Adoption of Augmented Reality in Distance Education: A Scoping Review

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Keywords	Abstract
augmented reality, distance education, scoping review, technology adoption	Augmented Reality (AR) has garnered significant attention in the field of education over the last two decades, with data indicating that it improves the effectiveness of teaching and learning in a variety of academic environments. There is, however, the absence of a framework that can guide the institution-wide adoption of AR in distance education. Distance Education (DE) has always been linked to advances in (educational) technology in terms of facilitating the transactional distance between providing institutions and learners, supporting them both synchronously and asynchronously, and providing educators with tools to improve pedagogy and resource utilisation. However, it is unclear why AR has yet to be institutionalised in distance and distributed learning environments. A scoping review was done to identify the enabling conditions for implementing AR in DE, and the results were deductively analysed. While the scoping review results did not reveal any frameworks or models that could guide the implementation of AR, it pointed out several factors to consider when adopting AR in a distance learning environment.

Introduction

Technology's growing effect continues to alter, interrupt, and expand education in the context of worldwide educational trends (Altbach et al., 2019). Although it is frequently assumed that technology can enhance learning (Kirkwood & Price, 2013), research shows that using technology by itself does not necessarily make pedagogical methods more effective and acceptable (Daniel et al., 2009). Moreover, technology is not the only factor affecting the provision of knowledge, as illustrated by the Covid-19 pandemic, which forced educational systems worldwide to review their teaching models. In response to the worldwide emergency caused by the pandemic, many universities closed their on-campus academic activities and initiated online classes (Daniel, 2020; Murphy, 2020).

Teachers were challenged to use relevant educational technologies to respond to the impact of the pandemic. However, adopting technology in response to the pandemic unveiled significant structural difficulties many learners and instructors face, such as internet access or issues regarding digital literacy skills, cost, and increased privacy concerns (He et al. 2021). The adoption and implementation of various technologies in response to the pandemic illustrated the complexities of implementing technology at scale.

Over the past two decades, published studies of the positive impact of AR on the effectiveness of teaching and learning in several disciplines have been increasing. According to Fitria (2023), AR makes learning more immersive and experiential, leading to increased memory retention among students. In their study, Nurbekova and Baigusheva (2020) claimed that using

digital educational resources with AR enriched the learning process with benefits such as making the learning material more exciting and understandable, while also assisting in the increased visibility of the learning material and improving the revelation of theoretical material. Tekedere and Göker (2016) argued that AR use in the classroom increased students' favourable attitudes towards improved enthusiasm for studying.

This present study will, therefore, explore published evidence to inform institution-wide deployment of AR in distance learning environments to answer the following research questions:

RQ1. What insights does the existing literature offer on frameworks or elements of frameworks for the adoption of Augmented Reality in distance education?

RQ2. What insights does the existing literature offer on the factors influencing AR adoption in distance education?

Methods

Scoping Review

Scoping reviews attempt to map the current literature in a field of interest in terms of the scope, nature, and characteristics of the primary study (Arksey & O'Malley, 2005). While the scoping review adopted in this study was based on the five-stage framework developed by Arksey et al., (2005), which adheres to a rigorous, transparent approach, the results were reported using the PRISMA 2020 (Page et al., 2021) reporting guidelines for systematic reviews.

Stage 1: Identifying the Research Question

The following research questions served as motivating factors for the search:

1. What insights does the existing literature offer on frameworks or elements of frameworks for the adoption of Augmented Reality in distance education?
2. What insights does the existing literature offer on the factors influencing AR adoption in distance education?

