



Trends in the Use of Augmented Reality from Tangible Interfaces in School Learning : A Systematic Literature Review

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Abstract: This study aims to analyze trends in the use of augmented reality from tangible interfaces in the context of formal and informal education. This study employed a systematic literature review (SLR) method adapted from the PRISMA model. This research used the Publish or Perish application to search for various relevant scientific articles taken from international journals, Scopus, with a range of 2019-2023. The data analysis technique for this research used thematic analysis. The development of AR media showed significant improvement, especially in the aspect of increasingly realistic and diverse user interfaces, enabling closer integration with the curriculum and presenting more engaging learning experiences. The interactive and collaborative features of AR applications showed great potential for enhancing student interaction with learning materials through immersive and interactive visual experiences. In addition, such collaborative features could also facilitate cooperation between students, creating a more dynamic and effective learning environment in schools. This research emphasized the importance of using appropriate research methods to deepen the understanding of the development of AR media in education and the potential of AR applications in creating more interactive and collaborative learning experiences in school environments.

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Introduction

Augmented reality (AR) is becoming increasingly vital in education today (Rodríguez-Vizzuett, 2019). By incorporating digital elements into a physical environment, AR opens the door to engaging and interactional learning. It allows students to experience abstract concepts in a more real and practical way (Bettati, 2023). Not only that, AR also fuels the spirit of learning by providing a fun and immersive learning experience. Both in the scope of formal and informal education, AR plays a major role in expanding students' observations, providing a better understanding of learning materials, and advertising cooperation and creativity among students (Quesada, 2022). In this way, the emergence of AR tools has become a very valuable innovation in making the future era of education more energetic and inclusive (Tsou, 2023). The introduction must contain (in sequence) a general background, a state of the art as a basis for statements of scientific novelty from articles, statements of scientific novelty, and research problems or hypotheses. At the end of the introduction, the purpose of the article review must be written. In the format of scientific articles, a literature review is not permitted, as is the case with research reports. However, it is manifested in the form of a state-of-the-art study to show the scientific novelty of the article.



Two forms of AR currently available to educators are location-following AR and vision-based AR (Topsakal, 2019). Location-following AR presents digital media to participants as they move through the physical environment using a GPS-equipped smartphone or device (Velazco-Garcia, 2021). These media, such as text, graphics, audio, video, and 3D models, add narrative information, navigation aids, and/or academic materials relevant to the physical location (Yang, 2020). In contrast, vision-based AR presents digital media to participants after they point the camera on their mobile device at an object, such as a QR code or 2D target (Wang, 2022).

The potential advantage of Augmented Reality (AR) as a learning tool lies in its ability to develop new perspectives for students, allowing them to see the world around them in a way they have never experienced before (Lian, 2023). AR also allows students to engage with realistic problems in conditions that are directly relevant to their daily lives (Keil, 2019). Two main forms of AR have their advantages, namely location-aware AR and vision-based AR. Both forms integrate the capabilities of smartphone devices, such as GPS, cameras, object recognition (Harvel, 2019), and tracking to create immersive learning experiences in physical environments.

This AR approach creates a truly immersive learning experience, giving educators a potentially transformative tool to improve the way they teach and students learn (Schubert, 2023). The concept of immersion is very important in this case, where one really feels involved in such a real and comprehensive experience. This provides the use of interactive media that further increases the level of digital immersion (Bauer, 2022). Research has shown that these immersive experiences have a positive impact on education, especially in terms of allowing students to see from multiple perspectives, learn in actual places, and transfer knowledge more effectively. In addition, both location-aware AR and vision-based AR utilize context sensitivity, which allows mobile devices to deliver digital content that corresponds to the user's physical location (Chen, 2021). Although research focuses more on location-aware AR, vision-based AR also has great potential in learning (Laera, 2021). Research on immersive media shows that vision-based AR can be powerful, especially in creating different frames of reference, such as egocentric and exocentric, which have unique strengths in the learning process (Quesada, 2023).

