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The Implementation Fidelity, Contributions, and Challenges of Augmented Reality in Some Selected Pre-Primary Schools of Addis Ababa City Administration

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Abstract

This study aimed to investigate preprimary school teachers' perspectives on the fidelity, contributions, and challenges of Augmented Reality and 3D visualization in the preprimary education program. Quantitative and qualitative approaches with concurrent triangulation designs were employed to address the purpose of the study. The participants of the study were seventeen preprimary education teachers, two preprimary education principals, one Augmented Reality designer, and four staff members from Plan International, selected by employing purposive sampling techniques. A survey questionnaire, interview, focus group discussion, and document analysis were used to collect the data. Both quantitative (mean and standard deviation) and qualitative (thematic analysis) techniques were used to analyze the data. Findings revealed that Augmented Reality application practice in exploration, installation, and implementation stages were well addressed through the project activities. Preprimary education teachers believed that augmented reality had several contributions, including improving children's motivation, interest, memory, active involvement, fine motor skill, social interaction, and digital literacy skills. There are a variety of difficulties that affect how Augmented Reality is implemented. The application has several hurdles including limitation in the pedagogy, misalignment with the curriculum, inadequate preparation of the Augmented Reality for KG2, and challenges with using Augmented Reality in large classes. Finally, preprimary education opts to consider emergent ideas, outcomes, and methods. Thus, the application of Augmented Reality needs to reconsider how it can foster curiosity, imagination, reflection, and creativity in the learning process.

Keywords: Augmented Reality, 3D Visualization, contributions, fidelity, challenges, preprimary education

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Introduction

Mobile technology contributes positively in education (Radosavljevic et al., 2020) and Augmented Reality (hereinafter-AR) along with Virtual Reality (VR) and Mixed Reality (MR) are considered to be key educational technologies over the next decade (Becker et al., 2018). AR is one of the new sciences (technologies) with excellent reflection in the field of education (Jaiswal et al., 2021) and pedagogical tools that have a pervasive role in the process of teaching-learning. AR technology has been recognized from educational sciences expertise as one of the most promising technologies that will be adopted by educators the next decade and along with VR have the potential to be a standard tool in educational sciences.

The power of augmented reality to meet the need for educational technology to be interactive and attractive for preschool children (Aladin et al., 2020) has attracted the attention of researchers to preschool children in recent years (Gecu-Parmaksiz & Delialioğlu, 2020; Mowafi & Abumuhfouz, 2021; Pan et al., 2021; Preka & Rangoussi, 2019; Redondo et al., 2020; Zhu et al., 2020). According to constructivism theory, it can be said that augmented reality applications support children who actively participate to gain confidence and motivation by providing an innovative and interesting environment for learning (Rasalingam et al., 2014; Sommerauer & Müller, 2018).

Studies indicate that AR enhances problem solving skills (Hassan et al., 2022); motivation (Ozdamli & Karagozlu, 2018), attention (Tuli & Mantri, 2021), and it provides more authentic learning experiences and creative thinking skills (Ivanova & Ivanov, 2011) through rich interaction. Furthermore, the use of AR in the classroom increases students' motivation and improves their concentration and thus teaches more

(Sobral & Menezes, 2012). Masmuzidin and Aziz (2018), in their study examining early childhood studies on augmented reality, revealed that this application mostly developed motivation. Similarly, Bacca et al. (2014) stated that studies on augmented reality provide the most learning outcomes and motivation. Children's interactions with content material, peer-to-peer interaction, child-teacher interaction and real-time feedback provided by AR make it easier for children to focus better (Madanipour & Cohrssen, 2020).