Stage 2: Identifying Relevant Studies

The choices made at each process level must be transparently documented in scoping reviews (Levac et al., 2010). In adherence to established research methodology, it is conventional practice to examine several databases while doing a scoping investigation, even though bibliometric databases frequently share sources (Bramer et al., 2013). Two databases, Web of Science (WoS) from Clarivate Analytics (all indices from 1972) and Scopus from Elsevier, were used in this review. Regarding general-purpose scientific literature, which includes journal articles, conference proceedings, and books, these frequently serve as leading databases and citation indexes. Both WoS and Scopus provide extensive coverage of a wide range of scientific fields, although their coverage of these fields only partially overlaps: WoS provides broad coverage of the natural sciences and engineering, whereas Scopus provides larger coverage of the social sciences (Mongeon & Paul-Hus, 2016).

The assumption is that merging various data sources may produce outcomes that vary more in terms of the literature. The search strings listed in Table 1 were used to examine the literature, with both databases filtered to allow searches in all fields (author, title, and abstract). The search strategies are a combination of multiple search strings guided by the research questions. *"Augmented Reality"* being the core element, it was added to all search strings. It was important to first investigate the available literature on *"Augmented Reality"* and *"Higher Education"* but exclude *"Virtual Reality."* Some search strings also picked up literature related

to *"Virtual Reality".* The search was followed by the addition of *"Framework"* and *"Model."* As several terms, such as distributed learning, e-learning, m-learning, and online learning, are broadly associated with distance education (Ilisagvik.edu., 2023), the search strings were narrowed down to replace higher education with distance education.

Table 1: Search Strings and Results

Search Strategy	Search Strings — ALL FIELDS (Author, Title & Abstract)	Web of Science	Scopus
1	'Augmented Reality' AND 'Higher Education' AND NOT 'Virtual Reality'	301	1522
2	'Augmented Reality' AND 'Higher Education' AND 'Framework'	56	5514
3	'Augmented Reality' AND 'Higher Education' AND 'Framework' AND 'Implement'	13	1054
4	'Augmented Reality' AND 'Higher Education' AND 'Model'	116	8393
5	'Augmented Reality' AND 'Higher Education' AND 'Model' AND 'Implement'	31	2044
6	'Augmented Reality' AND 'Distance Education'	32	1516
7	'Augmented Reality' AND 'Distance Education' AND 'Framework'	1	744
8	'Augmented Reality' AND 'Distance Education' AND 'Model'	5	1062
	Total	**555**	**21,849**

As shown in Table 1, the search strings with the database filter in all fields (author, title, and abstract) produced 22,404 total results, comprising 21,849 Scopus findings and 555 Web of Science findings. This reveals that the database filter must be adjusted to eliminate publications that do not specifically address the core research question. The search strings were maintained but the database filter was amended from *"All Fields"* to *"Abstract Only."* The amended filter produced 257 results (58.6%) for Scopus and 181 (41.4%) for Web of Science. A total of 438 studies could then be further analysed, which was a comprehensive collection of important studies that struck a balance between depth, breadth, and viability.

Stage 3: Study Selection
Initial examination of the findings, which were now limited to *"Abstracts Only"*, revealed that some studies, although investigating AR, were not in the context of higher education or education delivery. Therefore, it was necessary to adopt a process to weed out studies, such as those that failed to respond to the research questions in Stage One. To address this issue, the mechanism from Seaton et al. (2019) was adopted.

