ARs such as ARToolKit and Unity 3D. While content management tools like Vuforia (virtual content storage) and Maya 3D are used for virtual content creation [131,132].

In the relationship between AR and Motivation, it is noteworthy that the motivational factors of attention, satisfaction, and confidence increase with the use of AR, but not for the factor related to relevance [85,108].

This SLR of 72 research works shows that there is a great deal of diversity in the type of studies conducted, with a focus on exploratory and quasi-experimental studies. However, only 27 explicitly state the reliability of the instruments applied, nine mention the validity, and only eight only show the reliability and validity obtained in the design and application of the instruments. This does not detract from the quality of peer review and the editorial process of the journals, but it is a call to the community to offer reliable data and instruments for subsequent use (replicability).

Although the 72 studies are related to teacher training through AR, only 52 focuses explicitly on this topic. As for the AR component used according to the user's point of view the studies focus their application on the use of markers (53) with an emphasis on teachers' technological training of teachers. Few studies were related to the components of artificial intelligence based on projection and superimposition. On the other hand, regarding the stage of teacher training, 66 studies focus their attention on initial training (66), which highlights the limited number of studies on in-service teacher training. This reinforce the idea that educational research on AR is still on a preliminary phase and needs of more evidence to test whether this technology is efficient for the teachers' training.

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Finally, an overwhelming number of studies focus on student teachers leading us to think that main results are limited to the initial teacher training and could be different when applied in other Teacher Education Phases such as beginner or expert teachers.

5. Conclusions

A Systematic Literature Review (SLR) was conducted to find research articles related to the use of AR in teacher Education. However, it is important to consider that the study selection was based on those articles detected by Scopus during the period ranging from the year 2012 to October 2022 and on articles written in English. Therefore, valuable studies written in other languages may have been excluded from this study. Although 72 studies by authors from 32 countries were analyzed, this does not imply that it is representative of the world's current educational reality but may however offer a possible perspective on the use of AR in the field of education.

The results of this systematic review reaffirm the scarcity of studies on teacher training using Augmented Reality. However, regardless of the type of studies, the didactic use of Augmented Reality in teacher training requires (a) initial and ongoing didactic training of teachers; (b) digital literacy appropriate to the new technological environments; and (c) the adaptation of techno-pedagogical models for teacher training in the context of Augmented reality.

Another relevant finding from this review is the lack of research papers connecting the use of AR with the teaching Practicum, which highlights the importance of this type of study for empirically validating the extent to which this immersive technology could be useful in preparing future teachers. Further research could consider conducting qualitative and mixed method studies to enrich the comprehension of the phenomenon under study, specially to those areas that are less researched and more prominent such as the AR based on Artificial Intelligence (e.g., superimposition). Only by generating a robust corpus of knowledge around this topic would enable teachers and teacher educators to know whether this type of technology would be beneficial for learning purposes.

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