This literature review highlights the utilization of augmented reality (AR) in learning contexts by leveraging context-aware mobile technologies, such as smartphones and tablets (Park, 2021). These technologies enable participant interaction with digital information embedded in a physical environment (Sauda, 2022). We outline research results on AR in learning environments, both formal and informal, such as in schools, universities, museums, parks, and zoos, focusing on the advantages and limitations of AR in the context of teaching, learning, and instructional design (Z. Li, 2021).

So, the purpose of this research is to study the progress of using augmented reality media in the school environment. This research is highly urgent due to the rapid advancement of augmented reality (AR) technology, which requires a deep understanding of how to integrate it into education effectively. Delaying this research could result in missed opportunities to leverage cutting-edge technology to enhance learning experiences. Additionally, educators and policymakers are seeking innovative tools to increase student engagement and learning outcomes, making timely insights from this study crucial for informing decisions and encouraging the adoption of AR in curricula. There is also an urgent need to consolidate findings from diverse and rapidly growing studies to provide a clear understanding of AR's role in education.



This research is expected to conduct a comprehensive literature review to identify various types of AR media used in education, addressing the posed research questions. The study will categorize and analyze the research methods employed in existing AR studies, providing insights into the research designs, data collection techniques, and analytical approaches used by researchers. By examining the development and use of AR in formal and informal educational contexts, the research will highlight trends, challenges, and success stories, offering a historical and contemporary overview. Furthermore, this research will explore the interactive and collaborative capabilities of AR applications in school learning, providing insights into their practical implications and effectiveness. Overall, this research is crucial for understanding the current landscape and future potential of AR in education, and it aims to offer valuable insights that can guide educators, researchers, and policymakers in leveraging AR to enhance learning outcomes.

Research Method

This research used a qualitative approach, with a systematic literature review method using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis). PRISMA emphasizes the importance of having clear criteria, using reliable sources of information, implementing an effective search strategy, undergoing a rigorous selection process, and conducting a thorough analysis of the search results. In the information search process, we used the Publish or Perish application with a focus on Scopus-listed articles between 2019 and 2023. This method ensured that we obtained relevant and up-to-date data in order to produce reliable findings. In the article search process, the keywords used were "augmented reality" and "augmented reality for education". The search resulted in 225 articles with the keyword "augmented reality" and 45 articles with the keyword "augmented reality for education". Thus, the total number of initial articles found was 270. In selecting the articles, the inclusion criteria applied included publication in English and a clear exposition of the augmented reality medium used or developed. Meanwhile, the exclusion criteria included methods that were not well explained, research that was a prelude to other research, augmented reality media for formal and informal education, incomplete articles, and not published in English.

Table 1. Summary of Augmented Reality Usage

Description	Result
Time Period	2019-2023
Article	270
Average Citation Per document	362
Author	300
Single-author Documents	75
Document with Co-Author	195

A total of 270 different documents were then included in PRISMA. First, the most active countries, institutions and authors from this period were examined. The second step was to look at the distribution of the most cited journals and articles. The third step was to look at the most prolific authors and sources. The diagram of the article selection process can be seen in the figure below