Moreover, applications with augmented reality technology improve the skills of knowing, exploring, perceiving and expressing emotions and artistic expression of the environment (Kelpšienė, 2020). Thus, it can make learning more effective, fast and fun (Roopa et al., 2021). AR provides a natural environment where children can both interact with virtual manipulatives and relate them to the real physical world (Gecu-Parmaksiz & Delialioğlu, 2020). This natural link has the potential to support skills such as attention and spatial cognition. In addition, AR attracts the attention of children as it enables them to manipulate and interact with objects (Chen & Chan, 2019). Augmented reality applications that provide attention, interest and motivation enable children to learn words and keep them in memory (Santos et al., 2016). Likewise Baragash et al. (2022) found that AR was useful for teaching literacy skills and efficient for fostering children's arithmetic skills. In addition, using technology improves children' focus and attentiveness on their tasks (Hassan et al., 2022).

Despite the advantages of AR in pre-primary education, it is important to consider a developmentally appropriate practice as a significant factor while working on design and development of children’s AR applications (Tuli & Mantri, 2020). It is also essential to consider age and culture-appropriate design (Radu & MacIntyre, 2012). On the other hand, studies have revealed that usability issues have been reported based on the fact that children found AR complicated and difficult to use, faced technical problems while using an AR application due to device characteristics such as a small size screen, network speed, or battery capacity (Tuli & Mantri, 2020). Other studies describe as a drawback of using AR technology the children distraction and cognitive overload (Kelpšienė, 2020). In the case of preprimary schools with large classes, there are challenges with the way the classrooms are set up. Another study also showed that teachers who have received training in AR are better at integrating and practicing science activities (Roopa et al., 2021). In Ethiopia, little is known about the contribution of AR technology to teaching practice and learning outcomes in preprimary education, and its applications in early childhood education remain limited. Thus, this study attempted to unlock the potential fidelity, contributions, and challenges of AR on the children's learning process and outcomes in preprimary education

Statement of the Problem

Research revealed the preferences of preschoolers to augmented reality over the traditional one. Educators also considered augmented reality as innovative and beneficial teaching approach in preschool program (Rapti et al., 2023). Despite its long history of use in university and lower grades, the application of this technology in preprimary education is limited (Aydoğdu & Kelpšiene, 2021). Although augmented reality has many benefits, its use in educational settings is not widespread (Dobrovská & Vaněček, 2021). Studies have also shown that the application of augmented reality enhances early literacy skills (Masmuzidin & Aziz, 2018) and foreign language teaching skills (Fan et al., 2020) in preprimary education. In addition, augmented reality assists children in enhancing the learning process (Godoy Jr., 2020). While there are not many augmented reality practices in preprimary education programs in Ethiopia, the technology is recommended as an additional pedagogy because it can engage children's senses, capture their attention, and create a fun environment.

The use of this application in education has gained popularity and has been linked to improved learning outcomes across a variety of academic disciplines. It permits the use of 3D objects, texts, photos, videos, and animations to be used simultaneously, and it can be utilized on devices such as desktops, laptops, portable devices, and smartphones (e.g., Kirner et al., 2012). Numerous studies attest to the value of augmented reality as a pedagogical tool and its educational benefits in preschool programs. However, no research has been done in Ethiopia to assess the fidelity, contributions and challenges of AR application in pre-primary education program in Ethiopia.

Moreover, studying AR contributes to the field of preprimary education, providing insights into innovative teaching methods that can enhance learning experiences for young children. This research offers a deeper understanding of how AR and 3D visualization align with preprimary education pedagogy, shedding light on effective strategies for integrating technology into early childhood education. The finding has theoretical values, including informing educational theories related to constructivist learning theory, cognitive development, learning styles, and engagement. They offer theoretical frameworks for utilizing AR and 3D visualization in educational settings. Regarding its practical values, the AR findings support children to personalize learning, enhance hand-on experiences, address diverse styles of learning, motivation, interactive and visual learning. In addition, understanding the fidelity, contributions, and challenges of AR and 3D visualization can lead to the development of tailored educational content that enhances children's engagement, comprehension, and retention.

