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IMPACT OF USING AUGMENTED REALITY FOR CHILDREN'S EDUCATION: A SYSTEMATIC REVIEW

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ABSTRACT

Augmented Reality (AR) is an emerging technology with significant potential to transform children's education by enhancing engagement, motivation, and overall learning outcomes. Despite its increasing adoption, the systematic exploration of its applications, benefits, and challenges within educational settings for children remains limited. This study aims to bridge this gap by conducting a systematic literature review on the use of AR in children's education, focusing on its applications, advantages, limitations, and future directions. To achieve this, we performed a comprehensive search of scholarly articles from reputable databases, including Scopus and Web of Science, with a specific focus on studies published between 2023 and 2025. The research follows the PRISMA framework, and after screening, a total of 28 primary studies were analysed. The findings were categorized into three key themes: (1) AR for Language and Literacy Development, (2) AR for Skill Development and Special Needs, and (3) Broad Applications of AR in Education. AR applications range from interactive storytelling and science simulations to mathematics and language learning, demonstrating its ability to support diverse learning needs, including those of children with special educational requirements. However, several challenges were identified, such as technological constraints, inadequate teacher training, and the necessity for pedagogically sound AR design. The study emphasizes key design principles for AR tools, including usability, accessibility, and alignment with educational goals. In conclusion, while AR presents immense potential as an innovative educational tool, addressing existing barriers and conducting further research on its long-term effects are crucial for effective implementation in learning environments.

Introduction

The early childhood years are critical for cognitive, emotional, and social development, laying the foundation for lifelong learning (Dang, 2023). As technology continues to reshape the educational landscape, innovative tools such as Augmented Reality (AR) are gaining traction for their potential to transform learning experiences in this formative stage. AR, which seamlessly integrates digital content with the physical world, offers unique opportunities to create interactive, engaging, and multisensory learning environments. These immersive experiences are particularly impactful in early childhood education, where curiosity and active exploration are key drivers of development. AR-based learning addresses the diverse needs of young learners by fostering engagement and enhancing comprehension through visual and interactive elements (Pratama & Sukirman, 2023). For instance, AR applications can bring stories to life, enable virtual exploration of distant places, and demonstrate abstract concepts in tangible ways (Ghobadi et al., 2023) (Shi, 2024). These experiences not only capture children's attention but also support the development of critical thinking, creativity, and problem-solving skills. By making learning enjoyable and memorable, AR has the potential to foster a lifelong love for education (Daniel A & Suleiman, I.A, 2023). Despite its advantages, integrating AR into early childhood education poses several challenges. The development and deployment of age-appropriate AR content require significant expertise and resources, while access to AR-enabled devices and infrastructure remains limited in many regions (Kartika et al., 2024). Additionally, educators must navigate the pedagogical implications of AR, ensuring it complements traditional teaching methods without becoming a distraction (Perifanou et al., 2023). Effective implementation demands collaboration among educators, technologists, and policymakers to address these barriers and create scalable, inclusive solutions. This paper examines the impact of AR-based learning in early childhood education, with a focus on its benefits, challenges, and practical applications. Drawing on recent studies, case examples, and empirical data, we analyze how AR enhances cognitive, emotional, and social development in young learners (Jiang & Hussain, 2023). Furthermore, we explore strategies for integrating AR into early childhood education, emphasizing the importance of aligning technology with developmental and educational goals. By leveraging AR, educators can create a more engaging and inclusive learning environment that nurtures the natural curiosity and creativity of young children. As educational institutions and stakeholders strive to prepare the next generation for the challenges of the 21st century, AR-based learning offers a powerful tool for enriching early education (Deng et al., 2024; Naida et al., 2024). Through thoughtful integration and collaborative efforts, AR has the potential to revolutionize the way young children learn and grow.

