Augmented Reality in Education: An Overview of Research Trends

F. Sehkar FAYDA-KINIK

Istanbul Technical University

kinik@itu.edu.tr

ORCID: 0000-0001-6563-4504

Abstract

Augmented reality (AR), a cutting-edge technology, has the potential to change the way students learn by superimposing virtual items and information onto the real environment. Through more immersive and interesting interactions with digital content, AR might help students better understand difficult concepts and boost their drive to learn. As a result of its contribution to student learning, AR has become increasingly appealing to educational researchers. This study aimed to descriptively explore the characteristics of AR studies in education and to qualitatively analyze the most influential ones indexed in the Web of Science (WoS) between 2000 and 2022. A scoping review was conducted to determine the sample of the AR studies in education based on the inclusion criteria. Accordingly, descriptive analyses were conducted to identify the characteristics of the AR studies in education between 2000 and 2022 in terms of publication year, country, affiliations, journals, funding agencies, and citation trends Then, the research methodologies and implications were found among the most influential AR studies in education between 2000 and 2022 by synthesizing qualitatively. The overall results indicated that AR studies in education have been conducted since 2008, with an increasing number of studies over time. Based on the implications of the most influential studies identified in terms of citation numbers, it was detected that AR has the potential to enhance education and training by providing interactive and engaging environments, linking real-world contexts with digital resources, and promoting efficiency and effectiveness in learning.

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Introduction

Augmented Reality (AR) is “a system that enhances the real world by superimposing computer-generated information on top of it” (Furht, 2006) by overlaying digital information such as text, images, or videos, onto the real world to increase users’ perception of the environment. According

to Azuma (1997), real-time interaction and precise 3D model registration of real and virtual objects are made possible by the fusion of the real and virtual worlds, which is called AR technology. Compared with virtual reality (VR), AR can be regarded as a more recent technology with an interdisciplinary application framework by "supporting learning [through] increasing on content understanding and memory preservation, as well as on learning motivation" (Cipresso et al., 2018). Therefore, AR has been applied and investigated in education to develop interactive learning experiences that can help students improve engagement and retention.

The term "augmented reality" was first introduced by Tom Caudell in the early 1990s (Lee, 2012). Due to the advancements in mobile computing power and functionality, AR systems have been integrated into mobile devices, which accelerates its development and growth by providing access for a large group of users (Bower et al., 2014). Its innovative approach to learning has paved the way for AR use and research in the field of education. Accordingly, AR technology is utilized for educational purposes due to its potential to enhance the learning experience by providing a more interactive and engaging environment for students.

The AR technology blending real and virtual world experiences supports true inquiry in the real world for students because virtual components including texts, videos, and photos serve as supplemental materials for them to perform investigations of their immediate environment (Dede, 2009; Klopfer & Sheldon, 2010). AR can make abstract concepts more tangible and accessible, which can aid in comprehension and retention. Additionally, AR can offer students the opportunity to explore virtual objects and scenarios that may not be possible in real-life situations. Furthermore, AR can facilitate collaborative learning and allow for personalized and adaptive learning experiences. Instead of only being dependent on the use of technologies, the educational benefits of using AR are closely related to how it is developed, put into use, and incorporated into both formal and informal learning environments (Wu et al., 2013). In this context, AR research in education significantly gains importance for improving student learning outcomes respectively. Therefore, this study aimed to descriptively explore the characteristics of the AR studies in education between 2000 and 2022 and to qualitatively analyze the most influential ones indexed in the Web of Science (WoS).

Method

Research Design

A scoping review approach was adopted in the present research to descriptively explore the characteristics of AR studies in education between 2000 and 2022 (RQ1) and to qualitatively analyze the most influential ones (RQ2). The following research questions (RQs) were investigated in the research:

RQ1: What are the characteristics of AR studies in education between 2000 and 2022?

RQ1.1: What is the distribution of AR studies in education by year?

RQ1.2: What is the distribution of AR studies in education by country?

