

Augmented Reality in Preschool Enhancing Storytelling and Cognitive Development

Yanti Pasmawati¹ , Yesi Novaria Kunang² , Muhammad Hatta³ , Jonathan Parker^{4*} , Dwi Nur

Ramadhan⁵ 

¹Magister of Informatics Engineering, Universitas Bina Darma, Indonesia

²Faculty of Science Technology, Universitas Bina Darma, Indonesia

³Department of Information System, Catur Insan Cendekia University, Indonesia

⁴Master of Information Technology, Harvard University, USA

⁵Faculty of Economics Business, University of Raharja, Indonesia

¹yantipasmawati@gmail.com, ²yesinovariakunang@binadarma.ac.id, ³muhammad.hatta@cic.ac.id, ⁴p.jonparker@rey.zone,

⁵dwi.nur@raharja.info

*Corresponding Author

Article Info

Article history:

Submission July 24, 2025

Revised August 26, 2025

Accepted August 28, 2025

Keywords:

Augmented Reality (AR)

Storytelling

Early Childhood Education

Interactive Learning



ABSTRACT

Augmented Reality (AR) is a technology that enables the integration of digital elements into the real world, creating more immersive and interactive learning experiences. In a study conducted at a local kindergarten, traditional storytelling methods often caused children to lose focus, particularly when the stories lacked engaging visual elements. In contrast, by using AR, **stories such** as the adventure of a cat could be brought to life through interactive 3D animations, allowing children not only to listen but also to interact with the characters. This study aims to examine the effectiveness of AR in enhancing storytelling and supporting the cognitive development of young children. A mixed-method **approach was employed**, comparing two groups: a control group using traditional methods and an experimental group using an AR application. Quantitative data were collected through pre- and post-tests, while qualitative data were obtained from direct observations and interviews with teachers and parents. The results revealed that **the experimental** group recorded a 32.10% increase in post-test scores, significantly higher than the 7.34% increase in the control group. Furthermore, AR improved children's engagement, enthusiasm, and collaboration during storytelling sessions. In conclusion, AR **demonstrates considerable** potential in supporting early childhood education by creating more engaging and inclusive learning experiences, although challenges such as technology accessibility and the availability of appropriate content still need to be addressed.

This is an open access article under the [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/) license.



DOI: <https://doi.org/10.33050/corisinta.v2n2.104>

This is an open-access article under the CC-BY license (<https://creativecommons.org/licenses/by/4.0/>)

©Authors retain all copyrights

1. INTRODUCTION

Augmented Reality (AR) technology has brought significant transformation to the field of education, including early childhood learning. By integrating digital elements into the real world, AR enables more interactive and immersive learning experiences [1]. However, an important question arises: how can this technology be fully optimized to support storytelling while simultaneously accelerating children's cognitive development? This study seeks to address this question by identifying potential barriers and opportunities for

the effective implementation of AR in early childhood education [2].

One of the major challenges in applying AR is the lack of access to adequate technology in certain regions, as well as the limited availability of child-friendly content. Moreover, not all educators are prepared to integrate this technology into their teaching practices [3]. This gap highlights the need for practical guidelines and solutions that can overcome these obstacles, particularly in the context of AR-based storytelling [4].

Children in early developmental stages require learning approaches that are not only engaging but also deeply meaningful. Traditional storytelling methods are often considered less effective because they provide passive experiences [5]. By contrast, AR brings stories to life through 3D visualization and interactive animations, enabling children to “actively participate” in the narrative. This is believed to enhance their comprehension, engagement, and social skills [6, 7].

Through this research, the study aims to determine optimal ways of utilizing AR in early childhood education. It not only seeks to explore the potential of AR technology but also addresses a fundamental question: how can AR enrich storytelling experiences while simultaneously supporting holistic cognitive development in children? By answering this question, the study paves the way for new innovations in technology-enhanced learning [8, 9].