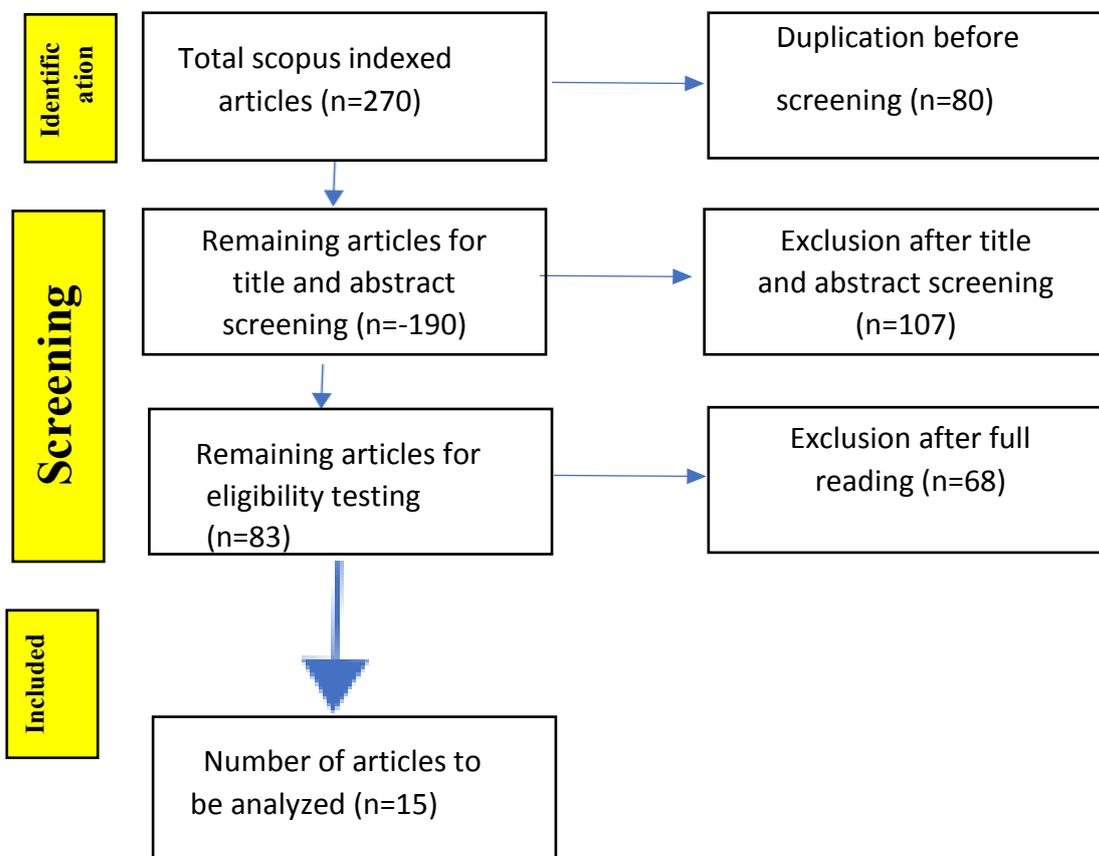


Figure 1. The diagram of the search and selection process

The number of articles identified as indexed by Scopus was (n=270). In the first stage, duplication checks were carried out on the identified articles, which resulted in the exclusion of (n = 80) so that the number of articles remaining for title and abstract screening is (n = 190). Exclusion after screening the title and abstract as much as (n = 190) and the remaining 83 articles for feasibility testing by reading the entire contents of the article. The exclusion of the feasibility test reduced the number of articles to 270. So, the number of articles analyzed was 15. In this study, content analysis was employed to identify and categorize the main themes emerging from the selected articles. The research process began with the identification of 270 articles indexed by Scopus. After a duplication check, 80 articles were excluded, leaving 190 articles for title and abstract screening. This screening resulted in the exclusion of 107 articles, leaving 83 articles that were then subjected to a full-text eligibility assessment. Out of these 83 articles, only 15 met the criteria for further analysis. Content analysis was applied to these 15 articles to categorize the content based on relevant themes, allowing researchers to identify patterns and trends in the existing literature. Through systematic coding and categorization, this study successfully revealed key themes that provide deep insights into the researched topic.

Results and Discussion

Research methods

The first formulation of the problem tested was about the most widely used research design in the 2019-2023 timeframe, which is related to the use/development of digital books. Of the 15 articles that were output from the screening process, the results of the analysis



regarding the research designs used can be presented as follows. The results and discussion contain scientific research findings and discussions. Write down scientific findings obtained from the results of research that has been done but must be supported by adequate data. The scientific findings referred to here are not the results of the research data obtained. The scientific findings must be explained scientifically, including the following: What scientific findings were obtained? Why did that happen? Why are trend variables like that? All these questions must be explained scientifically, not only descriptively, but if necessary, supported by phenomena of an adequate scientific basis. In addition, it should also be explained in comparison with the results of other researchers who are almost the same topic. The results of the research and findings must be able to accommodate the research objectives in the introduction.