RQ1.3: Which affiliations conducted AR studies in education between 2000 and 2022?

RQ1.4: Which journals contributed to AR studies in education between 2000 and 2022?

RQ1.5: Which funding agencies supported AR studies in education between 2000 and 2022?

RQ1.6: What are the citation trends in AR studies in education between 2000 and 2022?

RQ2: Which AR studies in education are the most influential ones?

RQ2.1: Which research methodologies were used in the most influential AR studies in education between 2000 and 2022?

RQ2.2: Which research implications were found in the most influential AR studies in education between 2000 and 2022?

Data Collection

A scoping review is a form of literature review to provide an overview of existing research on a particular topic (Peters et al., 2015). After the RQs were defined, the database of WoS core collection was selected to collect data (WoS, 2023). The related keywords and the search string were identified as (("augmented reality" OR AR) AND (education OR learning OR teaching)) by using the Boolean method. The publications were collected based on the inclusion criteria (IC) including the date range of “01-01-2000 and 31-12-2022” (IC-1), the document type as “articles”

(IC-2), and the WoS categories as "Education Educational Research and Education Specific Disciplines" (IC-3). At the initial screening stage of the publications, 2159 results were obtained from the WoS database. After the elimination processes were carried out to meet the IC, 344 documents were determined as the sample of this review.

Data Analysis

After the determination of the studies, the data were extracted from the WoS database in EXCEL and BIBTEX formats. First, the descriptive analyses were conducted to reveal the characteristics of the AR studies in education between 2000 and 2022 in terms of publication year, country, affiliations, journals, funding agencies, and citation trends (RQ1). Next, the research methodologies and implications were revealed in the most influential AR studies in education between 2000 and 2022 by synthesizing qualitatively (RQ2).

Findings

Characteristics of AR Studies in Education

To address RQ1, publication year, country, affiliations, journals, funding agencies, and citation trends in 344 AR studies in education were descriptively analyzed on EXCEL. First, the AR studies in education were analyzed by publication year (RQ1.1) as depicted in Figure 1.

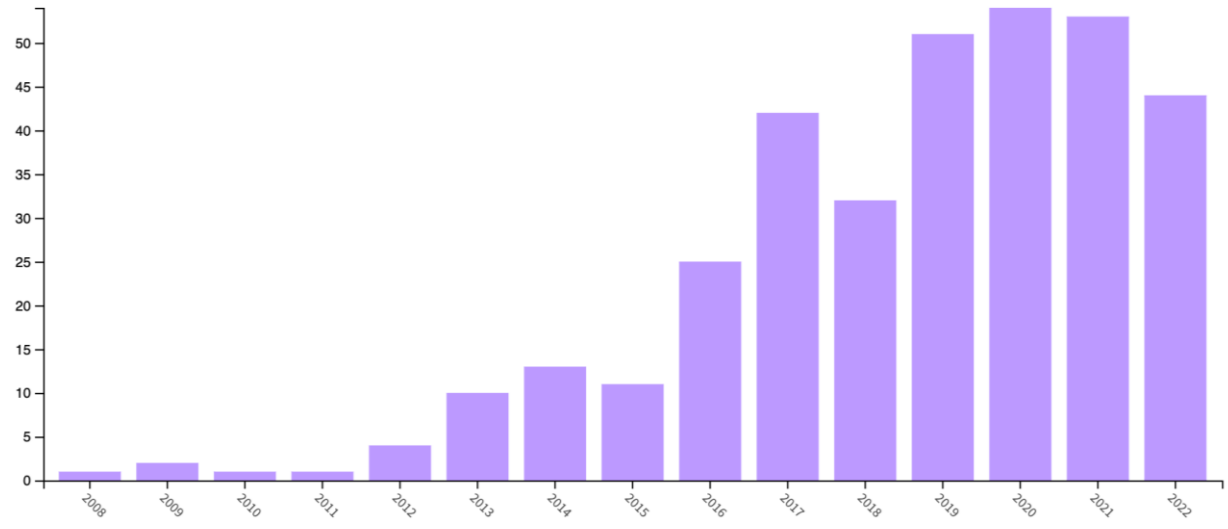

Figure 1. The distribution of the AR studies in education by year

As illustrated in Figure 1, no AR studies in educational contexts were conducted between 2000 and 2007. The first AR study in education was carried out in 2008. As observed, there was an upward trend in the AR studies with 51 records in 2019, 54 records in 2020, 53 records in 2021, and 44 records in 2022.