Literature Review

The integration of Augmented Reality (AR) into early childhood education (Naida et al., 2024) has garnered significant attention in recent years, particularly from 2015 to the present. During this period, numerous studies have explored its potential to transform traditional learning paradigms. AR's ability to overlay digital content onto physical environments provides opportunities for creating interactive and engaging learning experiences that align with the developmental needs of young learners (Dewi, Finita, 2020). However, despite the growing body of research, there remain critical gaps and emerging trends that require further investigation to fully understand AR's impact on early childhood education. One of the most notable trends since 2015 is the increasing focus on gamification and interactive storytelling (Palomino et al., n.d.,2024). Studies from this period highlight the efficacy of AR in enhancing engagement and motivation among young learners through game-like elements and narrative-driven content (Zuo et al., 2022) (Amanatidis, 2022) . For example, AR-based storytelling applications developed during this time allow children to interact with characters and settings, fostering both creativity and comprehension (Hadjistassou et al., 2023). Additionally, AR's use in teaching STEM (Science, Technology, Engineering, and Mathematics) concepts has gained prominence, as it provides visual and hands-on experiences that make abstract concepts more tangible and accessible (Ghobadi et al., 2023) (Sakdiah et al., 2023). Another trend during this period is the emphasis on personalized learning facilitated by AR technologies. Adaptive AR applications leveraging artificial intelligence have been introduced to tailor content based on individual learning needs and preferences, thereby supporting differentiated

instruction (Marienko & Shyshkina, 2020). Moreover, AR has been increasingly adopted in inclusive education settings, where it aids children with special needs by providing multisensory learning experiences and assistive features (Asatryan et al., 2023). These developments reflect a broader recognition of AR's potential to address diverse learning styles and requirements. Despite advancements since 2015, several gaps in the literature highlight the need for further exploration. First, there is limited empirical evidence on the long-term effects of AR-based learning on cognitive and socio-emotional development in early childhood (Yang & Jia Wang, 2017). While short-term benefits, such as increased engagement and improved knowledge retention, are well-documented, longitudinal studies from this period are scarce (Sommerauer & Müller, 2018). Second, the accessibility of AR technologies remains a major challenge, especially in underprivileged or rural areas where access to digital resources and infrastructure is limited. Many studies highlight the benefits of AR in education, but they primarily focus on well-resourced environments, neglecting the disparities faced by students in less developed regions (Wang et al., 2024). This digital divide raises significant concerns about the scalability, affordability, and inclusivity of AR-based learning solutions, as students from lower-income backgrounds may struggle to access necessary devices and stable internet connections. Without addressing these challenges, AR technology risks widening the educational gap rather than bridging it. Additionally, the lack of standardized frameworks for evaluating AR's effectiveness in early childhood education presents another hurdle. Existing studies use diverse methodologies and metrics, making it difficult to compare findings or establish generalizable conclusions about AR's impact on young learners (Anastasiadis et al., 2018). Clear evaluation criteria and evidence-based frameworks are needed to measure AR's long-term benefits. Ethical concerns also warrant attention, particularly regarding screen time, data privacy, and potential over-reliance on technology in early education. Understanding these implications is crucial to ensuring that AR applications enhance learning experiences without compromising children's cognitive, social, and emotional development (Karpouzis, 2024). Emerging areas of interest during this period include the integration of AR with other advanced technologies such as virtual reality (VR), artificial intelligence (AI), and the Internet of Things (IoT) (Rane et al., 2023). These technological combinations offer new possibilities for enhancing the interactivity, adaptability, and intelligence of AR-based learning systems. AI-powered AR applications introduced during this period are capable of analyzing real-time user interactions, providing instant feedback, and adapting content dynamically based on learners' progress and needs. Additionally, IoT-enabled devices facilitate interconnected learning environments where physical and digital experiences blend seamlessly, promoting hands-on engagement and immersive educational opportunities. Another area gaining traction is the cultural contextualization of AR content. Researchers are exploring ways to integrate local languages, traditions, and cultural narratives into AR applications to create more relatable and meaningful learning experiences, particularly for young learners. By embedding cultural elements, AR-based learning tools not only increase engagement but also foster cultural awareness, identity, and inclusivity in education. This approach ensures that technology adapts to diverse educational contexts, making AR learning solutions more accessible and impactful for children from various backgrounds.The literature from 2015 to the present underscores the transformative potential of AR in early childhood education, highlighting trends such as gamification, personalized learning, and inclusivity. However, critical gaps remain, particularly in understanding long-term effects, addressing accessibility challenges, and developing standardized evaluation frameworks. Future research should prioritize longitudinal studies, explore strategies for scaling AR solutions in diverse contexts, and address ethical considerations to ensure responsible implementation. By addressing these gaps and building on emerging trends, AR-based learning can become a powerful tool for enriching early childhood education. Collaborative efforts among educators, technologists, and policymakers will be essential in realizing this potential and creating equitable, effective, and engaging learning environments for all children.