Table 2: Recap of research design

No	Research Design	Source
1	Qualitative	(Rodríguez-Vizzuett, 2019), (Quesada, 2022). (Pedersen, 2020), (Chromik, 2021), (Barrera-Machuca, 2020)
2	Experiment	(Pfeuffer, 2021), (Kwak, 2020)
3	Design/development	(Bettati, 2023), (Tsou, 2023), (Park, 2021), (Sauda, 2022), ((Kong, 2019), ((Z. Li, 2021), (Lian, 2023)
4	Meta analysis	(Wang, 2022)

The data listed in the table above is presented visually through the diagram below.

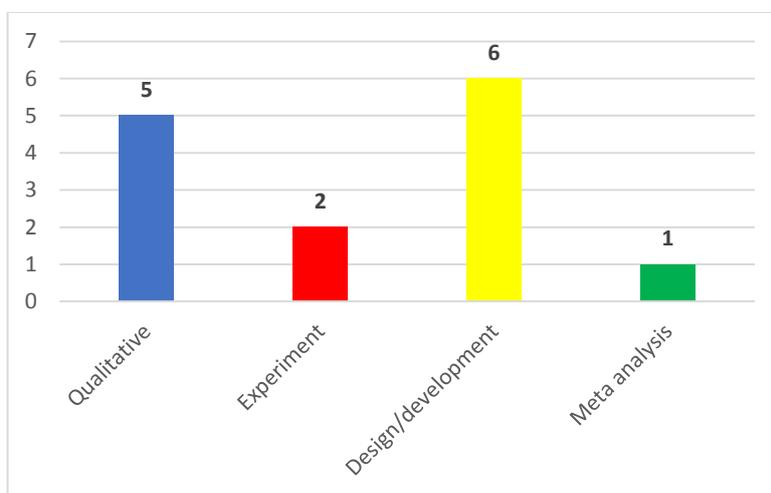


Figure 2: Illustration of research design distribution diagram

From the data in Table 2 and Figure 2, quality research is divided into several types. About one-third of the research is qualitative, while experimental research accounts for about ten percent. The majority of research, almost half, is design or development research, and the rest is meta-analysis research. Of all these types of research, the most frequently conducted in the context of augmented reality is design or development research. So, there is much research focused on developing augmented reality technology with varying degrees of quality.

The development and use of augmented reality media in formal and informal educational contexts in real user interfaces in recent years

In recent years, the advancement and use of augmented reality (AR) tools have become an important feature of education, both formal and informal. AR not only provides a more interactive training experience but also changes the method we correlate with



information and surrounding areas. In formal education, teachers and curriculum developers are exploring ways in which AR can be integrated into training to increase students' understanding of complex learning materials. The use of Augmented Reality (AR) in the category of creating more energetic practice areas allows students to actively engage in more immersive imitation of virtual depictions and research. Meanwhile, in the aspect of informal education, AR applications have become a very efficient tool in providing outdoor upgrading categories. For example, museums and origins sites use AR to bring artifacts and historical areas to life so that attendees can have an immersive and interactive experience. Not only that, online training programs are also increasingly using Augmented Reality (AR) technology to provide a more immersive and engaging training experience for remote students. In conclusion, the second issue regarding the advancement and use of augmented reality tools in official and informal education conditions can be integrated, which is one of the main parts of viewing the task of AR in improving the quality of training.

