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PAPER

Augmented Reality in Early Childhood Education: Trends, Practices, and Insights from a Literature Review

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ABSTRACT

In recent years, the use of augmented reality (AR) in early childhood education (ECE) has grown significantly. However, there remains a limited understanding of publication trends, research methodologies, and the overall impact of this technology. This study evaluates the evolution of AR in ECE from 2013 to 2023 through a comprehensive review of 49 articles published in journals indexed by Scopus. We employed VOS viewer for bibliometric analysis, alongside Google Scholar for database searches and Microsoft Excel for statistical evaluation. Three researchers conducted content analysis of the selected papers based on established criteria. Our findings reveal a consistent increase in AR-related publications in ECE over the past decade. In studies utilizing quantitative methods, participant numbers typically ranged from 30 to 100. Researchers developed AR applications using marker-based techniques and assessed their effectiveness through questionnaires. The results indicate that AR offers numerous advantages, including enhanced motivation, a supportive learning environment, improved academic performance, assistance for children with special needs, and promotion of social and emotional development. This study recommends that early childhood educators incorporate AR into their teaching practices as an innovative and engaging tool for future educational endeavors. This revision aims to improve readability while preserving the essential information and findings of your original abstract.

KEYWORDS

augmented reality (AR), early childhood education (ECE), current trends, literature review, bibliometric

1 INTRODUCTION

In the rapidly advancing digital age, incorporating technology into education is becoming increasingly vital. Among the newest innovations capturing the interest of educators and researchers is augmented reality (AR) [1]. AR provides the capability to merge physical and digital environments [2]. AR enables students to engage in interactive, immersive, and stimulating learning experiences [3–5].

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AR holds significant promise for enriching the educational experience [6], [7]. AR reflects substantial investments by the technology sector and is regarded as a pivotal advancement likely to evolve further over the coming years [8].

There are only a limited number of studies available on the application of AR in early childhood education (ECE) [9], [10]. Research by [11] on AR trends in early childhood from 2003 to 2013 indicates that there has been no research specifically addressing the use of AR in ECE. This technology is not yet fully optimized for use by children, as several interaction features, such as tracking and marker utilization, require enhancement. Additional studies indicate that the application of AR in ECE remains underdeveloped, with only six research projects exploring its use to support learning models over the past decade [12]. According to research by [1], just 1 out of 68 studies on AR concentrated on ECE. This observation is corroborated by a literature review conducted by [13], which revealed that among 105 articles examining AR in education, only four addressed early childhood settings.

In recent years, there has been a growing trend in utilizing AR for ECE, accompanied by extensive study and development aimed at investigating its advantages and uses. Research by [14] revealed that ten papers about the benefits of AR technology for early childhood were analyzed from 2020 to 2022. Consequently, [1] suggested broadening AR research to include different demographics, such as ECE. As interest and studies on AR in early education grow, it is anticipated that educators will gain additional training and resources to enhance their skills in incorporating digital technology into their teaching practices. Furthermore, the findings of [15] indicate that students are generally more engaged and exhibit better performance when their learning experiences are integrated with digital technology.

Although the use of AR in ECE is on the rise, there remains a lack of focused research on its applications within this specific context. This study aims to address this gap by examining recent advancements from 2013 to 2023. It will explore publication trends, research types, and practical considerations such as the advantages of AR for ECE and potential future applications. The goal is to enhance our understanding of how AR can be effectively utilized to support early childhood development. In light of these issues, this paper seeks to answer the following research questions:

RQ 1. What are the trends in annual AR publications for ECE from 2013 to 2023?
RQ 2. What are the categories of research type, sample size, data collection instruments, and kind of AR used?
RQ 3. Based on citations, who are the 10 most influential writers in the field of AR for ECE?
RQ 4. What are the documents by subject area for AR in ECE from 2013 to 2023?
RQ 5. What are the benefits of AR research in ECE from 2013 to 2023?
RQ 6. What is the potential for future practice regarding AR for early childhood?

While AR holds considerable promise for ECE, its application continues to encounter substantial obstacles. According to research by [16], despite the rapid advancement of AR technology, its effective incorporation into early childhood care and education (ECCE) curricula remains inadequate. [17] pointed out a disconnect between AR's theoretical advantages and its practical use in ECE settings, highlighting that many educators are still unfamiliar with its optimal application. [18] stressed the insufficient grasp of how AR can aid in cognitive and social-emotional development in young children. This underscores the need for a thorough evaluation of research trends and best practices in this area [19], [20]. This study will also pinpoint the prevalent research types, typical sample sizes, commonly utilized data collection

methods, and different forms of AR featured in the literature. This examination will offer a clearer understanding of the various approaches and methodologies employed in AR research for early childhood education [10].