In order to better understand how augmented reality is practiced in preprimary education, this study looked to assess teachers' views, because teachers in preprimary education programs tend to examine an issue from different perspectives, have long and multifaceted experiences of the education system, and could identify factors that might not initially be taken into account. By conducting this study in Yekabado and *Miazia* 23 preprimary schools in Addis Ababa city administration, Plan International Organization (PIO) and its partners aimed to contribute to the ongoing efforts to improve the quality of early childhood education in the region and explore innovative approaches to enhance children's learning experiences. Therefore, this study aimed to assessing augmented reality applications fidelity, contributions, and challenges in some selected pre-primary schools of Addis Ababa City Administration.

Objectives of the Study

The present study attempts to:

- Investigate the fidelity of augmented reality (AR) and 3D visualization in the preschool education program
- Examine the contributions of AR to enhancing children's learning outcomes.
- Analyze the challenges of augmented reality in preschool education program.

Research Questions

This research is aimed to address the following questions:

- What is the fidelity of augmented reality (AR) and 3D visualization in the preschool education program?
- What are the contributions of AR to enhancing children's learning outcomes?
- What are the factors that affect the proper practices of AR in the preschool education?

Operational Definitions

- **Augmented reality:** refers a technology that combines computer-generated elements with the real world images and videos of preprimary education contents, allowing children to get hands-on learning experiences.
- **Fidelity:** expresses the way the intervention protocol of AR is effectively implemented as intended.
- **Contributions:** assesses the use of AR in enhancing children's learning outcomes.
- **Challenges**: defines and assesses the factors that affect the proper implementation of AR in the preprimary education program

Methods

Study Area

The study was conducted in Addis Ababa city administration, specifically in two government preprimary schools, *Yekabado* and *Miazia* 23, were purposively selected as the study sites. These schools were chosen as they were part of a pilot project initiated by Plan International Organization (PIO) to introduce and evaluate the use of AR technology in enhancing children's learning outcomes. Both *Yekabado* and *Miazia* 23 preprimary schools catered to a diverse group of children from different socio-economic backgrounds, providing an opportunity to evaluate the intervention's effectiveness across various demographics. PIO, a renowned non-governmental organization (NGO) working in child rights, education and development, partnered with the Addis Ababa City Administration Education Office to provide the necessary support and resources for the implementation of the intervention. The intervention aimed to enhance the learning experience of the preprimary school children by incorporating AR and 3D visualization into their curriculum.

The intervention involved the use of AR technology, which overlays digital content onto the real world, and 3D visualization, which enables the children to interact with three-dimensional objects and scenarios. These technologies were integrated into various educational activities, including literacy, science and mathematics skills. To ensure effective implementation, the teachers and staff at *Yekabado* and *Miazia* 23 preprimary schools received training and support from PIO. This training equipped them with the necessary skills and knowledge to integrate AR and 3D visualization into their teaching methodologies effectively. At the end of the intervention, research was conducted to determine the effectiveness of the AR and 3D visualization intervention.

Research Design

The study conducted was based on a mixed-method research design, which combined both quantitative and qualitative approaches. The concurrent triangulation design ensured that both quantitative and qualitative data were collected simultaneously and analyzed separately. By comparing and contrasting the findings from both methods, researchers identify convergence or divergence in the results, enabling a more comprehensive and nuanced interpretation of the research topic. Triangulation of data from different sources also enhances the validity and reliability of the study, as multiple perspectives and sources of evidence are considered.

Participants

The selection of participants for the study was done through purposive sampling. Seventeen (17) teachers who had received training on AR application in the classroom were included in the study. These teachers were chosen based on their experience and willingness to participate in the study. Additionally, two (2) preprimary school principals, who were responsible for overseeing the implementation of AR in their respective schools, were selected as participants. Furthermore, one (1) AR designer, who played a crucial role in developing and customizing the AR applications for the pre-primary education, was included in the study. The AR designer had expertise in creating interactive and engaging content using AR technology. In addition, four (4) staff members that initiated and supported the AR project from PIO were also selected as participants.

Instruments

Data for the study was collected using a combination of survey questionnaires, in-depth interviews, Focus Group Discussions (FGD), and document analysis. Items for all these instruments were developed based on background, statement of the problem, objectives, related literature, and AR documents. Some details about the instruments are provided below.