Methodology

Identification

In this study, key steps of the systematic review process were employed to collect a substantial body of relevant literature. The process began with the selection of keywords, followed by identifying related terms using dictionaries, thesauri, encyclopedias, and prior research. These terms were then used to formulate comprehensive search strings for the Web of Science and Scopus databases (refer to Table 1). This initial phase of the systematic review resulted in the retrieval of 1,101 publications relevant to the study topic from both databases.

Table 1: The search string

Scopus	TITLE-ABS-KEY (augmented AND reality AND for AND children AND education) AND PUBYEAR > 2022 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English"))
	Date of Access: January 2025
Wos	(Augmented Reality for Children Education (Abstract) and 2023 or 2024 (Publication Years) and Article or Review Article (Document Types) and English (Languages) and Computer Science or Engineering or Social Sciences Other Topics (Research Areas)
	Date of Access: January 2025

Screening

During the screening phase, potentially relevant research items were evaluated to ensure alignment with the predefined research question(s). This process involved selecting studies based on the impact of augmented reality on children's education. Duplicate papers were removed at this stage. Initially, 1,022 publications were excluded, leaving 79 papers for further examination based on specific inclusion and exclusion criteria (see Table 2). The first criterion focused on literature as the primary source of practical recommendations, including reviews, meta-syntheses, meta-analyses, books, book series, chapters, and conference proceedings not covered in the most recent studies. The review was restricted to English-language publications from 2023 to 2025. Notably, only 1 duplicate paper was found in the Scopus and Web of Science databases.

Table 2: The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2023 – 2025	< 2023
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Subject	Social science, computer Science and Engineering	Besides Social science, computer Science and engineering

Eligibility

In the eligibility phase, the third step of the process, 78 articles were selected for review. During this stage, the titles and key content were thoroughly examined to ensure they met the inclusion criteria and aligned with the study's objectives. As a result, 50 articles were excluded for reasons such as being outside the research scope, having insufficiently relevant titles, abstracts not aligning with the study objectives, or lacking full-text access. Ultimately, 28 articles were retained for the final review.

Data Abstraction and Analysis

An integrative analysis was employed in this study as an assessment strategy to examine and synthesize various research designs, primarily focusing on quantitative methods. The objective was to identify key topics and subtopics relevant to the study. The data collection stage served as the foundation for theme development. As illustrated in Figure 1, the authors meticulously analyzed a compilation of 28 publications to extract assertions and material pertinent to the study's focus on augmented reality in children's education. Subsequently, significant studies in this domain were evaluated, with particular attention to the methodologies used and research findings. The authors collaborated to develop themes based on the evidence within the study's context. A log was maintained throughout the data analysis process to document observations, interpretations, and any emerging questions relevant to data interpretation. Finally, the authors compared the results to identify potential inconsistencies in the theme development process. In cases where conceptual disagreements arose, discussions were conducted among the authors to reach a consensus. The authors also compared the findings to resolve any discrepancies in the theme development process. In cases where inconsistencies emerged, they were addressed through discussions among the authors. Finally, the themes were refined to ensure coherence and consistency. The research questions are outlined below:

1. What are the effects of Augmented Reality-supported literacy tools on reading fluency and engagement in primary school students with limited literacy skills compared to traditional literacy development methods?
2. What is the effect of Augmented Reality-assisted physical therapy on motor skill development and patient motivation in children with physical disabilities compared to conventional physical therapy?
3. How do Augmented Reality-based immersive learning experiences affect academic performance and student engagement among children compared to conventional teaching methods?