This study will assess how AR research contributes to ECE by examining its impact on enhancing student learning outcomes, boosting motivation, and increasing engagement [21], [22]. Grasping this insight is crucial for persuading educators and policymakers of the benefits of investing in AR technology for education. This study will also outline potential future applications of AR in ECE, highlighting opportunities for innovation and technological advancement that could enhance the learning experience for young children. The goal is to equip educators and educational institutions to address the evolving challenges and demands of the future [23].

2 LITERATURE REVIEW

2.1 Future trends of augmented reality

The volume of research on AR in education has grown considerably over time. While there were few publications in the early 2000s, the number has surged in recent years, particularly between 2021 and 2023 [24]. This pattern indicates an increasing enthusiasm among educators and researchers regarding the potential of AR to enhance teaching and learning. Recent investigations have examined diverse applications of AR, including visualizing abstract concepts and providing interactive simulations that support experiential learning [3], [22], [25]. This growth also mirrors advancements in AR technology, which have made it more readily available and useful across different educational settings, ranging from early childhood to higher education [22–26].

2.2 Augmented reality for early childhood education

Augmented reality holds great promise for enhancing young children's motivation and learning outcomes by providing engaging and immersive educational experiences. For instance, a study by [29] demonstrates that incorporating gamification elements can substantially enhance student motivation and improve learning outcomes, as evidenced by a notable rise in post-test scores relative to pre-test results. The effectiveness of gamified environments in boosting student motivation and engagement highlights the potential of AR to deliver immersive and captivating learning experiences for young children. Research conducted by [30] similarly revealed that AR enhances children's comprehension of complex concepts and boosts their engagement by offering improved visualizations and making learning more enjoyable and interactive.

In the early stages of adopting AR, users encountered several challenges, including technical difficulties, limited hardware availability, varying levels of IT proficiency among educators, and associated costs [24]. As technology progresses, integrating AR has become increasingly straightforward. [31] The technological pedagogical content knowledge (TPACK) framework is endorsed as a valuable tool for educators to effectively incorporate digital technology into their teaching practices. In the context of AR for ECE, the TPACK model is particularly useful as it assists educators in navigating initial challenges and leveraging the technology's full potential to enhance learning experiences.

2.3 Advantages of using augmented reality technology

Incorporating AR-based learning tools into education offers numerous benefits for both teaching and learning processes. Research results by [25] reveal that AR has great potential to increase the effectiveness and attractiveness of learning. AR technology does not substitute traditional educational methods but seeks to enhance the overall learning experience [32]. AR is used to help young children visualize abstract concepts, such as animated animals, by displaying digital content in the real world [22], [33]. AR-based application technology allows preschool educators and children to change how they learn and interact with information in the classroom [34]. AR notably boosts student engagement and aids in the development of learning and fine motor skills [35]. AR applications have the potential to engage children's interest in learning and enhance educational results [36]. AR can enhance children's grasp of financial concepts through the creation of AR-integrated financial literacy storybooks [27]. AR is also employed in therapeutic interventions for children with autism spectrum disorders and various other special needs [37–40].

3 METHOD

3.1 Research design

The study primarily aims to examine emerging trends and practices in the use of AR for ECE. The methodology employed involves a literature review combined with bibliometric analysis to identify publication trends and patterns. This bibliometric investigation offers an extensive overview, exploring the current state and evolving trends in AR research for early childhood from 2013 to 2023, based on the criteria set for the study. The search, carried out in 2024, utilized the Scopus database as the main resource.

The search strategy incorporated AND/OR logical operators with keywords such as AR, early childhood, learning, and AR in early childhood. The search query was constructed as follows: (augmented AND reality AND early AND childhood) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "ar")). This search in Scopus's online database yielded 49 research papers addressing AR in early childhood settings.