The 438 publications that were initially chosen in Stage 2 underwent further screening, as shown in Figure 1, for final selection in line with the PRISMA 2020 (Page et al., 2021) guidelines to consolidate the pertinent material. The researcher performed the initial evaluation, and the selection and findings were member-checked by an independent researcher. Only when the two reviewers had reached an understanding were the search results transferred to the data processing software Microsoft Excel and the whole data extraction was carried out.
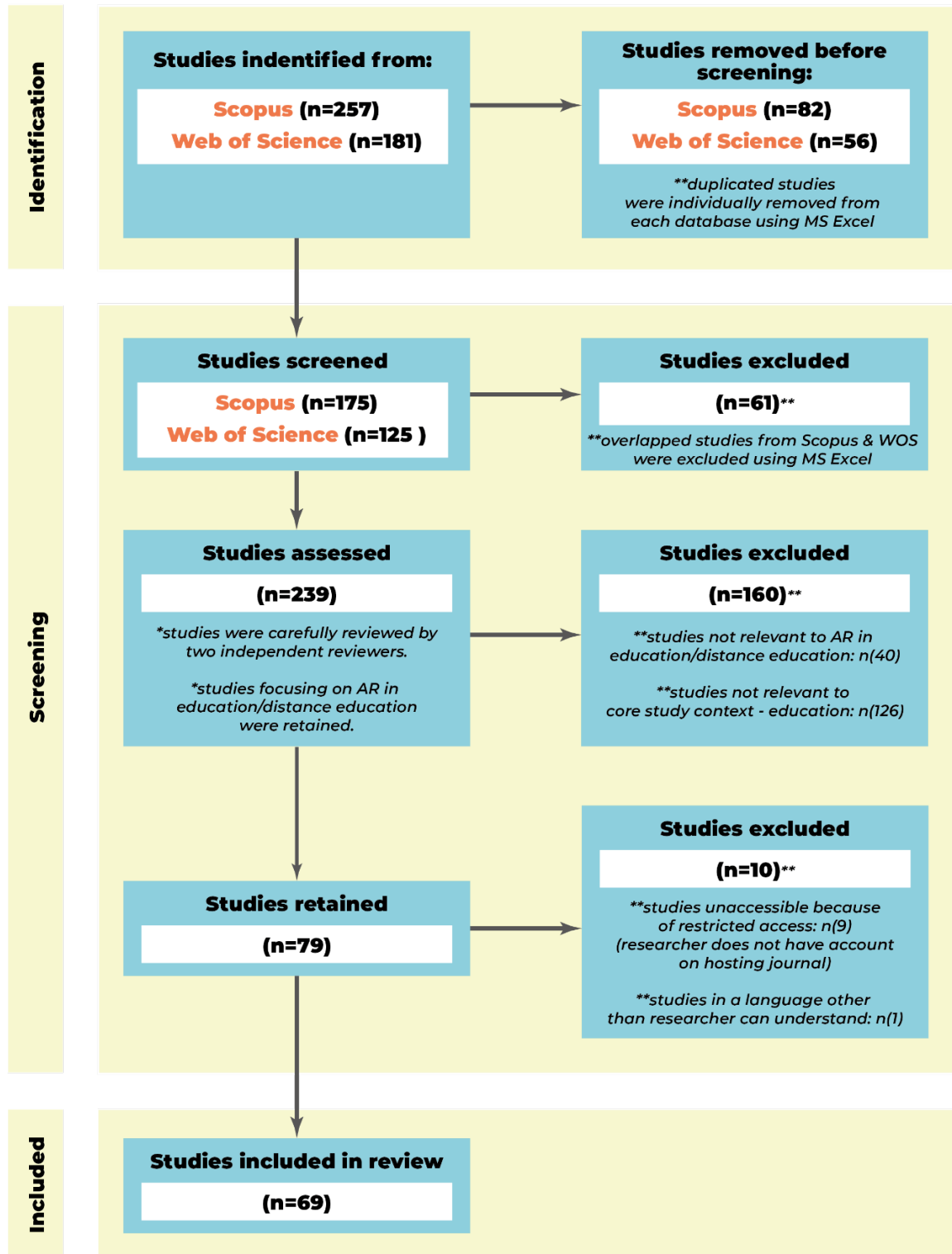
Identification

Studies indentified from:

Scopus (n=257)
Web of Science (n=181)

Studies removed before screening:

Scopus (n=82)
Web of Science (n=56)

**duplicated studies were individually removed from each database using MS Excel

Screening

Studies screened

Scopus (n=175)
Web of Science (n=125)

Studies excluded

(n=61)**

**overlapped studies from Scopus & WOS were excluded using MS Excel

Studies assessed

(n=239)

*studies were carefully reviewed by two independent reviewers.