Table 3 Recap of aspects of using augmented reality media in formal and informal education contexts

Type of education	Description	Articles
formal	The application of AR can also increase student engagement through fun and interactive learning experiences. They can participate in activities such as solving AR puzzles, collaborating on joint projects using AR technology, or even creating their own AR content. This helps to reinforce the understanding of the concepts being taught and encourages creative and collaborative thinking.	(Sauda, 2022),(Huang, 2022),(Chen, 2021),(Lima, 2023),(Bettati, 2023),(Wang, 2022),(Lian, 2023),(Rodríguez-Vizzuett, 2019),(Li, 2023),(Keil, 2019)
informal	The use of AR to deliver a fun and engaging learning experience can improve the attraction and retention of information. In addition, AR can also change the way users interact with their surrounding environment, creating a more immersive and convincing learning experience.	(Chromik, 2021),(Pedersen, 2020),(Quesada, 2023),(Ejaz, 2019),(Laera, 2021),(Croft, 2020),(Cannavò, 2020),(Kong, 2019),(Chamzas, 2020),(Park, 2020),(Tong, 2019),

In the context of formal education, the use of Augmented Reality (AR) is applied with the aim of improving the understanding of abstract concepts visually and interestingly. For example, AR can be utilized in science learning to display three-dimensional models of astronomical objects or complex molecular structures. With AR technology, students can directly interact with the subject matter, which in turn increases their engagement and understanding of the material. On the other hand, in informal education contexts such as museums or science centers, AR is used to provide a more enjoyable and immersive learning



experience for visitors. Visitors can use AR devices to view additional information, historical reconstructions, or interactive simulations that enrich their experience while visiting.

The interactive and collaborative capabilities of Augmented Reality (AR) applications in school learning

In this section we review the interactive, multi-user, and collaborative capabilities of the AR apps described in the selected studies. We categorize the studies into five different groups, based on the way the apps provide interactive functions. First of all, we identify the basic interactive category, where students can interact with the app through User Interface (UI) elements such as menus and buttons directly in the augmented space. Then, we looked at object interaction, where students can interact directly with additional content without having to use UI elements. The next category is quizzes, where the app provides quizzes to test students' understanding of a topic directly within the app or includes gamification concepts. We also look at behavior tracking, where the app tracks student behavior to modify the content shown to the user. Finally, we highlight augmented interactions, where the additional content displayed may change depending on the user's interaction with the surrounding environment. Additionally, we consider multi-user AR experiences, where multiple students can view the same augmented content from different devices, and any changes can be seen by all other students. We are also interested in collaborative AR apps, where students share a common goal and work together or compete to achieve it. We are interested in this type of app because interactive learning environments have been shown to have a positive impact on students' education. Meanwhile, collaborative learning offers a number of benefits to students in different areas.

Table 4 shows the articles that have been classified based on the level of interactivity and collaboration.

Interaction type	Articles
Basic interactivity	(Ang , 2019), (Lin et al., 2019), (Pombo, 2019) (Chang et al., 2019), (Chen et al., 2019),(Yin, 2020),(Macariu et al., 2020)
Object interaction	(Costa, 2019), (Iqbal, 2019), (Cao,2019), (Kum, 2019) (Ibáñez et al.,2020), (Kenoui, 2020), (López-faicán,2020) (Carlos, 2020), (Syahidi , 2020), (Thamrongrat,2020)
Augmented interaction	(Cen, 2019), (Nasongkhla et al., 2019),(Lam et al., 2020), (Abriata, 2020), Dave et al.,2020 (Macariu et al., 2020), (Theodoropoulou et al., 2020)
Multi-user	(Kum-biocca et al., 2019), (Lee et al., 2019), (Dave et al., 2020), (López, 2020)
Collaborative	(Lee et al., 2019), (Xeftaris ,2019), (López, 2020)