A survey questionnaire: The survey questionnaire was designed to gather quantitative data and was developed based on key variables related to contributions and challenges of AR. Teachers responded to 24 items with a 5-point Likert scale to gauge their attitudes towards the importance of AR in children's memory, motivation, active engagement, social interaction, digital literacy, and fine motor skill development. The survey includes 3 items to assess the importance of children's memory, 5 items to assess the importance of children's motivation, 6 items to assess the value of active engagement, 5 items to assess the value of social interaction, 3 items to assess the value of digital literacy, and 2 items to assess the value of the development of fine motor skills. Seven criteria were used to gauge the difficulties posed by AR technology in pre-primary education.

In-depth interviews: Two preprimary school principals, four experts from PIO, and one AR designer were interviewed bout fidelity, contributions, and challenges of AR and 3D visualization.

Focus group discussions: FGDs were conducted with teachers of the two preschools. Two FGDs were conducted, one at *Yekabado* preprimary school and one at Miazia preprimary school, with 7 and 8 teachers, respectively. The FGDs were believed to provide insights into the fidelity, contributions, and challenges of AR and 3D visualization.

Document analysis: The relevance, level of linguistic difficulty, and cultural appropriateness of the AR guidelines were all evaluated using document analysis. In addition, fidelity of AR was also reviewed and evaluated from AR report document.

The items for all instruments were carefully prepared to ensure their alignment with the study objectives, rationale, and significance. Relevant sources were consulted during the item preparation process. To ensure the validity and reliability of the data, several steps were taken. Firstly, the reliability of the survey questionnaire was assessed using Cronbach's alpha, a commonly used measure of internal consistency (see Table 1 below). To establish content validity, a panel of experts was consulted. These experts included researchers, staff members from the PIO, and AR designers. The selection of experts was based on specific guidelines, which included their experience as academicians and familiarity with the thematic domains and concepts related to evidence-based practice in AR in preprimary education. Each expert was provided with a copy of the instrument, and asked to review it. The reviewers were requested to identify any deficiencies and provide recommendations or suggestions to improve sentence structure, clarity, and conciseness. The experts' feedback was then incorporated into the instrument by the investigators, ensuring that a significant number of items received the desired degree of ratings from the content experts. The review process also involved making editorial corrections, such as ensuring language consistency and clarity.

The researchers transcribed all the qualitative data to ensure that no critical information provided by the sources was missed. This transcription process facilitated a thorough analysis of the qualitative data. Overall, the data collection process involved a comprehensive approach that incorporated both quantitative and qualitative methods. Steps were taken to establish the validity and reliability of the instruments, including consultation with content experts and the use of appropriate statistical measures. The combination of survey questionnaires, in-depth interviews, focus group discussions, and document analysis allowed for a thorough examination of the research objectives and provided a robust data set for analysis.

Table 1

Reliability of AR Contributions and Challenges

Dimension	Sub-variable	Number of Items	Crobach's Alpha
Contributions of AR	Memory	3	.89
	Motivation	5	.90
	Active Engagement	6	.83
	Social Interaction	5	.87
	Digital Literacy Skill	3	.78
	Fine Motor Skill	2	.72
Challenges		7	.81

Procedures

Before the implementation, consent letters to conduct the study were submitted to the two preprimary schools. After getting the appropriate consent to conduct the study, different steps were carried out to execute the data collection procedures of the study. Information about the number of teachers, principals, AR designer, and PIO staffs were collected from the two schools. Before the data collection team travelled to the research sites, the necessary preparations had been made by the core research team members. The preparations included finalizing data collection instruments, organizing logistics necessary to travel to the two schools, securing support letters from Addis Ababa City Administration Education Office, searching for and recruiting qualified and experienced data collectors who were well acquainted with the local context of the study. In all the two schools, prior communication had been made with relevant government offices particularly, Addis Ababa Bureau of Education to obtain their support during the field data collection process. Accordingly, the field data collection teams enjoyed extended support of government offices. The first field work day was devoted to training data collectors on the data collection instruments, orienting them about the objectives of the study and PIO's child protection policies, ethical considerations, and standards to be followed before-during- and after FGD sessions with different types of participants. In collaboration with offices of Addis Ababa Bureau of Education, gate keepers were identified and contacted to guide the field data collection team at each of the study sites.