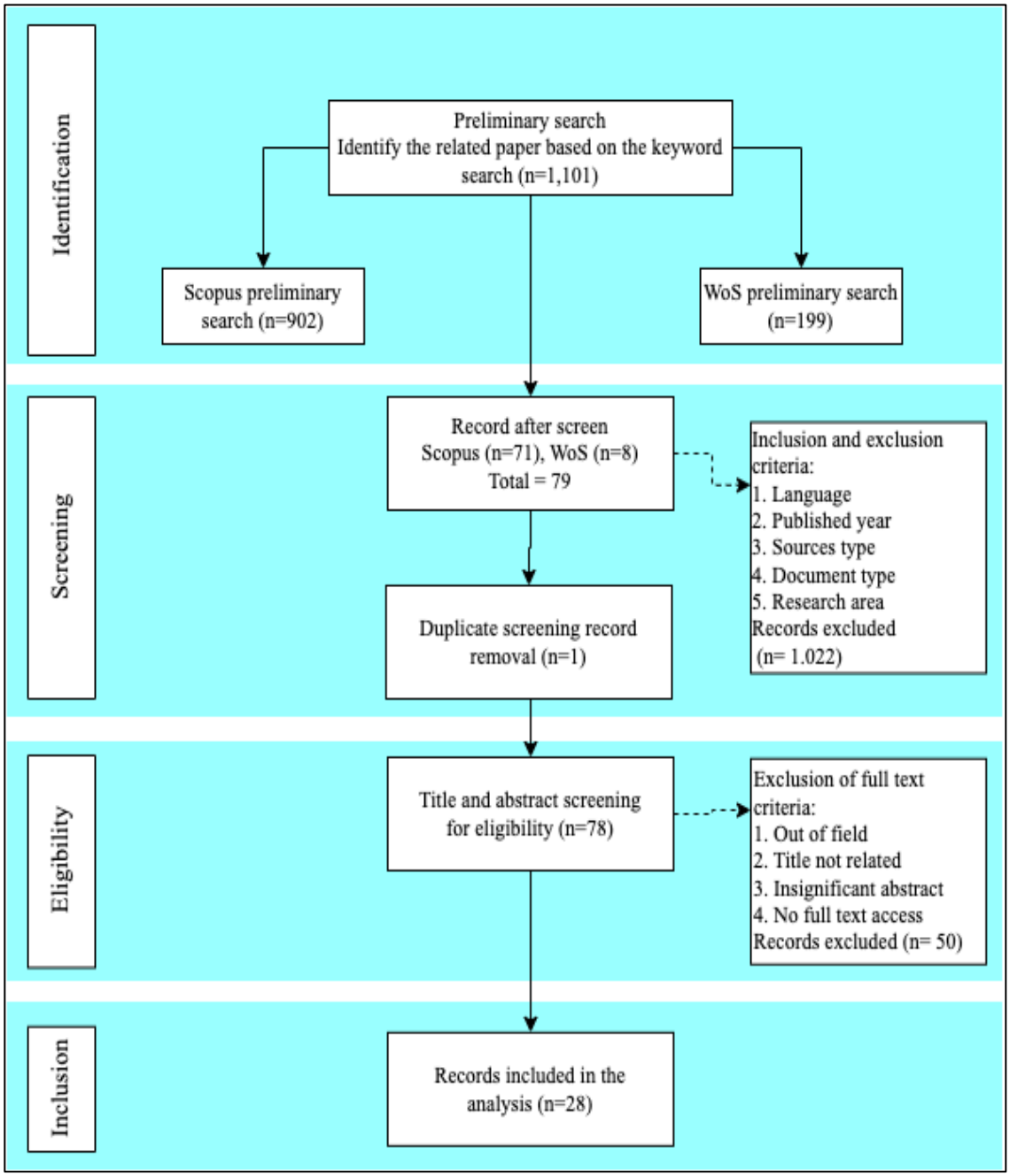

Figure 1: Flow Diagram of PRISMA Framework (Moher D, Liberati A, Tetzlaff J, 2009)

Results and Findings

A total of 28 articles were extracted as well as examined based on the search methodology. Three primary categories were used to categorize all the studies: 1) Augmented Reality for Language and Literacy Development (5 articles), 2) Augmented Reality for Skill Development and Special Needs (9 articles), and 3) Broad Applications of AR (9 articles). As noted, five article is not included because not suitable for the three themes. Eleven articles were published in 2023, followed another eleven and one article in 2024 and 2025 respectively. As for research design, 6 were qualitative, 13 quantitative and 4 mixed method studies (Figure 2).

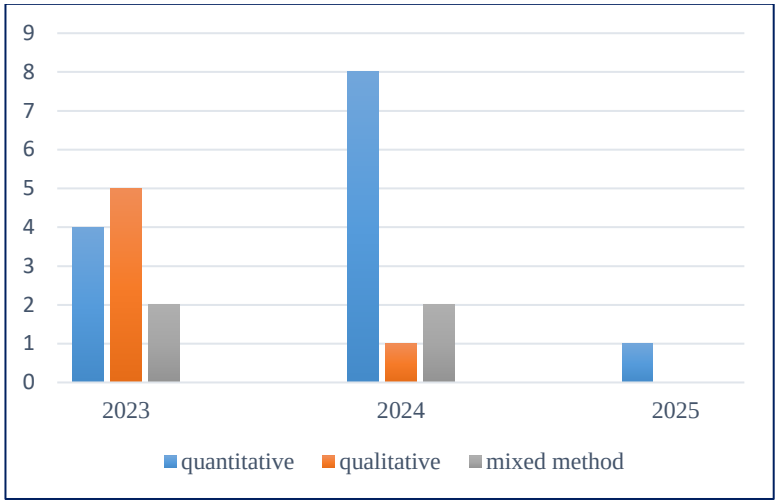

Figure 2: Research Frequency and Approach

Based on thematic analysis, three main themes were identified: Language and Literacy Development, Skill Development and Special Needs and Broad Applications of AR (Table 3).