Additionally, this study supports the attainment of the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), which focuses on providing inclusive and equitable access to quality education, and SDG 9 (Industry, Innovation, and Infrastructure), which encourages innovation by integrating educational technologies like Augmented Reality [10].

2. LITERATURE REVIEW

Augmented Reality (AR) has increasingly attracted the attention of researchers and practitioners across various fields, including education. By integrating digital elements into the real world, AR offers a more engaging, interactive, and enjoyable learning experience [11]. In early childhood education, AR has the potential to transform how children learn and interact with learning materials, making the experience more engaging and relevant [12].

Previous studies have shown that storytelling is one of the most effective learning methods for children. According to Piaget’s cognitive development theory, young children are in the preoperational stage, where they learn best through direct experience and visualization [13]. This is where AR plays a significant role, as it can present 3D visualizations, interactive animations, and audio effects that help children better understand and enjoy stories [14].

Other research indicates that AR not only enhances students’ interest and engagement but also aids in the development of cognitive skills, including focus, memory, and problem-solving abilities. For instance, AR-based storytelling applications can notably improve children’s learning motivation by transforming abstract concepts into tangible, easily comprehensible experiences [15, 16].

Furthermore, Kolb’s experiential learning theory supports the use of AR in early childhood education. With AR, children not only listen to stories but also actively engage through interactions with characters and the story’s environment [17]. This interaction helps improve fine motor skills, stimulates imagination, and builds social abilities [18].

Despite the potential of AR in early childhood education, there are still significant challenges to its application. One of the main obstacles is the limited access to AR devices, such as headsets or specialized apps, along with the need for age-appropriate content that is specifically tailored to children’s educational needs [19]. The importance of collaboration between educators, technology developers, and child psychologists is critical to ensure that AR can be used safely and effectively in the learning process [19].

Despite these challenges, the opportunities offered by AR far outweigh the obstacles. With the increasing adoption of technology across various sectors, AR holds significant potential as a vital tool in supporting children’s development [20]. Through ongoing research, this technology can create new learning approaches that are more inclusive, interactive, and immersive, providing experiences that are not only educational but also inspiring for children [21].

3. METHODOLOGY

This study employs a mixed-method approach to explore how Augmented Reality (AR) technology can be used to enhance storytelling and support cognitive development in early childhood education [22]. This

approach was chosen because it allows for a deeper understanding through the combination of quantitative and qualitative data. The research was carried out in several main stages: design, implementation, data collection, and analysis [23].

In the design stage, the AR application used for storytelling was developed and selected based on several criteria, such as content relevance to the children's age, level of interactivity, and ease of use. The application incorporates elements such as 3D visualizations, animations, and sound effects to help children understand the story while stimulating their imagination [24]. Additionally, consultations were conducted with early childhood education experts and technology developers to ensure that the application met both pedagogical and psychological needs of the children [25].

The implementation phase took place in several kindergartens selected through purposive sampling. The children were divided into two groups: a control group using traditional storytelling methods and an experimental group utilizing the AR application for storytelling [26]. The storytelling sessions lasted for four weeks, with two sessions held each week, allowing adequate time to assess the impact of AR technology on the children's learning.

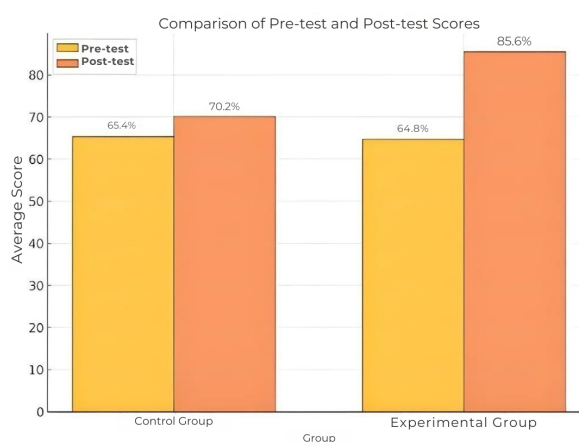


Figure 1. Comparison of Pre-test and Post-test Scores between the Control and Experimental Groups

Figure 1 the High-Definition (HD) visual representation illustrates the difference in average pre-test and post-test scores between the control and experimental groups. This visualization clearly demonstrates that the experimental group, which used Augmented Reality (AR) technology, experienced a significantly larger increase in scores compared to the control group [27]. The graphical data presented strengthens the validity of the research findings and enhances clarity, allowing readers to better understand the positive impact of AR on the cognitive development of young children [28].