*studies focusing on AR in education/distance education were retained.

Studies excluded

(n=160)**

**studies not relevant to AR in education/distance education: n(40)

**studies not relevant to core study context - education: n(126)

Studies excluded

(n=10)**

**studies unaccessible because of restricted access: n(9) (researcher does not have account on hosting journal)

**studies in a language other than researcher can understand: n(1)

Studies retained

(n=79)

Included

Studies included in review

(n=69)

Figure 1: Flow diagram for study selection

As illustrated in Figure 1, 257 and 181 studies were identified from Scopus and Web of Science, respectively. However, it was found that each database may have picked the same articles twice under different search strategies. Therefore, their titles and abstracts were loaded into the database software Microsoft Excel, where duplicate studies were removed for each database, then 82 studies were excluded from Scopus and 56 from Web of Science. Hence, 175 studies were retained for Scopus and 125 for Web of Science. Further rounds of filtering excluded 61 overlapping studies from both databases combined and another 160 were excluded because they were either irrelevant to AR in education and distance education or irrelevant to education. A total of n = 79 studies were retained for further assessment by the researcher.

The researcher proceeded to download the full paper for an in-depth assessment. Ten studies had to be excluded because of the inaccessibility of the hosting journal (the researcher did not have an account) or because the studies were in a language other than that of the researcher (n = 1). The final group of articles (n = 69) was downloaded and moved to Atlas.ti for qualitative analyses.were

Stage 4: Charting the Data

The final phase involved outlining key information collected from all 69 analysed articles. Ritchie and Spencer (1994) defined 'charting' as a technique for synthesising and comprehending qualitative data, which entails grouping data into charts and tables according to significant subjects and themes. Cooper et al. (2019) subsequently recommended the following:

1. The research team should collectively develop a data charting format and identify the variables to extract answers to the research question(s).
2. The data obtained should be charted through sifting and sorting in the form of tables, which include the study details based on the full texts.
3. A numerical analysis of the extent and nature of included studies should be mentioned.

The 69 articles were then transferred to Atlas.ti, a program for qualitative data analysis (QDA), for additional assessment and classification.

Stage 5: Collating, Summarising, and Reporting the Results

At this point, the findings of the scoping study were gathered, summarised, and reported. In contrast to systematic reviews, scoping reviews do not seek to 'synthesise' the data or compile the findings of several studies (Arksey et al., 2005). Furthermore, a scoping review cannot determine whether the research produces credible or generalisable conclusions because it does not assess the quality of the evidence. Cooper et al. (2019) outlined the following criteria for obtaining, summarising, and presenting scoping results:

1. Results should be presented in a logical, descriptive, diagrammatic or tabular format.
2. The results should be presented in the form of a narrative account.
3. Issues associated with a bias should be discussed.
4. Implications for future research, education practice and/or policy should be discussed.
5. Finally, the conclusion should describe the current state of the overall literature concerning the topic.

It takes deliberate effort to pick out the most significant details and write them up into a compelling 'story' that answers the research questions and offers insights that are true to the data, rather than the findings and results of qualitative research simply emerging from transcripts and documents (Miles et al., 2013).

Data Analysis

The qualitative data for this study were inductively coded on Atlas.ti following Saldana (2015). According to Charmaz (2001), qualitative analysis coding serves as an 'essential link' between the gathering of data and the interpretation of their importance. The 69 retained studies yielded twenty-seven (27) codes, as described in Table 2.

Table 2: Codes Generated in Atlas.ti from Scoping Articles

Codes Generated in Atlas.ti		
Acceptance	Engagement	Motivation
AR Content	Enhance	Negative Impact
Augmenting Reality	Framework	Online
Autonomous Learning	Higher Education	Pedagogy
Challenges	Implementation	Potential
Collaborative Learning	Interdisciplinary	Student Learning
Cost	Learner-Generated	Support
Distance Education	Mobile AR	Technologies
Effectiveness	Mobile Learning	Virtual World

Some codes were assigned to more than one category. Each category created from the codes resulted in the creation of themes. Once the codes were generated from the quotations in the 69 articles from the scoping research, they were further refined to create categories and themes, as illustrated in Figure 2.