After gathering results from the chosen sources, the researcher applies specific selection criteria to eliminate papers that do not address the research question. Papers that are irrelevant due to suboptimal search engine results are excluded based on their titles and abstracts. This initial filtering process ensures that only papers meeting the criteria outlined in Table 1 are considered.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
– Timeline of published paper	– 2013–2023	– Less than 2013 and more than 2023
– Type of literature	– Indexed journal	– Non-indexed journal Conference proceedings Book series
– Languages	– English and Spain	– Non-English and Spain
– Research settings	– For early childhood education targets	– For other targets

Researchers chose papers according to specific inclusion and exclusion criteria. Each paper was assigned a unique code or identification number. The selection process involved several stages: First, only papers published between 2013 and 2023 were considered. Second, the study focused exclusively on journal articles, excluding non-indexed journals, conference proceedings, and book series. Third, only papers written in English or Spanish were included. Fourth, the studies had to be set in early childhood contexts. The process for selecting papers is illustrated in Figure 1.

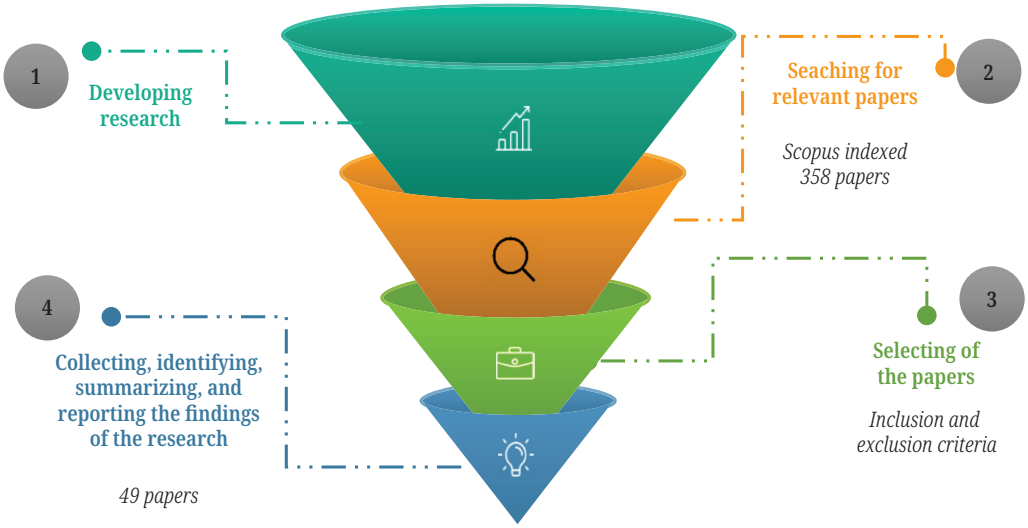

Fig. 1. A description of the process for selecting papers

3.2 Data collection and synthesis

Data for the paper were sourced from Scopus, covering the years 2013 to 2023. The researcher then manually organized and processed the selected papers. Each paper was evaluated to ensure it met the established inclusion and exclusion criteria. Initially, 358 papers were identified, and data were extracted from 49 relevant papers, detailing aspects such as publication year, authorship, research focus, methodology, sample size, key findings, and recommendations. Additionally, the study utilized Google Scholar, Microsoft Excel for statistical analysis, and VOS viewer for generating bibliometric network maps. The bibliometric analysis was conducted according to the guidelines recommended by [41].

3.3 Quality assessment

The selected papers underwent a manual quality assessment to verify their reliability and appropriateness for inclusion. Ultimately, the study comprised 49 papers.

A methodical process was implemented to assess the quality of the papers, where each was scrutinized based on a predefined set of criteria. The evaluation factors included relevance to the research topic, scientific viability, credibility of sources, dependability of results, educational impact, and suggestions for future research. Each document was thoroughly reviewed, and key components were

meticulously verified for accuracy and reliability. Only those papers that met these rigorous standards were considered for inclusion. This quality assessment was conducted collaboratively among researchers, with specific roles and responsibilities assigned.

3.4 Data analysis and synthesis

A narrative synthesis method was employed to condense and examine the 49 chosen research articles. This approach integrates various concepts, theories, identified gaps, results, and suggestions for future investigations related to AR in ECE. The outcome of this evaluation and synthesis offers an extensive overview of the research findings.

4 RESULTS AND DISCUSSION

Augmented reality is a technology that merges virtual elements with the physical world. By using devices such as smartphones, tablets, or specialized glasses, users can view digital objects or information integrated into their real-world surroundings. In ECE, AR is applied in various forms, including AR storybooks, interactive games, mobile apps, flashcards, puzzles, and creative tasks such as coloring or crafting. The goal of AR is to spark children's creativity, enhance their engagement with learning, and broaden their understanding of their environment. Recently, AR has become increasingly popular in ECE, with educators beginning to incorporate this technology into their teaching methods. This study examines emerging trends and practices related to AR technology in ECE from 2013 to 2023, which are further explored in the following section.