Second, the sample was examined for distribution by country (RQ1.2). It was revealed that 344 AR studies were conducted in 63 different countries. The countries with at least 10 AR studies in education are listed in Table 1.

Table 1. The distribution of the AR studies in education by country

	Countries/Regions	**Records (n)**	**% of 344**
	Spain	70	20.349
	Taiwan	53	15.407
	The USA	33	9.593
	Turkey	28	8.140
	China	22	6.395
	Germany	13	3.779
	Australia	10	2.907
	Others (n=56)	fewer than 10 records	33.43
Total	**63**	**344**	**100**

Table 1 shows the number of records and the percentage of total records out of 344 AR studies for each country/region. Of the total records (N=344), Spain had the highest number of publications at 70, which accounted for 20.349%. Taiwan followed closely with 53 studies, elucidating 15.407% whereas the USA had 33 records, which was 9.593%; Turkey with 28 studies (8.140%), and China with 22 records (6.395%); Germany with 13 publications (3.779%); and Australia with 10 records

(2.907%). 56 countries/regions had fewer than 10 records each, but in total, they accounted for 33.43% of the total records.

Next, the affiliations where the researchers conducted 344 AR studies in education (RQ1.3) were analyzed by the number of records and the percentages. Accordingly, it was detected that the total number of affiliations was calculated as 395, which means that 344 AR studies in education were conducted by researchers affiliated with 395 different institutions. The names of the major institutions are listed in Table 2 by country, record count, and percentages.

Table 2. The distribution of the AR studies in education by affiliation

	Affiliations	Country	Records (n)	% of 344
	National Taiwan Normal University	Taiwan	12	3.488
	University of Sevilla	Spain	12	3.488
	Universidad de Cordoba	Spain	11	3.198
	National Taiwan University of Science Technology	Taiwan	9	2.616
	Ataturk University	Turkey	7	2.035
	National University Tainan	Taiwan	6	1.744
	University of Granada	Spain	6	1.744
	University of Murcia	Spain	6	1.744
	University of Oviedo	Spain	6	1.744
	Beijing Normal University	China	5	1.453
	Chitkara University Punjab	India	5	1.453
	Universidad de Castilla la Mancha	Spain	5	1.453
	Others (383 affiliations)	58 countries	fewer than 5	73.84
Total	**395**	**63**	**344**	**100**

As indicated in Table 2, the top two affiliations with the highest record count were the National Taiwan Normal University and the University of Sevilla, both with 12 records each. The top three

institutions with the highest number of AR publications in education were located in Taiwan, Spain, and Turkey with 3.488%, 3.198%, and 2.035% of the total records (N=344), respectively. The other 383 affiliations were from 58 different countries with fewer than 5 records each, which represented 73.84%.

After the analysis of the affiliations, the top journals having contributed to the AR studies in education between 2000 and 2022 were investigated by record numbers and percentages (RQ1.4). Of 121 journals, the ones with 10 or more AR publications in education are presented in Table 3.