Figure 2: Streamlined codes-to-theory model

Results

According to Saldana (2015), "themes" are a product of coding, classification, or analytical reflection rather than being coded in and of themselves. The author further added that, in general, a theme is an extended-phrase or sentence that identifies a unit of data. A theme was also used after a comprehensive qualitative research literature review. This scoping review resulted in five themes from the initial ten categories, as described in Figure 4. The subsequent sections discuss each theme and the distinct categories associated with them.

Scoping Themes
Potential of AR in Education
This "Potential of AR in Education" includes three categories: "Potential of AR to enhance pedagogy," "Potential of AR to enhance Learning", and "Potential of AR to enhance Curriculum." Thus, the theme encompasses potentials that affect all major education stakeholders, including teachers, students, and education institutions, through curriculum development or pedagogical approaches. According to Liarokapis and Anderson (2010), several institutions of higher learning are open to incorporating AR technology into their current online teaching methodology. Zhang et al. (2022) argued that the use of AR technologies in education

has become more frequent, since students can interact in a more immersive manner with their environment, which allows them to foster a better understanding of concepts.

Many authors have explored AR and its potential, including Annetta et al. (2012), Bressler and Bodzin (2013) and Enyedy et al. (2012). Godwin-Jones (2023) argued that one of the most common findings in AR studies was the strong motivation factor for learners when they created or co-created learning aspects, leading to enhanced learner engagement. This author further added that one of the primary advantages of AR was the ease of access, as most of the AR apps for education can be widely used on mobile phones.

Some have studied how AR affects cognitive function using educational games, such as Arvanitis et al., (2009), who examined how it affected science students with physical limitations. Morrison et al. (2011) also investigated the effects of AR using several educational apps that scan paper maps. Regardless of the characteristics of the target population, all these studies unanimously agreed that AR has immense potential and positively influences a variety of learning outcomes (e.g., whether they were samples of traditional learners or those with learning disabilities).

Challenges of AR in Education

The "Challenge of AR in Education" theme elaborates on the various challenges of using AR in an educational environment. In a study conducted by Hanafi et al. (2019), while discussing the success of gaming and new AR in science and technology learning, they also acknowledged that one of the most important challenges remains the integration of AR resources into learning materials. According to Akçayır and Akçayır (2017), although augmented reality technology is advancing, it can still be challenging for students. Therefore, additional research on creating and using augmented reality apps is required. In an AR-based learning environment, learners' preferences and opinions regarding usability must be investigated.

Several other authors have reported the challenges of AR use in educational settings. Munoz-Cristobal et al. (2015) argued that AR can be difficult for students to use and Chiang et al. (2014) reported that GPS errors can cause student frustration and distract student attention. Bautista et al. (2022) highlighted several socio-techno-economic challenges of using AR and, as Panchapakesan (2020) reported, managerial challenges exist when adopting AR. However, according to Al-Ansi et al. (2023), with the right resources and strategies, AR use in education can be a very promising tool in teaching and learning.

Mobile Learning

"Mobile Learning", as introduced by Moreira et al. (2017), is increasingly being considered a paradigm that could potentially change the face of education in general. Santiago et al. (2022) reported that, in recent years, mobile applications have become increasingly popular in the field of education. This theme discusses both mobile learning in education in a more holistic manner as well as using mobile devices for AR learning, including access to AR software applications.