RQ 1. What are the trends in annual AR publications for ECE from 2013 to 2023?

From the Scopus (meta) database, 49 research papers were chosen. The years with the most publications are 2019, with seven papers; 2022, with eleven papers; and 2023, with thirteen papers. In line with the results of literature studies, [24] show a significant increase in interest and publications related to AR in the education sector every year. However, in 2017, there was a decline in publications, with only a single study addressing AR in early childhood. Additionally, Scopus data shows that no papers on AR for ECE were published in 2013 and 2014. This is in line with the study results of [11], who stated that from 2003 to 2013, more research on AR needs to focus on early childhood. This is because early childhood educators require additional time to prepare for incorporating AR-based media into their classrooms. They believe that their skills and understanding of technology still need further development [42]. Certain early childhood educators also lack adequate access to and resources for effectively implementing AR technology [5]. Educators are also worried about the potential drawbacks of AR technology on children's development, including overreliance on screens and limited attention spans, which may lead children to overlook crucial aspects of the learning process [19], [43]. Consequently, the literature review highlights the need for additional studies focused on how AR can be utilized to train future educators in early childhood settings [44].

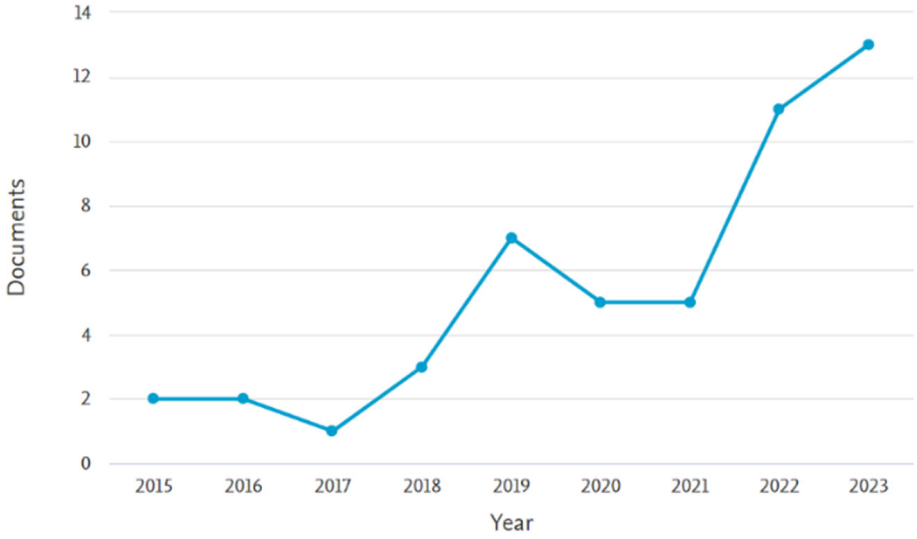

Fig. 2. Augmented reality trend graph for early childhood

With ongoing advancements in technology, according to Figure 2, the use of AR in early childhood is expected to rise significantly in 2023, as evidenced by the publication of 13 papers. This trend indicates a growing interest among early childhood researchers in examining the advantages of AR in education. Previous studies also highlight the need for further investigation into AR-based mobile applications within the early childhood context. Additionally, Figure 3 illustrates the countries with the highest volume of published research on AR for early childhood.

Figure 3 shows that Spain leads with the highest number of publications on AR for early childhood, with data sourced from 13 papers. This is followed by Malaysia with eight papers, and India, Indonesia, and the United States, each contributing four papers. Hong Kong, Peru, and Turkey each have three papers, while Australia and Saudi Arabia have two papers each. [45] stated that Spain has made notable advancements, reflecting the growth of international study and the variety of concepts that drive educational innovation.