Data Analysis

To analyze the quantitative data, various statistical measures were employed. Descriptive statistics involving mean and standard deviation (SD) were utilized to analyze the quantitative data, and IBM SPSS Statistics 25 was employed to assist in the data analysis. Moving on to the analysis of qualitative data, researchers employed thematic analysis. Thematic analysis is a qualitative research method used to identify, analyze, and interpret patterns, themes, and meanings within textual data. It involves systematically coding and categorizing the data to identify recurring themes and patterns that emerge from the responses. Researchers read and reread the qualitative data to immerse themselves in the content and gain a comprehensive understanding of the participants' perspectives. Throughout the thematic analysis process, researchers ensured transparency and rigor by discussing and validating their interpretations with the research team. This iterative process allowed for the refinement and revision of the identified themes, ensuring the accuracy and reliability of the findings.

Ethical Considerations

The study complied with PIO Child Protection Policy, Research Policy and Standards, and Guideline for Consulting with Children and Young People with Disabilities. The rights and dignity of study participants were fully respected and protected by applying all required research ethics including securing consent from each participant. Signed consents were secured from many of the participants. When signed consents were not possible, recorded oral consents were secured. All field staff members signed PIO Child Rights Protection Policy Acknowledgement Form.

Results

Teacher's Demographic Characteristics

Table 2

Summarized Teacher's Demographic Characteristics (N= 17)

No.	Variables	Categories	Frequency	Percent
1	Sex	Male	3	17.6
		Female	14	82.4
2	Age	25 – 30	6	35.4
		31 – 36	8	47.2
		Above 37	3	17.4
3	Work experience	4 – 9 years	13	76.4
		10 – 13 years	4	23.6
4	Teachers qualification	Diploma	16	94.1
		Degree	1	5.9

Table 2 shows that 82.4% of teachers were female and the remaining 17.6% were male. With regard to age, 47.2% were between the age of 31-36, 35.4% were between the age of 25-30 and the remaining 17.4% were above 37. With respect to teacher qualification, of the total 17 teachers, 16 (94.1%) were diploma holder and only 1 (5.9%) had first degree. Looking at the data on their work experience, 76.4% of teachers had 4 to 9 years and 23.6% had 10 to 13 years of experience. Additionally, one male and one female school principals 1 female and 3 male PIO and 1 male AR designer participated in the study.

Teacher's view towards the fidelity of Augment Reality and 3D Visualization

Exploration and Installation Stage of Augment Reality and 3D Visualization

The utilization of AR and 3D visualization in pre-primary schools has undergone exploration and installation stages, uncovering significant aspects. Initially, the selection process aimed to identify children facing challenges in reading, writing, and math skills for the AR intervention. Although the initial plan was altered, the teachers and PIO reached an agreement to provide AR for all children. The selection was carried out by the principals of *Miazia* and *Yekabado* preprimary schools in consultation with teachers. To ensure successful implementation, a four-day training program was conducted for the selected teachers, KG coordinators, special needs experts, ICT professionals, and Woreda experts or supervisors involved in the AR intervention. The training covered various AR topics, pre-primary education issues, and relevant materials, equipping stakeholders with the necessary knowledge and skills. This is supported by the following quotes, which indicate the exploration and installation of AR with a focus on fidelity. From *Miazia* and *Yekabado* Preschool, FGD participants' teachers described on the fidelity situation as, ‘‘First, group of children were selected from our preschools, and then beneficiaries were identified and a discussion was held on the actual implementation of AR.''