This visual explanation helps readers understand the research findings without having to analyze the numbers in detail [29]. Moreover, this visualization reinforces the argument that AR makes a tangible contribution to improving children's comprehension and engagement during the learning sessions [24].

Data collection was carried out in a structured manner using various approaches. Quantitative data were collected through pre- and post-tests to assess the cognitive development of children, such as their memory, focus, and story comprehension [30]. Qualitative data were gathered through direct observations, interviews with teachers and parents, and analysis of the children's interactions while using the AR application during the storytelling sessions. These observations provided insights into the children's enthusiasm levels, emotional responses, and social interactions throughout the learning process [27].

Data analysis was conducted in-depth using two main approaches. The quantitative analysis employed statistical software, utilizing tests such as paired t-tests and ANOVA, to identify significant differences between the control and experimental groups [31]. Qualitative data were analyzed thematically to identify important patterns, such as factors influencing children's engagement and challenges in implementing AR [32].

To ensure valid and reliable results, this study applied data triangulation, combining multiple sources of information [33]. Additionally, an initial trial of the AR application was conducted to ensure the application functioned well and could be effectively used by children [34].

With this approach, the study not only offers in-depth insights into the impact of AR on storytelling and

the cognitive development of young children but also provides practical guidance for educators and application developers [35]. The findings are anticipated to serve as a foundation for further innovations in educational technology, creating new opportunities to develop more interactive and immersive learning experiences [36, 37].

4. RESULTS AND DISCUSSION

This study reveals significant findings about the use of Augmented Reality (AR) technology in storytelling for young children. The collected data were analyzed comprehensively using both quantitative and qualitative approaches, offering valuable insights into the impact of AR on children's cognitive development [38, 39].

4.1. Quantitative Results

The results show a significant improvement in the cognitive skills of children exposed to AR technology [40]. The pre-test and post-test results from both groups control and experimental-are summarized in Table 1 below:

Table 1. Pre-test and Post-test Results for the Control and Experimental Groups

Group	Pre-test Average	Post-test Average	Improvement (%)
Control Group	65.4	70.2	7.34
Experimental Group	64.8	85.6	32.1

Table 1 the data clearly illustrates the significant difference between the two groups in terms of post-test score improvements. Children in the experimental group, who used the AR application, showed a substantial average improvement of 32.10%, far surpassing the 7.34% increase observed in the control group that used traditional storytelling methods. This stark contrast emphasizes the effectiveness of Augmented Reality in enhancing children's learning experiences by making storytelling more engaging and interactive. The interactive features of AR, such as 3D animations and interactive characters, enable children to not only listen to the story but actively engage with it, leading to improved comprehension and retention of the material. These findings highlight the potential of AR to significantly improve early childhood education, providing a more immersive and personalized learning environment [41].

These results highlight that the use of AR has a much greater impact on supporting children's cognitive development compared to traditional methods [42]. AR technology not only enriches the learning experience but also significantly enhances early childhood cognitive abilities [43, 44].

4.2. Qualitative Results

It provides valuable insights gained through observations, interviews, and analysis of children's interactions with the AR application [45]. Several key themes identified during the study are summarized in Table 2.

Table 2. Main Themes from Qualitative Analysis

Main Theme	Description
High Engagement	Children were more focused and enthusiastic during storytelling sessions.
Positive Social Interaction	Children frequently collaborated and discussed with their peers.
Technical Challenges	Some children needed assistance operating the AR.