According to Kinash et al. (2012), "mobile learning" means using mobile devices with an internet connection for learning purposes. Mobile devices are transforming human lifestyles by changing how we socialise, thus creating new habits (Oulasvirta et al., 2012). Higher education has not been spared during this transformation. Higher education has undergone significant changes due to the rapid growth of mobile computing devices and online resources (Liaw et al., 2010). Furthermore, mobile technology has introduced an array of new educational possibilities, thus opening new learning and teaching approaches. Hürsen et al., (2011) elaborated on the

various concepts that emerged with mobile technology, such as e-learning, m-learning, or u-learning.

Gikas and Grant (2013) argued that mobile technology has become an essential component of education in HEIs because it presents opportunities and challenges for both students and teachers. When mobile learning relates to the various learning management systems of HEI systems, it enables learning to occur anytime, anywhere. Mobile learning can also help students with special educational needs and help them to attend classes remotely. Although there have been several reports on the potential benefits of mobile learning, Sabah (2016) suggested that, for m-learning to be successful, identifying the variables that affect student acceptance and opinion is crucial.

Although mobile AR has existed for some time, Perez (2016) argued that it has only received widespread public attention owing to a popular mobile AR game called Pokémon Go. In the context of education, Fitzgerald et al. (2013) classified mobile AR projects in education using a simple taxonomy according to: device type, mode of interaction, method of sensory feedback, personal or shared experience, and fixed or portable experience. Cochrane et al. (2016) reported that mobile AR primarily enhances traditional content distribution techniques or learning experiences by enabling access to digital material in real-world settings.

The CONTSENS projects by Cook (2010) and the Zapp project by Meek et al. (2013) are two examples of educational use of mobile AR. The CONTSENS project, funded by Sony Ericsson, was a two-year project that was initiated in April 2008. It involved a European-wide consortium that was headed by Ericsson Education, Ireland; Giunti Labs, ECLO (Belgium); London Metropolitan University; Corvinno (Hungary) and Plovdiv University, Bulgaria. The project focused on developing learning and training materials, and was enhanced by context sensitive and location-based delivery for mobile learning. The CONTSENS project included two social constructivist education projects:

1. A Guided Urban Walk exploring the impact of urban planning on society using mobile phones.
2. Exploration of the historical ruin of a Cistercian Chapel using mobile AR students working in teams to compare the ruin with an overlaid model of the original site.

Cochrane et al. (2016) concluded that the convergence of mobile AR and pedagogy enabled the creation of novel learning experiences in networked, collaborative learning environments that emphasise learner-generated settings and material.

New Technologies, New Possibilities
The "New Technologies, New Possibilities" theme provided a broad overview of technologies in education. Our teaching-learning processes must be revised to accommodate modern technologies to better serve the generations of students born into the digital age (Moreira et al., 2017). However, the authors acknowledge that it is of utmost importance to understand whether the main users of educational technology, instructors and students, are open to and conscious of the need to adjust to this new edu-tech learning paradigm.

Martín-Gutiérrez et al. (2015) reported that computer technologies provide a strong enhancement to education tools allowing for the creation of new teaching technologies. They further added that university classrooms are equipped with many teaching technologies, such as internet networks, computers, electronic blackboards, projectors, and video conferencing tools.

All these tools allow the integration of AR, which, they acknowledged, is one of the most promising technologies to improve current teaching models.

The educational landscape is becoming more diversified, as innovative technologies can be easily adopted within the class as a cognitive exploratory tool and as a source of engagement and communication among students (Gargish et al., 2020). These authors further added that innovative technologies help keep the current generation of students motivated in their studies. Cabiria (2012) acknowledged that education and innovative technologies travel parallel pathways, where they often inform each other's development.

López-Peral et al. (2018) confirmed that recent technologies in an educational environment have been successful, which, in turn, motivated changes in the way teaching was conducted at universities. The authors concluded their research by mentioning that, in general, students were very satisfied with learning resources created using modern technologies. Additionally, students should view recent technologies as an opportunity to attain excellence in their studies, rather than a challenge imposed before they start their professional careers.