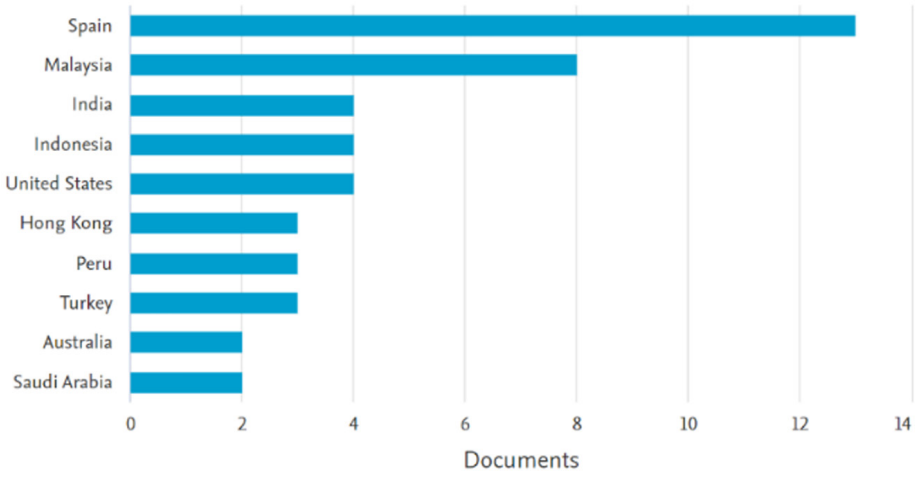

Fig. 3. Distribution of AR publications for early childhood

RQ 2. What are the categories of research type, sample size, instrument data collection, and kind of AR used?

Table 2 categorizes the types of research, sample sizes, data collection methods, and types of AR utilized across 49 papers analyzed from Scopus data.

Table 2. Categories including research methodologies, sample sizes, data collection tools, and types of augmented reality

Aspect	Category	Percentage
Types of research	A-Quantitative research	40.8
	B-Qualitative research	16.3
	C-R&D	20.4
	D-Mix methods	10.2
	E-Other	12.2
Sample size	30 or less than 30	12.2
	Between 30 and 100	65.3
	More than 100	8.2
	Not specified	14.3
Instrument data collection	A-Tests	14.3
	B-Questionnaires	22.4
	C-Interviews	14.3
	D-Cases observation	18.4
	E-Focus-groups	0
	F-Survey	18.4
	G-Other	12.2
Kind of AR	Marker-based AR	69.4
	Marker-less AR	0.0
	Location-based AR	0.0
	Not specified in the study	30.6

According to Table 2, the researchers employed quantitative approaches to gather data on AR for early childhood. This method enables the drawing of broad conclusions through statistical analysis, helps in understanding the relationships between variables, and facilitates the handling of extensive sample sizes [46]. Most researchers work with sample sizes ranging from 30 to 100 children. This approach is often chosen because it allows for the use of both control and experimental groups, ensuring that conditions are comparable across these groups [47]. Only 8.2% of the studies had sample sizes greater than 100 children. [11] stated that increasing the sample size for study would lead to higher expenses for supplying devices such as smartphones and markers to each participant.

The data collection method involves using questionnaires, which include both open-ended and closed-ended questions, to gather information on the effectiveness

of AR in ECE [48]. Approximately 69.4% of researchers utilize marker-based AR when applying AR technology in media. Marker-based is commonly used in the form of flashcards [49], printed puzzles [50], a single QR code [51], storybooks [27], and [32]. Educators tend to favor AR technology that employs markers over marker less AR. This preference stems from the belief that using physical AR markers makes it simpler to swap out virtual learning objects or media, as opposed to replacing them virtually, as one would with video-based AR [52].

RQ 3. Based on citations, who are the 10 most influential writers in the field of AR for ECE?

Table 3 highlights the top 10 most influential authors in early childhood AR research, as determined by citation counts from the 49 documents reviewed.

Table 3. Top 10 most influential writers

No	Cite	Authors	Title
1	415	RM Yilmaz [50]	Educational magic toys developed with augmented reality technology for early childhood education
2	193	RW Chen, KK Chan [49]	Using augmented reality flashcards to learn vocabulary in early childhood education
3	130	B Redondo, R Cózar-Gutiérrez... [49]	Integration of augmented reality in the teaching of English as a foreign language in early childhood education
4	104	C Oranç, AC Küntay [53]	Learning from the real and the virtual worlds: educational use of augmented reality in early childhood
5	90	RR Rasalingam, B Muniandy... [54]	Exploring the application of Augmented Reality technology in early childhood classroom in Malaysia
6	81	MZ Masmuzidin, NAA Aziz [19]	The current trends of augmented reality in early childhood education
7	61	Y Chen, D Zhou, Y Wang, J Yu [55]	Application of augmented reality for early childhood English teaching
8	50	N Tuli, A Mantri [56]	Evaluating usability of mobile-based augmented reality learning environments for early childhood
9	45	P Madanipour, C Cohrssen [2]	Augmented reality as a form of digital technology in early childhood education
10	43	Z Pan, M López, C Li, M Liu [28]	Introducing augmented reality in early childhood literacy learning