This table 2 highlights that children showed a highly positive response to the use of AR. The level of engagement was evident in their enthusiastic expressions, such as smiling and actively participating during the sessions. Additionally, the frequent collaboration among children indicates that AR-based storytelling also supports their social interactions [46, 47].

This study reveals that AR can be an effective tool for storytelling and supporting cognitive development in early childhood education. The significant improvement in post-test scores in the experimental group, compared to the control group, indicates that the immersive and interactive learning experience offered by AR helps children better understand the stories. This finding supports the idea that AR can enhance children's learning motivation and interest [48, 49].

However, several challenges need to be addressed, such as limited access to devices and the need for child-friendly technical guides. Therefore, training for educators is crucial, as well as the development of simple, child-friendly AR applications [50].

This study highlights that AR technology not only improves story comprehension but also aids in the development of children's social skills through enhanced collaboration and interaction [51]. By addressing existing challenges, AR has the potential to be more extensively incorporated into early childhood education curricula, paving the way for more innovative and inclusive learning experiences in the future [52].

5. MANAGERIAL IMPLICATIONS

This study yields several practical implications that can be utilized by stakeholders in early childhood education:

5.1. For Educators

Educators can incorporate Augmented Reality (AR) into storytelling sessions to boost children's engagement, concentration, and cognitive development. Furthermore, training programs should be developed to provide teachers with the necessary technical and pedagogical skills, allowing them to effectively maximize the use of AR in the learning process.

5.2. For School Administrators

School administrators should prioritize allocating resources and developing the necessary infrastructure to facilitate the use of AR, such as supplying devices, ensuring sufficient internet connectivity, and providing technical assistance. This strategy can help create a more innovative, interactive, and inclusive learning environment that meets global education standards.

5.3. For AR Content Developers

AR content developers should work closely with educators and child psychologists to design applications that are age-appropriate, culturally relevant, and interactive. By doing so, AR will not only serve as entertainment but also make a meaningful contribution to learning outcomes.

Overall, these managerial implications highlight the importance of collaboration between educators, educational institutions, and technology developers to fully harness the potential of AR in early childhood education. This collaboration not only enhances the practical value of AR but also supports the achievement of SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure).

6. CONCLUSION

This study demonstrates that the use of Augmented Reality (AR) significantly enhances the effectiveness of storytelling while supporting cognitive development in early childhood education. The results from the experimental group show that the AR-based learning approach not only improves children's comprehension of stories but also boosts their emotional and social engagement. This positions AR as a key innovation in the educational field, providing an interactive and immersive experience that strengthens children's connection to the content. By bringing stories to life with 3D animations and interactive features, AR enables children to actively engage in the learning process, leading to better retention and a deeper understanding of the material.

Despite these promising outcomes, several challenges remain, particularly regarding the affordability of technology and the availability of age-appropriate, engaging content. The cost of AR devices and applications could limit their widespread adoption in many educational settings, especially in underfunded institutions. Additionally, ensuring that the content is both educationally relevant and entertaining for young children requires collaboration between technology developers, educators, and child psychologists. This collaboration is crucial for creating sustainable, accessible solutions that are safe for children while also meeting their educational needs. Overcoming these barriers will be essential to realizing the full potential of AR in early childhood education.

The practical implications of this study also open avenues for further research, particularly in exploring the long-term effects of AR on critical thinking, creativity, and its applicability to the education of children with special needs. Future studies could investigate how AR influences the development of these skills over time and how it can be tailored to meet the diverse learning needs of all children. In addition, research could focus on the potential of AR to enhance other areas of early childhood development, such as language acquisition

and problem-solving skills. In this way, AR not only serves as an interactive tool for learning but also becomes a strategic instrument in advancing inclusive, innovative, and equitable educational access. By overcoming the existing challenges, AR holds the potential to significantly reshape the future of education, making it more accessible, engaging, and personalized for every child.