Table 3. The distribution of AR studies in education by journals

	Journals	Records (n)	% of 344
	International Journal of Emerging Technologies in Learning	23	6.686
	Interactive Learning Environments	20	5.814
	Education and Information Technologies	19	5.523
	Education Sciences	15	4.360
	British Journal of Educational Technology	12	3.488
	Journal of Educational Computing Research	11	3.198
	Journal of Science Education and Technology	11	3.198
	Anatomical Sciences Education	10	2.907
	Others (113 journals)	fewer than 10	64.826
Total	**121**	**344**	**100**

As listed in Table 3, the top three journals in terms of the number of records were the *International Journal of Emerging Technologies in Learning* (n=23), *Interactive Learning Environments* (n=20), and *Education and Information Technologies* (n=20) with 6.686%, 5.814%, and 5.523% of the total records (N=344), respectively. The remaining journals in Table 3 published AR studies in

education with a range of 10 to 19 records each, indicating a relatively even distribution of publications across these journals. The "Others" category (n=113) represents a large percentage of the publications (64.826%), with each journal in this category having fewer than 10 records.

Regarding the funding agencies supporting these 344 AR studies in education financially (RQ1.5), it was found that 230 records (66.860%) did not contain data in the field, and 138 funding agencies were detected as depicted in Table 4.

Table 4. The distribution of AR studies in education by funding agencies

	Funding Agencies	Records (n)	% of 344
	Ministry of Science and Technology Taiwan	21	6.105
	National Natural Science Foundation of China (NSFC)	5	1.453
	Spanish Government	5	1.453
	Portuguese Funds Through FCT Fundacao Para a Ciencia e a Tecnologia	4	1.163
	National Research Foundation of Korea	3	0.872
	Others (133 funding agencies)	fewer than 3	22.093
	No funding agencies	230	66.861
Total	**138**	**344**	**100**

As presented in Table 4, the top three funding agencies were the *Ministry of Science and Technology in Taiwan*, which funded 21 studies (6.105% of the total), followed by the *National Natural Science Foundation of China (NSFC)* and the *Spanish Government*, both of which funded 5 studies each (1.453% of the total each). 4 studies were funded by *Portuguese Funds through FCT Fundacao Para a Ciencia e a Tecnologia* (1.163%), and 3 studies were funded by the *National Research Foundation of Korea* (0.872%). The remaining 133 funding agencies supported fewer

than three studies each (n=76 in total) accounting for 22.093% of the total publications, and 230 studies (66.861%) did not receive any funding from any specific funding agencies.

Finally, the citation trends in 344 AR studies in education between 2000 and 2022 were analyzed to investigate the impact of the AR publications (RQ1.6). The results of overall citation analyses are illustrated in Figure 2.