According to Table 3, the research papers by [50] have the highest impact in the area of AR for early childhood, accumulating a total of 415 citations. The findings revealed that both educators and children enjoyed engaging in EMT activities. However, despite the interactive nature of these activities, optimal cognitive gains were not fully realized. While AR-based EMT games can be effectively utilized in ECE, enhancing cognitive outcomes requires incorporating collaborative and interactive learning opportunities. It is therefore recommended that educators and

researchers implement AR tools that foster teamwork, such as group projects or AR games designed to promote cooperative task completion.

RQ 4. What are the documents by subject area for AR in ECE from 2013 to 2023?

According to Figure 4, computer science (29.6%) and social science (29.6%) are the fields most frequently addressing AR in early childhood from 2013 to 2023. This suggests that a significant portion of the study on AR in education has focused on exploring its advantages within the realm of science education [11]. Following computer and social sciences, psychology (10.2%) and engineering (8.2%) are the next most common fields utilizing AR technology.

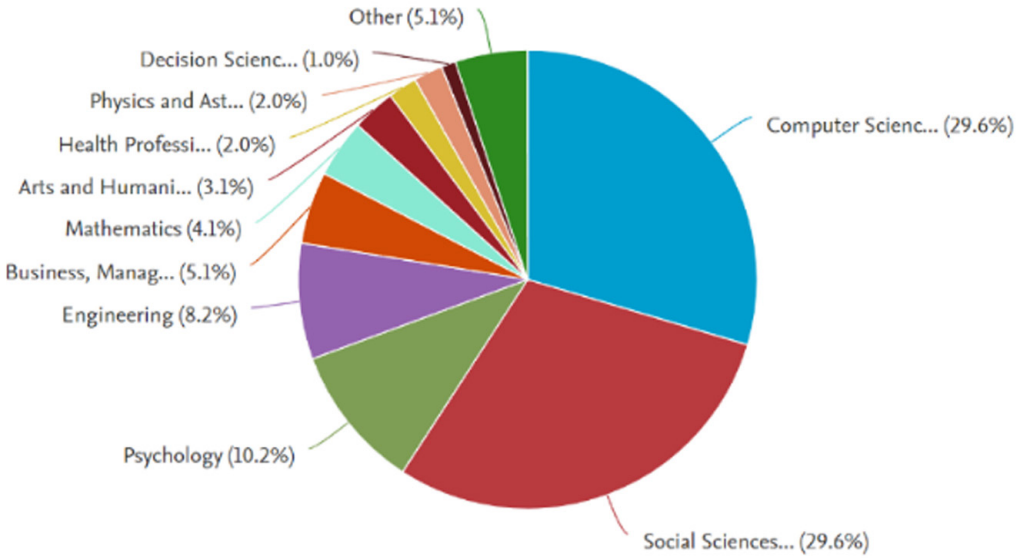

Fig. 4. Document by subject area

RQ 5. What are the benefits of AR research in ECE from 2013 to 2023?

From 2013 to 2023, trends in ECE research reveal a growing interest among scholars in examining how AR can enhance academic performance, support diverse intelligences, and improve understanding [57]. In addition, AR has also been proven to improve long-term memory retention, as demonstrated by [43] research, which showed that content learned through AR experiences was remembered better than non-AR experiences. AR has also been proven to increase student engagement [58], support the learning process [35], as well as increase children's literacy and numeracy [59], motivation and interest in learning and fun [28], [60], and foster interest in dramatic, interactive games and empathy for media [36]. Animated AR content can enhance comprehension and engagement for preschoolers, helping them stay focused and follow the learning process more effectively [61]. AR enables children to have fun while they learn, which can aid in retaining the lesson material [62]. AR technology offers distinctive features that can be leveraged in language learning and in helping children recognize important contexts. Its capacity to overlay virtual objects within real-world settings can enhance the effectiveness and engagement of the learning experience [63]. The advantages of AR are outlined in Table 4.