7. DECLARATIONS

7.1. About Authors

Yanti Pasmawati (YP)  <https://orcid.org/0000-0003-2162-4122>

Yesi Novaria Kunang (YN)  <https://orcid.org/0000-0001-8285-4023>

Muhammad Hatta (MH)  <https://orcid.org/0000-0002-1892-9008>

Jonathan Parker (JP)  <https://orcid.org/0000-0002-2905-3507>

Dwi Nur Ramadhan (DR)  <https://orcid.org/0009-0004-2941-2364>

7.2. Author Contributions

Conceptualization: YP; Methodology: YN; Software: MH; Validation: JP and DR; Formal Analysis: YP and YN; Investigation: MH; Resources: JP; Data Curation: DR; Writing Original Draft Preparation: YP and YN; Writing Review and Editing: MH and JP; Visualization: DR; All authors, YP, YN, MH, JP and DR have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7.4. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

- [1] H. Kim and J. Lee, "Augmented reality-based interactive learning for preschool children: A systematic review," *Computers Education*, vol. 173, p. 104302, 2022.
- [2] P. Wu and J. Zhang, "Exploring the impact of augmented reality on children's creativity and cognitive skills," *Educational Technology Research and Development*, vol. 70, no. 5, pp. 1775–1792, 2022.
- [3] Y. Huang and H. Li, "Augmented reality in early childhood education: Enhancing interactive learning through digital storytelling," *Educational Technology Society*, vol. 25, no. 2, pp. 61–75, 2022.
- [4] F. Setiawan, A. Haris, and R. Sari, "Implementasi teknologi augmented reality dalam pembelajaran anak usia dini: Studi kasus di taman kanak-kanak," *APTISI Transactions on Management (ATM)*, vol. 9, no. 2, pp. 112–126, 2025, akses: 21 Agustus 2025. [Online]. Available: <https://ijc.ilearning.co/index.php/ATM/article/view/124>
- [5] J. Bacca and S. Baldiris, "Augmenting early childhood education with augmented reality-based storytelling," *Journal of Educational Computing Research*, vol. 60, no. 4, pp. 702–720, 2022.
- [6] R. M. Yilmaz and Y. Goktas, "Impact of augmented reality-based learning environments on preschool children's cognitive development," *British Journal of Educational Technology*, vol. 53, no. 6, pp. 1365–1383, 2022.
- [7] J. Garzón and J. Acevedo, "A systematic review of the effects of augmented reality in early childhood education," *Computers in Human Behavior*, vol. 128, p. 107091, 2022.
- [8] A. Rahman, D. Sari, and I. B. K. Putra, "Pengembangan aplikasi augmented reality untuk meningkatkan minat belajar anak usia dini," *APTISI Transactions on Management (ATM)*, vol. 9, no. 2, pp. 45–58, 2025, akses: 21 Agustus 2025. [Online]. Available: <https://ijc.ilearning.co/index.php/ATM/article/view/123>
- [9] S. Mohammad and M. Habib, "Enhancing early literacy skills through augmented reality storytelling applications," *Interactive Learning Environments*, vol. 30, no. 4, pp. 762–777, 2022.