Table 3: Main Themes

No	Authors	Title	Research Approach	Themes		
				Language and Literacy Development	Skill Development and Special Needs	Broad Applications of AR
1	Abdullah A.S. et al., 2024	Enabling Technology Integrated Learning for Autistic Children Using Augmented Reality Based Cognitive Rehabilitation	Quantitative		√	
2	AlAli R.M.; Al-Barakat A.A., 2024	Impact of Augmented Reality-Based Learning on Preparing Children for Creative Reading Skills in Childhood Education Stage	Quantitative	√		
3	Amado M.L.; Andrade-Arena L., 2023	Mobile Design for Disciplining Children with Attention Deficit Hyperactivity Disorder using Augmented Reality	Qualitative		√	
4	Anggara O.F. et al., 2024	Augmented Reality: Its Effect on Satisfaction and Interest in Learning Natural Science for Elementary School Children	Quantitative		√	
5	Chen P.-J.; Liou W.-K., 2023	The effects of an augmented reality application developed for paediatric first aid training on the knowledge and skill levels of nursing students: An experimental controlled study	Quantitative		√	

6	Chung & Ko, 2023	Augmented Reality-based Educational Content Application Development	**Qualitative**		√
7	Işik Arslanoğlu İ. et al., 2024	Think together, design together, code together: the effect of augmented reality activity designed by children on the computational thinking skills	Quantitative	√	
8	Kayaduman & Sağlam, 2024	An examination of the research studies on augmented reality use in preschool education: a bibliometric mapping analysis	**Quantitative**		√
9	López-Faican L.; Jaen J., 2023	Design and evaluation of an augmented reality cyber-physical game for the development of empathic abilities	Mixed Method	√	
10	Mamani-Calapuja A. et al., 2023	Learning English in Early Childhood Education with Augmented Reality: Design, Production, and Evaluation of the "Wordtastic Kids" App	Quantitative	√	
11	Nirmala et al., 2024	Augmented Reality in Early Childhood Education: Trends, Practices, and Insights from a Literature Review	**Quantitative**		√
12	Putri D.A.P. et al., 2024	Augmented Reality Development for Garbage Sortation Education for Children	Mixed Method	√	
13	Qing & Ramli, 2023	Augmented Reality Usages in Multimedia Based Training and Interactive Demonstration	**Quantitative**		√
14	Rakhimzhanova L. et al., 2025	Using Augmented Reality to Teach Digital Literacy Course to Primary School Children with Special Educational Needs	Quantitative	√	
15	Rapti D. et al., 2023	The effectiveness of augmented reality for English vocabulary instruction of Greek students with intellectual disability	Quantitative	√	
16	Rapti et al., 2023	Enriching a Traditional Learning Activity in Preschool through Augmented Reality: Children's and Teachers' Views	**Mixed Method**		√
17	Silva et al., 2024	Development of Design Principles for AR Authoring Tools for Education Based on Teacher's Perspectives	**Qualitative**	√	
18	Smith S.A. et al., 2023	Exploring the Promise of Augmented Reality for Dual Language Vocabulary Learning Among Bilingual Children: A Case Study	Qualitative	√	
19	Topu F.B. et al., 2024	The effects of using augmented reality on vocabulary learning and attitude of pre-school children in English education	Mixed Method	√	
20	Tu et al., 2023	Understanding young children's science learning through embodied communication within an MR environment	**Qualitative**		√

21	Zhang, 2024	Research on practical teaching of Ideological and political education based on VR technology in the information age	**Quantitative**	√
22	Zhou & Tai, 2024	Implementation of an Augmented Reality Guide: Auto-Presenting Suitable Content to Adults and Young Children about Chen Cheng-Po's Oil Paintings	**Quantitative**	√
23	Zimmerman et al., 2023	Mobile augmented reality supporting families' immersive collaborative learning: Learning-on-the-move for place-based geoscience sense-making	**Qualitative**	√