The *Miazia* preschool principal further described the situation:

> *The AR program was discussed. Groups to be included in the AR intervention were chosen. Children with writing, reading, and counting difficulties (connected to disabilities) were chosen from two parts. Twenty children from two KG1 sections were among the forty children.*

The *Yekabado* preschool principal further described the situation *as* "The KG1 children were selected from fourteen sections, and forty of them were found to have reading, writing, and math skills problems across the board. Teachers participated in the selection of the children."

In the FGD participants from PIO described on the fidelity situation as follows:

> *We picked the beneficiaries (as stated in the proposal). We have a connection to the preschools. We chose the special needs children; the schools selected the children. PIO supports the two schools. We invested in the schools; the leaders of the two schools were committed to carrying out new initiatives. We used our framework; it fitted with our innovation; the process took a long time, and the contents were prepared from curricula.*

In addition, the activities involved in the AR installation stage were clearly outlined in the quote presented below. Participants from *Yekabado* preschool mentioned the following activities:

> *Teachers were trained and AR tools were purchased. We received training on augmented reality and relevant pre-primary education issues. The session lasted for four days, 4 days training.*
>
> *We trained Teachers (8), KG coordinators (2), Special need experts (2), ICT (2) and Woreda experts or supervisors (2)*

Participants from *Miazia* preschool similarly shared about this situation:

> *All required materials were bought. AR technology was prepared. Curricular content was installed in the AR; teachers received training on how to utilize AR, and AR resources were relevant.*
>
> *Four days of training were provided, covering AR topics and other pertinent materials.*

The study has also unfolded the support provided by PIO to the two schools. The organization invested in the schools and aligned their innovation with its framework. The content used in the AR intervention was derived from curricula, ensuring its relevance and seamless integration into the educational context. Furthermore, the dedication and support demonstrated by the principals of the two schools in implementing new initiatives and conducting the AR intervention are commendable. Their commitment plays a pivotal role in the successful integration of AR and 3D visualization in pre-primary education.

Full Implementation of AR

Participants reported that a practice worksheet resembling their existing teaching methods was available, and they mentioned that AR was made available to all children, who treated it like a game. However, they emphasized that their teaching strategy was distinct from AR, as they focused on the curriculum's content organization. The principal of *Miazia* expressed that they didn't face challenges during practice, and children were learning through observation, touch, and letter connections. The principal of *Yekabado* stated that two days were allocated for AR implementation, with a specific focus on its relevance to children with special needs and the use of English as the language of instruction. The PIO staff and AR designer highlighted several key features of the project, such as the approval of AR design, its digitalized content, and the project's pilot nature. They also mentioned starting the project with some skepticism but acknowledged the potential benefits of technology-supported learning. The qualitative results from the quote below provide insights into the implementation stage of AR in the context of the study.

FGD participants from *Yekabado* preschool stated the following:

> *A practice worksheet is available; it resembles what we are doing and teaching. Two days have been set aside for AR, and we discuss the practice's relevance to children with special needs. It urges using English as a language of instruction.*

FGD participants from *Miazia* preschool detailed the following:

> *We made it available to all children; they treat it like a game; it happens twice a week, and we need time to carry out our own strategy. We teach them in accordance with the curriculum's (content), not AR. Our strategy is distinct from AR's system, and we base our instruction on the curriculum's content organization. We don't face challenges in*

> *the practice; children are learning by observing and touching the items. Children learn by connecting letters.*

FGD participants from PIO and AR designer described on the situation as follows:

> *The following are some of the project's key features: AR was not tested in the preschool program so far, but it was tried in grade two; AR design is approved; this is considered as a pilot work for Plan International Organization; it is a one year and seven month project; AR contents are digitalized; we started it with some skepticism because we do not know the future; and learning with the support of technology.*

Adherence of Augment Reality and 3D Visualization

The research unmasked the AR adherence, including quantity, quality, ecological, and system adherence. In the *Yekabado* FGD teachers, the AR project followed a one-year plan with two scheduled phases, covering 64 sessions per year. However, there were no revisions to incorporate new concepts, and the AR did not address all contents. The ecological adherence was lacking as self-correction, self-feedback, self-reflection, and proactive actions were not organized by the systems. In the *Miazia* FGD with 8 participants, no specific information regarding adherence was mentioned, except for the identification of shortcomings without taking necessary action. The Principal of *Miazia* mentioned completing the planned 64 AR sessions over a year, but there were implementation gaps and no support system in place. The principal of *Yekabado* highlighted the AR and 3D visualization training provided, but the content was deemed unsuitable for children, and assistance was lacking to address constraints. The PIO staff and AR designer mentioned that the AR project was a pilot effort, complementing their innovative style, but progress monitoring was absent, and improvements were made based on teacher feedback.