Table 4. Benefits of augmented reality

No	Benefits of AR	Number of Studies	Percentage
1	To enhance motivation by boosting focus, attention, satisfaction, and engagement.	9	18.4
2	Developing a learning environment	2	4.1
3	To increase achievement/multiple intelligences/understanding	18	36.7
4	Fo fun (enjoyment, excitement, symbolic play, etc)	8	16.3
5	Therapy for children with special needs	3	6.1
6	Develop emotional and social	3	6.1
7	Other	6	12.2

Research by [49] suggests no significant difference between AR-based flashcards and traditional flashcards in improving children's vocabulary understanding. While educators note that children find AR learning activities engaging, the use of AR-based flashcards in kindergarten presents distinct challenges. Additionally, study indicates that only a small number of so-called "educational" apps that have undergone evaluation and testing have been shown to enhance children's intelligence or improve their learning outcomes [64]. These findings highlight the critical need for thorough evaluation and testing of emerging educational technologies, including AR applications for young children. When creating educational AR apps, it is important to prioritize not only the entertainment and interactivity elements but also to ensure that the content and design are genuinely aligned with children's learning requirements.

Findings from [5], implementing AR in ECE encounters several challenges, particularly the necessity for deeper integration of information and communication technology (ICT) among ECE educators. This is due to the varying levels of ICT literacy among school principals and educators. Consequently, given the growing presence of digital technology in education, it is crucial for ECE educators to focus on introducing and broadening the use of technology to equip children with the skills needed in the technological age [65]. Furthermore, approximately 40% of digital learning media has been shown to enhance the computational and ICT literacy skills essential for the 21st century [66].

RQ 6. What is the potential for future practice regarding AR for early childhood?

Numerous researchers worldwide have explored the development of educational media through the use of AR technology. This study employed bibliometric analysis and descriptive content analysis to examine the data, aiming to identify future possibilities for implementing AR in ECE. Content analysis was conducted using data from Scopus, Google Scholar, Science Direct, and ProQuest databases. For the bibliometric analysis, VOS viewer version 1.6.19, a widely used mapping and visualization tool, was utilized. VOS viewer is a popular software specifically designed to offer various visualization techniques [67]. A total of 1,462 studies were identified as a result of searches performed with the specified keywords. The bibliometric information for these studies was downloaded in RIS and CSV formats and subsequently analyzed.