Augmented Reality for Language and Literacy Development

The implementation of AR in early childhood education has demonstrated significant potential in fostering language and literacy skills. Findings from multiple studies highlight the effectiveness of AR in vocabulary acquisition, creative reading, and inclusive education, reflecting its versatility and impact across diverse learning environments. Several studies have examined the role of AR in enhancing vocabulary learning among young children. (Mamani-Calapuja et al., 2023) demonstrated that the "Wordtastic Kids" app improved preschoolers' English vocabulary through interactive AR-based activities, as evidenced by significant improvements in pre-test and post-test scores. Similarly, (Topu et al., 2024) explored the effects of AR on vocabulary acquisition in preschool English education, revealing that AR applications incorporating 3D animations and auditory pronunciation support outperformed traditional tools like flashcards and puzzles. (Smith et al., 2023) added to this body of evidence by showcasing the promise of dual-language AR applications for bilingual children, where iterative design and user feedback suggested positive attitudes and acceptance among both children and parents. These findings collectively suggest that AR serves as an effective tool for vocabulary learning, promoting engagement, retention, and enjoyment. Beyond vocabulary, AR has proven beneficial in fostering creative reading skills and cognitive development. (AlAli & Al-Barakat, 2024) highlighted the transformative impact of AR on creative reading, demonstrating that children using AR outperformed their peers in traditional settings in creativity and reading comprehension. The study emphasized AR's ability to create multidimensional learning environments that align with real-world contexts, thereby motivating children and enhancing their engagement. Similarly, (Mamani-Calapuja et al., 2023) found that AR could complement traditional teaching methods, offering a robust tool to develop higher-order cognitive skills in early education. These insights underscore AR's capacity to integrate innovative, interactive elements into literacy instruction, driving both cognitive and imaginative growth. AR's potential extends to special education, where it addresses the unique challenges of learners with disabilities. (D. Rapti et al., 2023) investigated the use of AR for vocabulary instruction among Greek students with intellectual disabilities, finding that AR interventions significantly improved their ability to identify and retain correct vocabulary items. The study further noted the long-term maintenance of these improvements, reinforcing AR's practical utility in inclusive education settings. Additionally, the research by (Smith et al., 2023) underscored AR's adaptability for English language learners by providing first-language supports, making language instruction more accessible and effective. These studies highlight AR as a valuable resource in creating equitable learning environments that cater to diverse learner needs. While AR's potential is evident, several factors influence its successful implementation. (Mamani-Calapuja et al., 2023) emphasized the importance of teacher preparation and the quality of AR content in determining its effectiveness. Furthermore, (AlAli & Al-Barakat, 2024) recommended that AR content be adapted to local cultural contexts to ensure relevance and maximize impact. Limitations identified by (D. Rapti et al., 2023), such as the need for more extensive sample sizes and exploration of diverse thematic content, also point to avenues for future research. Expanding AR applications to other areas of early childhood education, such as storytelling and science learning, could further enrich educational experiences and outcomes. The findings from the reviewed studies illustrate in Figure 3 the potential of AR as a transformative tool in early childhood education, particularly for language and literacy development. By

leveraging interactive and immersive technologies, AR enhances vocabulary acquisition, supports creative reading, and addresses the needs of diverse learners, including those with disabilities. However, the successful integration of AR requires careful consideration of content quality, teacher training, and cultural adaptation. Continued research and development are necessary to broaden AR's applications and optimize its impact on young learners.