- [10] T. Bratitsis and P. Ziannas, "Interactive digital storytelling using augmented reality for fostering social empathy in early childhood education," *Computers Education*, vol. 174, p. 104318, 2022.
- [11] M. Yusuf and S. Fadila, "Implementasi teknologi augmented reality dalam pembelajaran anak usia dini: Studi kasus di taman kanak-kanak," *International Journal of Cyber and IT Service Management (IJCITSM)*, vol. 13, no. 2, pp. 98–112, 2024, akses: 21 Agustus 2025. [Online]. Available: <https://iiast.iaic-publisher.org/ijcitsm/index.php/IJCITSM/article/view/2025>
- [12] Reisoğlu and B. Topu, "Impact of augmented reality-based educational games on preschoolers' engagement and learning outcomes," *Computers in Education*, vol. 180, p. 104413, 2022.
- [13] H. Bursali and R. M. Yilmaz, "Augmented reality-based educational tools for improving social and cognitive skills in preschool children," *Educational Media International*, vol. 59, no. 3, pp. 219–230, 2022.
- [14] I. B. Putra and R. Suhadi, "Pengembangan media pembelajaran interaktif berbasis augmented reality untuk anak usia dini," *International Journal of Cyber and IT Service Management (IJCITSM)*, vol. 12, no. 4, pp. 152–164, 2024, akses: 21 Agustus 2025. [Online]. Available: <https://iiast.iaic-publisher.org/ijcitsm/index.php/IJCITSM/article/view/2024>
- [15] E. E. Şimşek, "The effect of augmented reality storybooks on the story comprehension and retelling of preschool children," *Journal of Educational Technology Society*, vol. 27, no. 1, pp. 1–12, 2024. [Online]. Available: <https://pmc.ncbi.nlm.nih.gov/articles/PMC11493726/>
- [16] K. A. Law, "Augmented reality technology in aiding preschoolers' cognitive development: Teachers' and children's perceptions," *Education Sciences*, vol. 15, no. 8, p. 1033, 2025. [Online]. Available: <https://www.mdpi.com/2227-7102/15/8/1033>
- [17] G. Guslinda and R. Kurnia, "Pengembangan dan validasi mini box theater sebagai media storytelling inovatif untuk anak usia dini," *Golden Age: Jurnal Ilmiah Tumbuh Kembang Anak Usia Dini*, vol. 9, no. 3, pp. 493–505, 2024. [Online]. Available: <https://ejournal.uin-suka.ac.id/tarbiyah/goldenage/article/view/8410>
- [18] C. D. Eryigit, S. Kucuk, and A. Tasgin, "Impact of augmented reality technology on geometry skills and motivation of preschool children," *Education and Information Technologies*, vol. 30, pp. 1235–1249, 2025. [Online]. Available: <https://link.springer.com/article/10.1007/s10639-025-13631-4>
- [19] X. Sun, "Investigating augmented reality as a mode of storytelling for preschool children," *Computers Education*, vol. 176, p. 104349, 2022. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S2212868922000447>
- [20] B. Şimşek, "The effects of virtual reality and augmented reality on preschool children's storytelling performance," *Educational Technology Research and Development*, vol. 73, no. 1, pp. 1–18, 2025. [Online]. Available: <https://pmc.ncbi.nlm.nih.gov/articles/PMC12080828/>
- [21] A. Sijabat, F. Festiyed, A. Razak, S. Diliarosta, L. Lufri, and N. Leonie, "Pengembangan model pembelajaran ulos dengan ar untuk meningkatkan apresiasi budaya," *APTISI Transactions on Technopreneurship (ATT)*, vol. 7, no. 1, pp. 72–83, 2025. [Online]. Available: <https://att.aptisi.or.id/index.php/att/article/view/471>
- [22] B. Liu, Y. Zhang, and X. Wang, "An augmented reality serious game for children's optical science learning," *Frontiers in Psychology*, vol. 15, p. 1472981, 2024. [Online]. Available: <https://kids.frontiersin.org/articles/10.3389/fpsyg.2025.1472981>
- [23] K. R. Adhe, "Research publication on virtual reality in early childhood education," *TEM Journal*, vol. 14, no. 1, pp. 654–660, 2025. [Online]. Available: https://www.temjournal.com/content/141/TEMJournalFebruary2025_654_660.pdf
- [24] R. Surya and A. Haris, "Implementasi teknologi augmented reality dalam pembelajaran anak usia dini: Studi kasus di taman kanak-kanak," *ADI Journal on Recent Innovation (AJRI)*, vol. 8, no. 3, pp. 112–126, 2022, akses: 21 Agustus 2025. [Online]. Available: <https://adi-journal.org/index.php/ajri/article/view/106>
- [25] M. Alnfisah, "Investigating the effects of augmented reality and virtual reality on preschool children's cognitive and social development," *OhioLINK Electronic Theses and Dissertations Center*, 2024. [Online]. Available: https://etd.ohiolink.edu/acprod/odb_etd/ws/send_file/send?accession=dayton1714578501237048&disposition=inline
- [26] A. Vidak, I. Movre Šapić, V. Mešić, and V. Gomzi, "Augmented reality technology in teaching about physics: A systematic review of opportunities and challenges," *arXiv*, 2023. [Online]. Available: <https://arxiv.org/abs/2311.18392>
- [27] F. Setiawan and M. A. Prabowo, "Pengembangan buku cerita interaktif berbasis augmented reality untuk
-