The initial implementation of AR is detailed in the quote below. An FGD participant teacher from *Yekabado* preschool stated as follows:

> *According to the AR project's plan, the intervention lasted a year and was divided into two scheduled phases. The AR project included 64 sessions per year, or 32 sessions per semester (quantity adherence). No revisions were made to incorporate new concepts, and AR did not cover all content areas (ecological adherence). Systems for organizing self-correction, self-feedback, self-reflection, and proactive actions to enhance ongoing AR practices were not established (system adherence). However, experts in AR provided training, and ECCE experts were involved (quantity adherence of AR).*

Moreover, the participant teachers from *Miazia* preschool stated the following:

> *We began with 40 children (quantity adherence), and they are prepared to assist us. We identified the shortcomings but did not take action (quantity adherence of AR).*

Details of AR implementations and challenges are also described by the participants. *Miazia* preschool principal described it as follows.

> *The AR project's strategy called for two time periods and 64 AR sessions (32 sessions in a semester), which were all completed over the*

> *intervention's one-year duration (quantitative adherence). Concerning implementation gaps, they enquired about availability to help us (ecological adherence). No system was developed to provide support (system adherence), but they are familiar with the AR application, and AR professionals led the training. Experts from ECCE were involved (quality adherence).*

According to *Yekabado* preschool Principal:

> *AR and 3D visualization training were offered, and these technologies have produced platforms that link letters to actual items. It is a suitable education (quantitative adherence); however, the content is not age-appropriate for children (ecological adherence). Despite their request for assistance, there was no way to address these constraints (system adherence), and they lack familiarity with the government curriculum (quality adherence).*

Participants from PIO and AR designer also stipulated the following:

> *It is accepted as an AR design, is a one-year, seven-month project, and is considered a pilot effort for Plan International Organization (quantity adherence). Since we have observed what other nations go through, we apply our framework. It complements our innovative style (ecological adherence). We are documenting the children this year, but we did not do this last year. We are also correcting sounds and certain AR items based on teacher feedback. No progress was monitored*

(system adherence), and contents are prepared from the curriculum (qualitative adherence).

Teacher's perspective on the contributions of AR and 3D visualization's in enhancing children's learning outcomes

Enhance Children's Memory Skills

Table 3

Enhance Children's Memory Skills (n=17)

	Items	Agree to Strongly agree	Undecided	Disagree to Strongly disagree	M	SD
Value to children's memory	Visualize for long period of time	16		1	4.41	.79
	Remembering learning organization	17			4.58	.50
Total					**4.5**	**.59**

The importance of the AR application on children's memories is shown in Table 3 above. The mean score and standard deviation of the items are displayed in the table. The average rating for memory items is M=4.5 (SD=.59), indicating that pre-primary instructors are closer to the higher rating level in terms of the importance of AR in children's memories. The teachers were also asked to rate the influence of AR-based applications on children's memory, as shown in Table 3. Nearly all of the teachers (99%) held a strong belief on the importance of AR for children's memory development. For item 1, only one instructor indicated that they disagree. The findings indicated that utilizing AR-based applications improved children' memory and visualization skills.