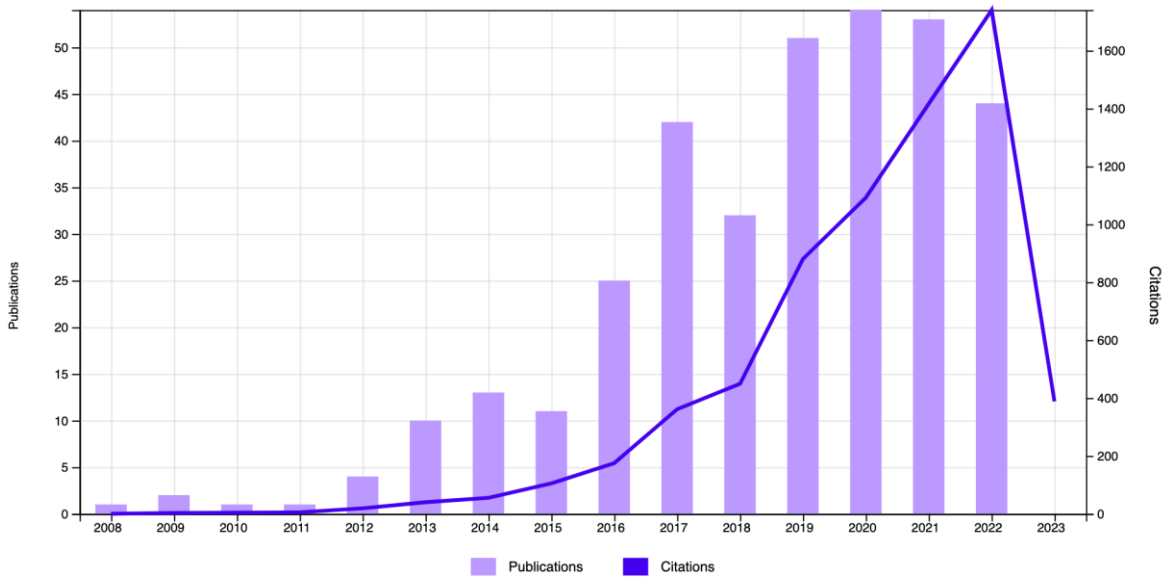

Figure 2. Citation trends in the AR studies in education

Figure 2 shows the number of publications and their corresponding citation counts for the years from 2008 to 2022. 344 AR studies were cited 5,943 times in total without self-citations with an average of 19.57 citations per item. A dramatic increase in citations was observed in 44 publications with 1740 citations in 2022 following 53 publications with 1416 citations in 2021, 54 publications with 1092 citations in 2020, and 51 publications with 880 citations in 2019.

The Most Influential AR Studies in Education

To correspond to RQ2, the AR studies in education were examined by determining the publications with more than 100 citations in total and classified as the most influential studies. Accordingly, 5 AR studies listed in Table 5 were detected as the most influential ones (RQ2.1).

Table 5. The most influential AR studies in education

Publications	Citation Average per Year	Total Number of Citation
Dunleavy et al. (2009)	39.87	598
Lee (2012)	28.83	346
Bower et al. (2014)	25.7	257
Chiang et al. (2014)	24.8	248
Hwang et al. (2016)	14.63	117

As indicated in Table 5, the study conducted by Dunleavy et al. (2009) had an average of 39.87 citations per year with a total of 598 citations while the study carried out by Lee (2012) was ranked second with an average of 28.83 citations per year and a total of 346 citations, followed by Bower et al. (2014) with an average of 25.7 citations per year and a total of 257 citations, Chiang et al. (2014) with an average of 24.8 citations per year and a total of 248 citations, and finally, Hwang et al. (2016) with an average of 14.63 citations per year and a total of 117 citations.

After a critical examination, the research methodologies adopted in the most influential AR studies in education were analyzed qualitatively (RQ2.1). The results are presented in Table 6.

Table 6. Research methodologies of the most influential AR studies in education

Publications	Research Methodology
Dunleavy et al. (2009)	Qualitative triangulation of observations, interviews, and documents
Lee (2012)	Qualitative literature review
Bower et al. (2014)	Qualitative case study
Chiang et al. (2014)	Qualitative experimental design
Hwang et al. (2016)	Qualitative experimental design

As described in Table 6, qualitative research methods were employed in all of the most influential studies with different approaches. Dunleavy et al. (2009) used a triangulation method involving the collection and analysis of data from multiple sources through observations, interviews, and documents. Lee (2012) conducted a literature review by analyzing and synthesizing the existing research on AR. Bower et al. (2014) developed a case study approach by studying a specific case or situation in depth to gain insights into a broader phenomenon. Chiang et al. (2014) used an experimental design by manipulating independent variables to observe their effects on dependent variables. Similarly, Hwang et al. (2016) carried out an experimental design, but with a qualitative approach to understand the effects of a particular intervention in AR.

At the final stage, research implications detected in these most influential AR studies in education were qualitatively synthesized (RQ2.2). The summarized results are listed in Table 7.

Table 7. Research implications of the most influential AR studies in education

Publications	Research Implications
Dunleavy et al. (2009)	AR improves student learning by creating immersive hybrid learning environments and fusing digital and physical components.
Lee (2012)	AR revolutionizes education by providing interactive and engaging environments, simplifying learning experiences, and increasing effectiveness and efficiency.
Bower et al. (2014)	AR has the potential for extensive use and should be effectively integrated into education to promote cognitive development and collaborative learning.
Chiang et al. (2014)	Mobile AR enhances student learning performance by connecting real-world situations with digital resources, improving motivation, and supporting inquiry-based learning.
Hwang et al. (2016)	AR-based gaming strategy improves learning outcomes and attitudes, motivating students to make observations and find solutions in field experiences.