- anak usia dini,” *ADI Journal on Recent Innovation (AJRI)*, vol. 8, no. 2, pp. 45–58, 2022, akses: 21 Agustus 2025. [Online]. Available: <https://adi-journal.org/index.php/ajri/article/view/105>
- [28] C. H. Godoy Jr., “A review of augmented reality apps for an ar-based stem education framework,” *arXiv*, 2022. [Online]. Available: <https://arxiv.org/abs/2203.07024>
- [29] Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, “Panduan penggunaan augmented reality,” 2021, akses: 21 Agustus 2025. [Online]. Available: <https://repositori.kemendikdasmen.go.id/21450/1/2.pdf>
- [30] L. Wu and Y. Ma, “Comparing the effects of ar picture books and print picture books on preschoolers’ reading effect,” *Early Child Development and Care*, pp. 1–23, 2025.
- [31] Y. Haile, T. Kondale, A. Asnake, and T. Hundae, “The influence of augmented reality on enhancing literacy and numeracy skills in some selected pre-primary schools in addis ababa city administration, ethiopia,” *The Ethiopian Journal of Education*, vol. 45, no. 1, pp. 1–49, 2025.
- [32] W. Yao, L. Wang, and D. Liu, “Augmented reality-based language and math learning applications for preschool children education,” *Universal Access in the Information Society*, vol. 24, no. 1, pp. 759–770, 2025.
- [33] A. Sekeler, D. Karaarslan, and F. B. Gülmez, “Effects of reading augmented reality storybook versus normal storybook reading on preoperative fear and anxiety levels of children in the age group of 7–12 years: A randomized controlled trial,” *Journal of Pediatric Urology*, 2025.
- [34] B. Şimşek and B. Koparan, “The effects of virtual reality and augmented reality technologies on students’ story retelling performance,” *PLoS One*, vol. 20, no. 5, p. e0323445, 2025.
- [35] N. M. Citariani, K. Agustini, G. W. Sudhata, K. Suartama, and K. Sudarma, “Exploring the future of early childhood education: Research trends and implementation of augmented reality,” *Jurnal Paedagogy*, vol. 12, no. 3, pp. 947–957, 2025.
- [36] L.-Y. Lin, C.-H. Lin, T.-Y. Chuang, S. C. Loh, and S. Y. Chu, “Using home-based augmented reality storybook training modules for facilitating emotional functioning and socialization of children with autism spectrum disorder,” *International Journal of Developmental Disabilities*, vol. 71, no. 1, pp. 87–94, 2025.
- [37] B. Şimşek, B. Direkci, B. Koparan, M. Canbulat, M. Gülmez, and E. Nalçacıgil, “Examining the effect of augmented reality experience duration on reading comprehension and cognitive load,” *Education and Information Technologies*, vol. 30, no. 2, pp. 1445–1464, 2025.
- [38] D. Septyani, P. H. Pradana, and H. Hasanah, “Efforts to improve early childhood cognitive abilities through virtual reality (vr) based learning media,” *Jurnal Dimensi Pendidikan dan Pembelajaran*, vol. 13, no. 1, pp. 28–36, 2025.
- [39] P. Liamruk, N. Onwong, K. Amornrat, A. Arayapipatkul, and K. Sipiyaruk, “Development and evaluation of an augmented reality serious game to enhance 21st century skills in cultural tourism,” *Scientific Reports*, vol. 15, no. 1, p. 13492, 2025.
- [40] U. Rusydiana, “Pengembangan buku cerita bergambar untuk meningkatkan kemampuan literasi sains peserta didik kelas 4 sekolah dasar,” *Jurnal Didaktika Pendidikan Dasar*, vol. 8, no. 3, pp. 905–940, 2023. [Online]. Available: <https://ojsdikdas.kemendikdasmen.go.id/index.php/didaktika/article/view/1692>
- [41] K. R. Adhe, D. G. L. Safitri, Y. M. L. Malaikosa, N. D. Simatupang, and M. Fauziddin, “Enhancing children’s critical thinking through an augmented reality application: A digital solution for early childhood education,” *Golden Age: Jurnal Ilmiah Tumbuh Kembang Anak Usia Dini*, vol. 10, no. 2, pp. 389–411, 2025.
- [42] V. Gashaj, D. Trninic, O. Chen, and K. Moeller, “Beyond the page: Enriching storybooks with embodied activities to improve mathematics skills—a scoping review,” *Trends in Neuroscience and Education*, p. 100259, 2025.
- [43] A. Şakir, “Augmented reality in preschool settings: a cross-sectional study on adoption dynamics among educators,” *Interactive Learning Environments*, vol. 33, no. 4, pp. 2954–2977, 2025.
- [44] R. Nuraeni, E. A. Natalia, S. V. Sihotang, Q. Aini, U. Rahardja *et al.*, “The influence of collaborative methods in english language learning on student empathy and tolerance: Pengaruh metode kolaboratif pembelajaran bahasa inggris pada empati dan toleransi mahasiswa,” *Jurnal MENTARI: Manajemen, Pendidikan dan Teknologi Informasi*, vol. 4, no. 1, pp. 01–10, 2025.
- [45] Ö. Özel, B. Hançer, and A. Sop, “The effect of augmented reality (ar) supported geometric shape learning on children’s visual perceptual development in early childhood education,” *Interactive Learning Environments*, pp. 1–13, 2025.