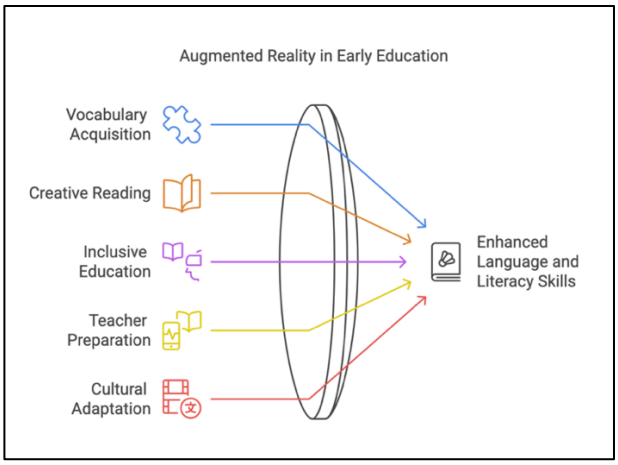

Figure 3: AR Transformative Tool

Augmented Reality for Skill Development and Special Needs

The literature on AR in education demonstrates its significant potential to address skill development and special needs in children. Researchers have focused on diverse themes, methodologies, and outcomes, highlighting AR's transformative role in fostering cognitive, social, and technical skills among young learners. Several studies emphasize the effectiveness of AR in improving empathy and emotional intelligence. (López-Faican & Jaen, 2023) discuss the EmpathyAR game designed to enhance empathic abilities in children. Their findings indicate that AR-based scenarios can stimulate affective and social experiences, promoting prosocial behavior. Players exhibited significant improvements in empathy dimensions such as fantasy and empathic concern, as measured by the Interpersonal Reactivity Index. Similarly, (Anggara et al., 2024) highlight AR's role in boosting student interest and satisfaction in science education, showcasing its ability to engage learners emotionally and cognitively. (Silva et al., 2024) extend this discussion by proposing design principles for AR authoring tools that prioritize educational perspectives, which could further refine AR's effectiveness in emotional and cognitive domains. AR's capacity to aid children with special needs is another critical focus. (Abdullah et al., 2024) explore AR's use for cognitive rehabilitation in autistic children, reporting significant improvements in object recognition and adaptive behaviors. Their study underscores the suitability of AR for diverse autism severity levels, with notable statistical significance in mild and moderate cases. Similarly, (Rakhimzhanova et al., 2025) reveal the benefits of AR in teaching digital literacy to children with special educational needs, demonstrating improved academic performance and engagement. (Amado & Andrade-Arena, 2023) add to this by detailing AR's role in addressing Attention Deficit Hyperactivity Disorder (ADHD). Their mobile application, developed using the Design Thinking methodology, significantly enhances attention and problem-solving skills in ADHD-affected children. AR's applicability extends to fostering computational thinking and technical skills. Işik Arslanoğlu et al. (2024) (Işik Arslanoğlu et al., 2024) assess the impact of AR-assisted programming education for preschoolers, finding that participatory design activities boost computational thinking and basic skills. Their study illustrates the importance of engaging children in co-creation processes to maximize AR's educational benefits. (Silva et al., 2024) further argue for integrating pedagogically informed design principles into AR authoring tools, enabling educators to create tailored learning experiences that align with curriculum goals. Environmental education is another area where AR shows promise. (Putri et al., 2024) developed an AR-based application to teach waste sorting, aiming to increase environmental awareness and knowledge among Indonesian children. Their research achieved high user satisfaction scores, reflecting AR's effectiveness in conveying complex ecological concepts interactively. (Anggara et al., 2024) corroborate

this by demonstrating AR's capacity to make abstract scientific topics like metamorphosis more accessible and engaging for elementary students. In healthcare education, AR enhances practical and theoretical learning. (Chen & Liou, 2023) evaluate an AR application for pediatric first aid training, finding significant improvements in nursing students' knowledge, skills, and confidence. These findings suggest AR's value as a teaching tool in specialized fields, providing immersive and interactive learning experiences that traditional methods lack. In summary, the studies reviewed collectively underline AR's broad applicability in children's education. Its ability to integrate physical and virtual worlds enhances empathy, cognitive development, technical skills, and environmental awareness. Future research should focus on refining AR technologies to address diverse educational needs and contexts, guided by insights from educators and interdisciplinary teams.