As summarized in Table 7, by generating immersive hybrid learning environments with a mix of digital and physical items, Dunleavy et al. (2009) found that AR technology improved student learning. With AR, many educational goals across the curriculum could be met by fusing fictitious stories with actual physical settings. The early stages of software development and the inherent

pedagogical and management complexity of an AR implementation were to blame for AR's limits in education. Many schools could not afford AR technology, but in the future, the usage of wireless computers and mobile devices may make it possible to scale up AR courses. Teachers must be ready to use AR and the various pedagogical techniques it calls for. The teacher's knowledge, outlook, and curriculum interpretation must be taken into account while putting the AR curriculum into practice. Teaching quality, not merely the medium used to provide instruction, is what determines how well a technology-based curriculum works.

According to Lee (2012), AR technology had the potential to revolutionize education and training by providing interactive and engaging environments for learners. AR could simplify education and training experiences and provide contextual information to enhance the quality of learning. By providing information at the right time and location and delivering rich content with computer-generated 3D images, it could also increase effectiveness and efficiency in academic and business settings. Occupational safety and health (OSH) applications in industrial settings could include safety inspection in power plants and oil refineries, OSH training for managers and staff, and AR games and simulations on handling dangerous products. The development and use of new AR tools and technologies in a variety of academic disciplines, including chemistry, biology, mathematics, history, and mechanical engineering in K–12 and higher education, bodes well for the future of AR in education and training.

Bower et al. (2014) concluded that AR had the potential to be larger and more widely used than the Internet. Ineffective use of AR could lead to more deprived learning outcomes. Current uses of AR are mostly related to information provision and lower-order thinking capabilities, which can limit cognitive development. Educators need to anticipate future developments in AR to prepare for its integration into education. Future developments in AR would incorporate new trigger types, more intelligent input recognition, and improved complexity of expression types. Future educational applications of AR would include classroom overlays for teachers and 3D interactive historical events for students. Future research on AR in education needs to examine how it can most effectively promote cognitive development, facilitate collaborative learning, and support teacher design thinking.

According to Chiang et al. (2014), a mobile AR technology was suggested for carrying out inquiry-based learning tasks in an elementary school natural science course. The experimental findings demonstrated that the deployment of a mobile AR method improved student learning performance by utilizing AR technology to connect real-world situations with digital learning resources at the appropriate time and place. The theory of multimedia design uses the concepts of spatial and temporal continuity to explain the outcome. The experimental group of students had a considerable increase in learning motivation and expressed satisfaction with the efficacy of the AR-based mobile learning system. Limitations included the requirement for teachers to create digital learning resources and learning processes for evaluation purposes. The approach would be used in additional mobile learning apps, behavioral patterns in online knowledge-sharing discussions, and the effectiveness of AR-based mobile learning for various cognitive or learning styles would all be investigated in the future.

Hwang et al. (2016) contended that an AR-based gaming strategy was suggested and found to improve students' learning outcomes and their attitudes toward learning while supporting in-field mobile learning activities. The use of competitive gaming encourages students to make their own observations, look for their own solutions, and participate in field experiences where events were presented using AR technology. The methodology, in contrast to earlier studies, made use of a competitive gaming strategy to motivate students to observe and look for solutions. Without detracting from the enjoyment of the game, the method could be used in other fields by replacing the in-game objectives and supplemental content. It was advised that researchers or educators follow a three-step design process when creating learning materials that incorporate competitive gaming. The learning tasks and content were seamlessly incorporated into the competitive gaming missions. The study used QR-code technology, which was a widely used sensing method in Taiwanese elementary schools. Future research could expand the approach to other subject areas, take into account learner characteristics, and employ markerless tracking technology to provide more organic interactions.