Broader Context
The "Broader Context" theme covers general higher education, AR, pedagogy, and learning content. Bryant et al. (2014) stated that though 'success' is an important variable of learning outcomes, it should not prohibit innovation that can support and enhance the learning journey experience of a student. The key conclusion for university policies and practices, which, incidentally, has been emphasised by distinguished authors in the literature on higher education, is that institutions must broaden the scope of the toolbox they now use to comprehend students' learning or failure experiences.

Technopedagogy, as reported by Espinosa et al. (2018), is the requirement of teachers to embed technologies in their pedagogy, which is a new methodological paradigm in which exclusively electronic and digital resources are employed in the teaching and learning processes. This enhances quality metrics and replicates creative learning opportunities under the control of educational technology (Cabero-Almenara & Barroso-Osuna, 2018).

Discussing the broader relationship between technology and higher education, Stojšić et al. (2020) reported that, in general, higher-education students own the necessary equipment to use technology for learning, as most participants have at least a smartphone. However, Bower et al. (2014) reported that using innovative technology in education does not guarantee success.

Discussion

"Potential of AR in Education" and "Mobile Learning" emerged as two of the primary themes developed for this scoping review. Even though only 69 publications could be fully accessed, there was a noteworthy shortage of literature on frameworks or adoption models dedicated to the use of AR in distance learning. Considering the rich entanglement of technology with the evolution of distance education, the absence of any published evidence on AR in formal distance learning contexts is peculiar.

Although Chen et al. (2016) enumerated the multiple advantages of AR in education, many aspects of this technology are viewed as obstacles to its deployment by Doerner and Horst (2022).

This scoping review's importance for distance education institutions, in general, can be seen not only in highlighting the strange absence of published evidence on the use of AR in formal distance education contexts, but also in the lack of guiding principles for the adoption of

AR in distance learning. The scoping review also highlights that AR implementation should be linked to mobile learning, led by pedagogy, and necessitates an interdisciplinary approach. The scoping review also foregrounded various challenges that should be addressed to ensure an enabling environment that maximises the potential benefits of AR to teaching and learning. The following central ideas emerged based on the five themes (see Figure 2):

1. Technology, particularly AR, is never considered on its own; it is always connected to education. Technology selection and use, including the use of AR, should always be tied to pedagogy to increase the efficiency, satisfaction, or depth of learning.
2. Transdisciplinarity emerged as a significant feature of the scoping review, demonstrating that using AR requires thinking beyond discipline boundaries and embracing interdisciplinarity.
3. The effective use of AR in educational settings depends heavily on mobile technology, necessitating the consideration of issues, including the design of AR, minimal requirements, operating speed, and internet connectivity, as well as the quality and cost of access. Institutions cannot and should not presume that all students have equal access to the internet, hardware, and software, as Covid has demonstrated.
4. The potential of AR includes references to the potential for more effective collaborative learning, increasing learner autonomy, teaching and learning effectiveness, and increasing engagement and motivation levels (for both lecturers and students).
5. The challenges in the effective and appropriate use of AR include cost (of design, development, and use), the need for support (instructional design, digital infrastructure, ICT support to staff and students, training, and professional development), acceptance (institutions, lecturer, and students), and possible negative impacts (e.g., access issues for students with disabilities, risks of distraction, and privacy concerns).

Conclusion

AR can streamline certain educational processes in distance education, or education in general, if the correct resources and strategies are used. While making real-time learning content accessible to diverse learners AR can also provide personalised learning and support. While students and educators may lack familiarity with AR, training and support are essential to ensure effective adoption. Cost remains a challenge as AR solutions require specialised hardware and software, however, compared to technologies like VR, which requires more specialised equipment, AR can replace traditional textbooks with dynamic 3D imagery and enriched learning materials. AR allows students to experience practical scenarios remotely, bridging the gap between theory and practice which, consequently, makes this technology more accessible for distance education.

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