Broad Applications of Augmented Reality in Education

The application of AR in education, particularly for children, has been extensively studied, revealing numerous benefits and challenges. The findings from various studies highlight the potential of AR to transform educational practices by enhancing motivation, engagement, and comprehension. Several studies emphasize the motivational aspects of AR in early childhood education. For instance, (Nirmala et al., 2024) report that AR fosters an engaging learning environment, leading to improved academic performance and emotional development in young learners. This finding aligns with (S. Rapti et al., 2023), who observed that preschool children showed a preference for AR-based activities over traditional methods, indicating a higher level of enjoyment and interest. Similarly, (Qing & Ramli, 2023) discuss the immersive and interactive features of AR, which create a realistic learning atmosphere, thereby stimulating curiosity and encouraging active participation. These studies collectively suggest that AR technology can significantly enhance the learning experience by promoting enthusiasm and a desire for exploration among children. The ability of AR to support skill development and cognitive performance is another recurring theme. (Silva et al., 2024) identify that AR applications can improve language learning for children and teenagers by integrating pedagogical principles into the design of AR authoring tools. This perspective is echoed by (Chung & Ko, 2023), who developed an AR-based educational application to simplify complex mathematical concepts for elementary school students. Their study demonstrates that AR can bridge the gap between abstract ideas and practical understanding, making learning more accessible and enjoyable. Additionally, (Tu et al., 2023) explore the role of embodied communication in mixed-reality environments, revealing that AR enables students to use gestures to represent and internalize challenging concepts, thereby enhancing comprehension and retention. These findings collectively underscore the cognitive benefits of AR in fostering critical thinking and problem-solving skills. The social and collaborative dimensions of AR-based learning also receive significant attention. (Zimmerman et al., 2023) highlight the role of mobile AR in supporting collaborative family learning during outdoor educational activities. Their research indicates that sensory and social immersion facilitated by AR can enhance observational inquiry and promote meaningful discussions. Similarly, (S. Rapti et al., 2023) note that while AR activities increase individual engagement, they also raise concerns about the potential limitations in fostering collaboration among preschoolers. Addressing these issues, (Silva et al., 2024) propose design principles for AR authoring tools that prioritize pedagogical needs, emphasizing the importance of integrating features that encourage teamwork and interaction. These studies collectively illustrate that while AR has immense potential to enhance social learning, careful consideration of its design and implementation is necessary to maximize its collaborative benefits. The practical applications and methodological approaches in AR education research further demonstrate its versatility. (Kayaduman & Sağlam, 2024) analyze the trends in AR usage in preschool education, identifying key themes such as children's experiences with AR and the design of AR applications. Their study highlights the importance of tailoring AR content to the developmental needs of young learners. Similarly, (Zhou & Tai, 2024) discuss the implementation of an AR guide for presenting art content to diverse age groups, showcasing the adaptability of AR in delivering personalized learning experiences. These findings align with the recommendations of (Nirmala et al., 2024), who advocate for the integration of AR into teaching practices as a means to innovate and enhance traditional educational methods. Together, these studies demonstrate the diverse applications of AR across various educational contexts and underscore the need for targeted, age-appropriate content design. In conclusion, the research on AR in children's education highlights its transformative potential across motivational, cognitive, social, and

practical dimensions. By synthesizing the insights from (Nirmala et al., 2024), (S. Rapti et al., 2023), (Qing & Ramli, 2023), (Tu et al., 2023), (Zimmerman et al., 2023), (Silva et al., 2024), (Chung & Ko, 2023), (Kayaduman & Sağlam, 2024), and) (Zhou & Tai, 2024), this literature review underscores the importance of designing AR tools that are engaging, pedagogically sound, and adaptable to diverse learning environments. Future research should continue to address the challenges of collaboration and accessibility, ensuring that AR technology remains an inclusive and effective educational resource.

Conclusion

Augmented Reality (AR) has demonstrated considerable potential in enhancing language and literacy skills in early childhood education. Research indicates that AR applications improve vocabulary acquisition more effectively than traditional tools by engaging children through interactive elements like 3D animations and auditory support. Beyond language learning, AR fosters cognitive development by creating dynamic learning environments that align with real-world contexts, promoting engagement and creativity. Its benefits extend to special education, where AR has enhanced vocabulary retention and comprehension for students with disabilities, as well as bilingual education, where first-language support has proven valuable for English language learners. However, effective implementation requires attention to content quality, teacher training, and cultural relevance. Further studies are needed to explore AR's role in areas like storytelling and science education. Beyond language learning, AR has been applied in various educational domains, including empathy development, cognitive rehabilitation, technical skills, and environmental education. Studies show that AR fosters emotional intelligence by enhancing empathy and prosocial behaviour. It has also been particularly effective in supporting children with special needs, aiding cognitive rehabilitation for autistic children and improving academic performance for students with Attention Deficit Hyperactivity Disorder (ADHD). Additionally, AR has contributed to technical skill development, particularly in computational thinking, and has facilitated immersive environmental education by helping children grasp complex ecological concepts. Healthcare education has also benefited, with AR improving practical training in paediatric first aid. These findings highlight the need for continuous refinement of AR technologies to align with educational objectives and ensure accessibility. AR's impact on motivation, cognitive performance, and social interaction has also been widely recognized. By creating immersive learning environments, AR enhances engagement and emotional development while aiding in skill acquisition, including language learning and mathematics. Despite its benefits, challenges remain in fostering collaborative learning among younger children. Future research should focus on improving AR's adaptability, accessibility, and content design to maximize its educational potential.

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