To conclude, the research implications in the most influential AR studies broadly discussed the potential and limitations of AR technology in education. Dunleavy et al. (2009) found that AR

technology could increase student learning by creating "immersive hybrid learning environments" including digital and physical items; however, the cost of AR equipment and the pedagogical complexity of AR implementation were identified as limitations. In addition, Lee (2012) argued that AR technology had the potential to revolutionize education and training by providing interactive and engaging environments for learners, and could promote efficiency and effectiveness in academic and corporate environments. Whereas Bower et al. (2014) found that poor use of AR could result in inferior learning outcomes, and educators needed to anticipate future developments in AR to prepare for its integration into education, Chiang et al. (2014) found that by integrating real-world contexts with digital learning resources at the appropriate time and place, a mobile AR approach improved students' learning performance in an elementary school natural science course. Finally, Hwang et al. (2016) revealed that students' learning attitudes were encouraged and their academic performance was enhanced by a method of supporting mobile learning activities in the field with the use of AR games.

Discussion

The findings of this scoping review deduced the characteristics (RQ1) and most influential studies of AR studies in education (RQ2). Accordingly, the AR studies in education were conducted between 2008 and 2022, and the studies' number has been increasing since then, which is evidently indicated also by Akçayır and Akçayır (2017). Spain, Taiwan, the USA, Turkey, and China were found as the top countries where these studies were conducted (Cai et al., 2017, 2019; Chiang et al., 2014; Dunleavy et al., 2009; Ferrer-Torregrosa et al., 2016; Hwang et al., 2016; Kucuk et al., 2016; Lee, 2012; Ozdemir et al., 2018; Tobar-Munoz et al., 2017).

The most influential AR studies were detected as the studies conducted by Dunleavy et al. (2009), Lee (2012), Bower et al. (2014), Chiang et al. (2014), and Hwang et al. (2014) in terms of their citation numbers. In terms of the research outcomes in these studies, it was concluded that AR technology has the potential to enhance education and training by providing interactive and engaging environments for learners, linking real-world contexts with digital learning resources, and promoting efficiency and effectiveness in academic and corporate environments. Consistently, Akçayır and Akçayır (2017), in their review to identify the advantages and challenges of AR use

in education, investigated 30 studies published between 2009 and 2015 and pointed out several advantages of using AR in education, such as enhancing students' motivation, engagement, and interest in learning, increasing students' knowledge retention and transfer, providing authentic and experiential learning opportunities, and facilitating students' learning process. Similarly, Wu et al. (2013) discussed the advantages of AR and stated that AR increased student motivation and enhanced their learning experiences by highlighting the potential of AR in different educational contexts such as science education, language learning, and cultural education.

However, the limitations of AR technology were identified as cost, pedagogical complexity, and poor use resulting in inferior learning outcomes to be addressed. Consistently, Akçayır and Akçayır (2017) mentioned several issues with AR use in education such as technical difficulties, high costs, and lack of teacher training and support, and concluded that while AR had the potential to enhance the teaching and learning process, careful consideration of the advantages and challenges was required for its successful implementation in education. Similarly, Wu et al. (2013) also argued some of the challenges and limitations of AR in education by indicating the need for appropriate hardware and software, cost-effectiveness, and proper teacher training. Briefly, this present study revealed that future developments in AR needed to be anticipated. Therefore, educators and researchers should examine how AR can most effectively promote cognitive development, facilitate collaborative learning, and support teacher design thinking.