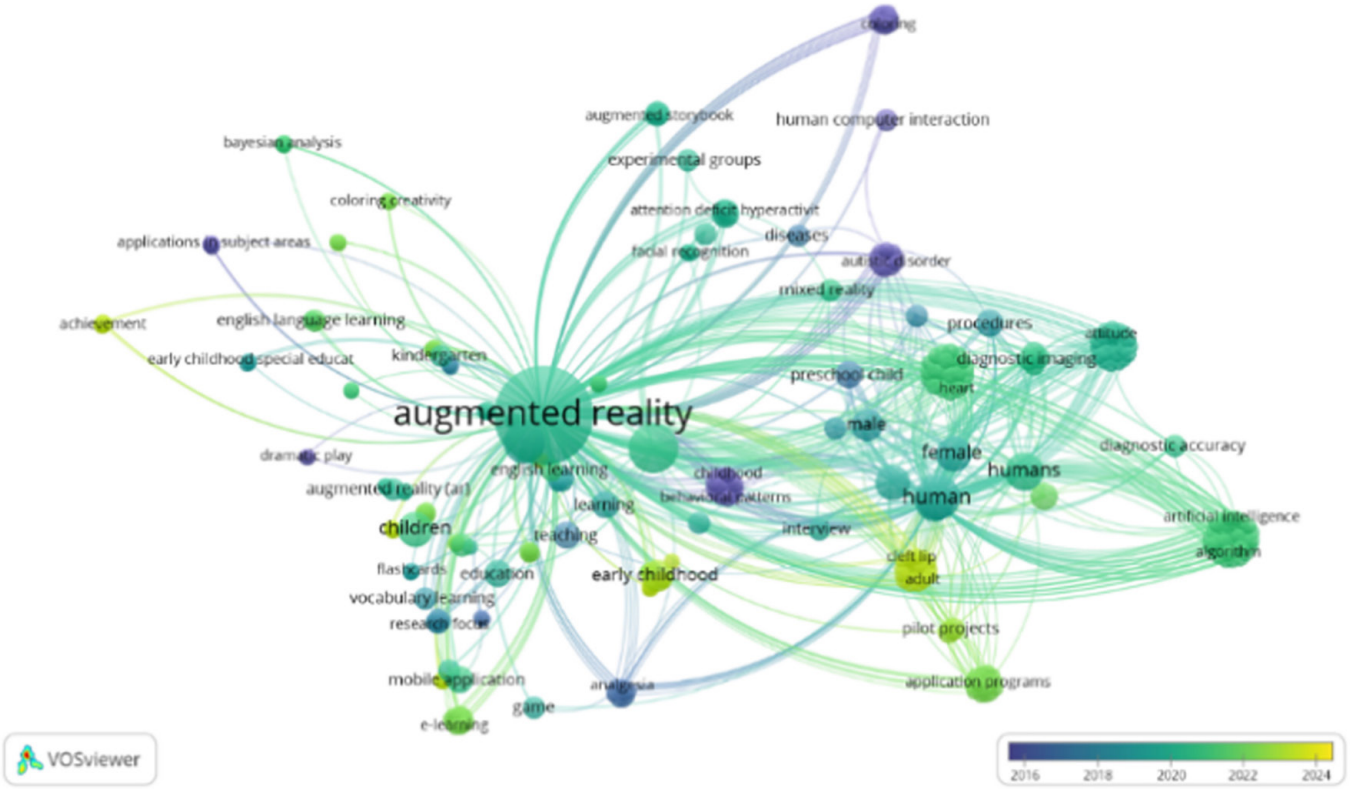

Fig. 5. Augmented reality bibliometric analysis results for early childhood

Figure 5 is the results of bibliometric analysis using the VOS viewer application, focusing on the keywords AR, early childhood, and the use of AR in ECE. This analysis reveals that the topic of AR for early childhood has not yet been widely researched, including aspects of achievement, behavior patterns, games, coloring creativity, dramatic games, mobile applications, story books based on AR, facial recognition, use of flashcards, experimental projects, learning vocabulary, learning English, cultural aspects, and so on. Based on these findings, researchers can make this topic the focus of further study. However, the application of AR in ECE faces several challenges. One of them is the technical difficulty in placing a cellphone to scan barcodes that can display 3D images and room lighting problems [68]. These kinds of technical obstacles can increase cognitive load, which can negatively impact learning outcomes [69]. Therefore, it is essential to emphasize the role of educators in increasing technological literacy to support the use of AR in ECE [27].

According to [65], there are two principles in using digital media for children: (a) it must prioritize the child's health, well-being, and holistic development, and (b) it must consider the child's characteristics, content, and context of use. These principles align with developmentally appropriate practice (DAP), which intentionally utilizes technology in the classroom environment.

5 CONCLUSION AND RECOMMENDATION

This study provides an in-depth analysis of AR research trends in ECE from 2013 to 2023. These findings show that most research focuses on using AR in language learning, multiple intelligences, literacy learning, special needs, learning environments, mathematics, etc. However, little research needs to discuss

achievement, behavioral patterns, games, coloring creativity, dramatic play, vocabulary learning, and culture. This highlights the need for more study and development in AR applications. The following are some recommendations regarding the use of AR for early childhood:

1. Select content specifically tailored for ECE that emphasizes interactive learning. The material should provide an engaging, enjoyable, and developmentally appropriate experience for the child.
2. Opt for AR content that offers a well-rounded sensory experience, incorporating visual, auditory, and other sensory inputs.
3. The application of AR in ECE should thoughtfully account for aspects such as health, safety, emotional well-being, and social interactions.
4. Assist children in making connections between what they observe on the screen and their real-world surroundings.
5. It is essential to strike a balance between AR usage and activities in the real world, such as outdoor play, socializing with peers, and engaging in other creative endeavors.
6. Engaging parents, educators, and AR content creators in collaboration can help guarantee that early childhood learning experiences with AR are consistent with curriculum objectives and educational goals.
7. Adult supervision and regulation of AR usage by young children are crucial. Setting appropriate time limits for AR use ensures it doesn't disrupt healthy playtime or social interactions.
8. Regularly monitor children's developmental progress when they interact with AR technology. Pay close attention to how AR influences their cognitive abilities, motor skills, and other developmental areas.

6 LIMITATIONS

This AR review study for early childhood has several limitations:

1. This systematic review draws upon peer-reviewed articles exclusively from the Scopus database, which limits the comprehensiveness of the analysis. To bolster the findings and arguments in this study, future study should incorporate additional databases related to AR in early childhood education.
2. The selection of peer-reviewed empirical journal articles in this review excludes other forms of scholarly work, such as book chapters, conference proceedings, and dissertations.
3. The scope of this review is confined to studies published within the last decade, specifically from 2013 to 2023.

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