By modifying the distance of each marker from the next, the additional animation generated by the app changes its behavior, visually showing the dual nature of light. Ang and Lim (2019) implemented a similar idea. In the app, each marker by itself displays only a letter in 3D. When multiple markers are combined to form an English word (from a predefined set), the app displays a 3D model of the word. Cao and Liu (2019), on the other hand, taught computer science fundamentals innovatively, using visualized algorithms. Each marker not only conveys additional content, but also represents instructions in the specially developed ALGO programming language. Different marker sequences result in different



behaviors of the additional content. As technology develops, applications for learning are getting more creative. Macariu and colleagues (2020) developed an app for learning Chemistry that combines text recognition with 3D animation. This allows students to understand the concept of molecules in a more immersive way. However, explorative research is still scarce when it comes to incorporating other senses besides vision. Kenoui and Mehdi (2020) used the IBM Watson SDK to enable interaction in English, with answers displayed as text and audio. Progress is also being made in education for students with special needs. Mikułowski and Brzostek-pawłowska (2020) designed a system for visually impaired students, which detects mathematical formulas and provides audio descriptions and Braille representations.

In the context of collaboration, in 2020, Dave and his team developed a jigsaw puzzle app that motivates students to work together in teams. Lopez and team in 2020 created an ARGBL app that stimulates healthy competition among students while expanding their understanding of different regions. Lee and friends in 2020 introduced an AR app that allows users to learn about the nature of light in an interactive way, even engaging users without smart glasses through a projector system.

All of these show how educational apps continue to evolve by combining innovative technologies and creative learning strategies. The systematic literature review on "Trends in the Use of Augmented Reality from Tangible Interfaces in School Learning" identifies significant impacts on education. Conceptually, augmented reality (AR) through tangible interfaces enhances learning experiences by allowing direct interaction between students and digital content in the physical world, supporting constructivist and cognitive learning theories emphasizing active engagement and deeper understanding. Practically integrating AR enriches the curriculum by making abstract concepts more concrete and accessible, though challenges such as adequate teacher training and equitable technology access need addressing. Thus, AR through tangible interfaces not only enhances student engagement and cognitive skills but also prepares them for a future driven by evolving technologies.

Conclusion

Based on the analysis of the literature sources presented it can be concluded that The development of AR media shows significant improvement, especially in the aspect of increasingly realistic and diverse user interfaces, enabling closer integration with the curriculum and presenting more engaging learning experiences. The interactive and collaborative features of AR applications show great potential for enhancing student interaction with learning materials through immersive and interactive visual experiences. In addition, such collaborative features can also facilitate cooperation between students, creating a more dynamic and effective learning environment in schools. This research emphasizes the importance of using appropriate research methods to deepen the understanding of the development of AR media in education and the potential of AR applications in creating more interactive and collaborative learning experiences in school environments. For the development aspect of augmented reality media in the context of formal and informal education it has experienced significant development. This is reflected in increasingly real and diverse user interfaces, enabling better integration with the curriculum and more engaging learning experiences for the interactive and collaborative aspects of augmented reality applications in school learning. AR applications have the potential to enhance the interaction between students and learning materials through immersive and interactive visual experiences. In addition, the collaborative features in AR apps can facilitate cooperation



between students in undergoing the learning process. Thus, from these three questions, the use of appropriate research methods can provide a deeper understanding of the development of augmented reality media in education and the potential of AR applications to create a more interactive and collaborative learning experience in the school environment.

Recommendation

For teachers, it is crucial to consider several recommendations when integrating augmented reality (AR) through tangible interfaces into learning environments. Firstly, gaining a deep understanding of AR's potential and how it can enrich students' learning experiences is essential. Secondly, comprehensive professional development is necessary to ensure teachers are proficient not only in the technical aspects of AR but also in effective teaching strategies for its integration. Selecting AR content that aligns with the curriculum and learning objectives is crucial for enhancing relevance and instructional effectiveness. Regular evaluation of AR implementation can help adjust teaching approaches for better effectiveness. Lastly, ensuring equitable access to AR technology for all students is important to mitigate accessibility gaps. By addressing these considerations, teachers can optimize the use of AR to enhance student engagement and deepen their understanding of learning materials.

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