Conclusion

To sum up, this study contributed to the descriptive exploration of the characteristics of AR studies in education between 2000 and 2022, as well as the qualitative analysis of the most influential studies indexed in the WoS. The findings revealed that AR studies in education have been conducted since 2008, with an increasing number of studies over time. The most influential studies, which were identified in terms of citation numbers, highlighted the potential of AR to enhance education and training by providing interactive and engaging environments, linking real-world contexts with digital resources, and promoting efficiency and effectiveness in learning. However, the limitations and challenges associated with AR technology were acknowledged as its cost, pedagogical complexity, and the need for proper implementation to achieve desired learning

outcomes. Both the benefits and challenges of AR in education should be taken into consideration, and further research and development are required to harness the full potential of AR technology in education.

References

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

Azuma, R. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments*, *6*, 355–385. https://doi.org/10.1162/pres.1997.6.4.355

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

Cai, S., Chiang, F.-K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interactive Learning Environments*, *25*(6), 778–791. https://doi.org/10.1080/10494820.2016.1181094

Cai, S., Liu, E., Yang, Y., & Liang, J.-C. (2019). Tablet-based AR technology: Impacts on students' conceptions and approaches to learning mathematics according to their self-efficacy. *British Journal of Educational Technology*, *50*(1), 248–263. https://doi.org/10.1111/bjet.12718

Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and augmented reality research: A Network and cluster analysis of the literature. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.02086

Chiang, T. H. C., Yang, S. J. H., & Hwang, G.-J. (2014). An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. *Educational Technology \& Society*, *17*(4), 352–365.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science*, *323*(5910), 66–69. https://doi.org/10.1126/science.1167311

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, *18*(1), 7–22. https://doi.org/10.1007/s10956-008-9119-1

Ferrer-Torregrosa, J., Angel Jimenez-Rodriguez, M., Torralba-Estelles, J., Garzon-Farinos, F., Perez-Bermejo, M., & Fernandez-Ehrling, N. (2016). Distance learning ects and flipped classroom in the anatomy learning: Comparative study of the use of augmented reality, video and notes. *BMC Medical Education*, *16*. https://doi.org/10.1186/s12909-016-0757-3

Furht, B. (Ed.). (2006). Augmented Reality. In *Encyclopedia of Multimedia* (pp. 29–31). Springer US. https://doi.org/10.1007/0-387-30038-4_10

Hwang, G.-J., Wu, P.-H., Chen, C.-C., & Tu, N.-T. (2016). Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations. *Interactive Learning Environments*, *24*(8), 1895–1906. https://doi.org/10.1080/10494820.2015.1057747

Klopfer, E., & Sheldon, J. (2010). Augmenting your own reality: student authoring of science-based augmented reality games. *New Directions for Youth Development*, *128*, 85–94. http://dx.doi.org/10.1002/yd.378.

Kucuk, S., Kapakin, S., & Goktas, Y. (2016). Learning Anatomy via Mobile Augmented Reality: Effects on Achievement and Cognitive Load. *Anatomical Sciences Education*, *9*(5), 411–421. https://doi.org/10.1002/ase.1603

Lee, K. (2012). Augmented reality in education and training. *Techtrends*, *56*(2), 13–21. https://doi.org/10.1007/s11528-012-0559-3

Ozdemir, M., Sahin, C., Arcagok, S., & Demir, M. K. (2018). The effect of augmented reality applications in the learning process: A meta-analysis study. *Eurasian Journal of Educational Research, 74,* 165–186. https://doi.org/10.14689/ejer.2018.74.9

Peters, M. D. J., Godfrey, C. M., Khalil, H., McInerney, P., Parker, D., & Soares, C. B. (2015). Guidance for conducting systematic scoping reviews. *JBI Evidence Implementation*, *13*(3). https://journals.lww.com/ijebh/Fulltext/2015/09000/Guidance_for_conducting_systematic_scoping_reviews.5.aspx

Tobar-Munoz, H., Baldiris, S., & Fabregat, R. (2017). Augmented reality game-based learning: Enriching students' experience during reading comprehension activities. *Journal of Educational Computing Research*, *55*(7), 901–936. https://doi.org/10.1177/0735633116689789

Web of Science [WoS]. (2023). https://clarivate.libguides.com/woscc

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