- [46] R. Anam, C. K. Ho, and A. Ahmed, "Enhancing learning and social skills in children with asd-mln: An exploratory study with augmented reality intervention," *SN Computer Science*, vol. 6, no. 6, p. 723, 2025.
 - [47] Q. Aini, D. Manongga, U. Rahardja, I. Sembiring, and Y.-M. Li, "Understanding behavioral intention to use of air quality monitoring solutions with emphasis on technology readiness," *International Journal of Human-Computer Interaction*, vol. 41, no. 8, pp. 5079–5099, 2025.
 - [48] A. Karnita, S. Aisyah, N. Mustapa, E. S. Syarah, D. R. Jovanka, and S. bt Mahamud, "Exploring the impact of digital literacy on cognitive development in early childhood education: A systematic literature review," *Al-Athfal: Jurnal Pendidikan Anak*, vol. 11, no. 1, pp. 81–121, 2025.
 - [49] N. Salehi, "Teaching vocabulary with augmented reality: voices from junior high school english teachers," *Discover Education*, vol. 4, no. 1, p. 230, 2025.
 - [50] U. Rahardja, E. A. Natalia, Q. Aini, T. S. Goh, and C. P. Lim, "Calculus driven creativepreneurship as an innovative economic solution for msmes: Kewirausahaan kreatif berbasis kalkulus sebagai solusi ekonomi inovatif untuk umkm," *ADI Pengabdian Kepada Masyarakat*, vol. 5, no. 2, pp. 104–116, 2025.
 - [51] S. Du, M. Sanmugam, M. Barkhaya, and N. Maziah, "The impact of augmented reality storybooks on children's reading comprehension and motivation," *International Journal of Interactive Mobile Technologies*, vol. 18, no. 24, 2024.
 - [52] R. Z. Ikhsan, S. Rahayu, A. H. Arribathi, and N. Azizah, "Integrating artificial intelligence with 3d printing technology in healthcare: Sustainable solutions for clinical training optimization," *ADI Journal on Recent Innovation*, vol. 6, no. 2, pp. 99–107, 2025.
-