Enhance Children's Interest and Motivation

Table 4

Enhance Children's Interest and Motivation (n=17)

Variable	Items	Agree to Strongly agree	Undecided	Disagree to Strongly disagree	M	SD
Value to children's motivation	Happiness	17			4.70	.46
	Increase children interest in learning	17			4.64	.49
	Increase children interest to show things	17			4.41	.50
	Increase children motivation to learning	17			4.58	.50
	Initiate children learning interest	17			4.52	.51
Total					**4.57**	**.49**

According to the study's mean value (M=4.57) for children's motivation, AR-based applications were found to improve children's interest in learning activities. A deeper analysis of the five motivation items shows that AR-based learning activities fostered higher levels of learning interest, initiation, and satisfaction of children.

Instill Children's Active Engagement

Table 5

Instill Children's Active Engagement (n=17)

Variable	Items	Agree to Strongly agree	Undecided	Disagree to Strongly disagree	M	SD
Value to enhance children's active engagement	Improve children learning process	17			4.29	.46
	Increase children classroom participation	17			4.64	.49
	Increase children independent problem-solving skills	15	2		4.23	.66
	Increase children independence learning	17			4.41	.50
	Help children to take responsibility for their learning	15	2		4.23	.66
	Help children to express their learning	17			4.58	.50
Total					**4.39**	**.54**

According to the results compiled in Table 5 all preschool teachers claimed that AR technology increased their students' active participation in the learning activity. The results indicate that AR promotes preschoolers to independently solve problems, take reasonability, express their learning interest and improve the learning process.

Promote Children's Social Interaction

Table 6

Promote Children's Social Interaction (n=17)

Variable	Items	Agree to Strongly agree	Undecided	Disagree to Strongly disagree	M	SD
Value to children's social interaction	Improve Interpersonal skills	17			4.47	.51
	Accelerate children interpersonal skills	17			4.64	.49
	Enhance children relationship and social interaction	17			4.52	.51
	Help children to express themselves	17			4.52	.51
	Increase children self-confidence	17			4.70	.46
Total					**4.57**	**.49**

The information in Table 6 demonstrates how AR-based applications accelerated and enhanced children's social engagement. The pre-primary school teachers hold the opinion that AR-based applications helped kids develop their ability to communicate with others as well as boost their confidence.

Increase Children's Digital Literacy Skill

Table 7

Increase Children's Digital Literacy Skill (n=17)

	Items	Agree to Strongly agree	Undecided	Disagree to Strongly disagree	M	SD
Value to children's digital literacy skill	Enhance children GLS	17			4.52	.51
	Implemented in learning process	17			4.47	.51
	Increase children knowledge of technology	17			4.64	.49
Total					**4.5**	**.50**

As shown in Table 7, teachers advise that AR-based applications improved children's digital literacy abilities. Teachers agreed that AR technology has a lot to offer in terms of improving and expanding kids' technological literacy in all of the items.

Foster Children's Fine Motor Skills

Table 8

Foster Children's Fine Motor Skill Development (n=17)

Variable	Items	Agree to Strongly agree	Undecided	Disagree to Strongly disagree	M	SD
Value to fine motor skill development	Improve eye-hand coordination	17			4.82	.39
	Enhance children motor skill development	16	1		4.70	.58
Total					**4.76**	**.48**

Table 8 shows that every preschool instructor agreed that the deployed AR application did aid in the children's growth of fine motor abilities. Children's motor skill development and eye-hand coordination were both improved by AR-based applications**.**

The Benefits of Augmented Reality and 3D Visualization's

The qualitative results identify several benefits of AR and 3D visualization in children's learning. According to the feedback provided by teachers, principals, and staff from the PIO and AR designer, AR was to be suitable for handling large class sizes and has made learning enjoyable for children. It sparks curiosity and increases engagement, making it easier for children to remember and express what they have learned. AR also promotes teamwork and provides additional assistance, especially for children with special needs. It encourages interaction, discovery, and communication, even for non-speaking children, thus fostering the development of strong characters. Furthermore, AR exposes children to technology they may not have access to otherwise, contributing to their spirit and technological expertise. While AR has its limitations, such as not promoting learning about letter sounds, it provides platforms for collaboration and enables children to touch and see the material they desire to learn. Overall, the qualitative results highlight the positive impact of AR on children's learning experiences, encouraging their active participation and supporting their diverse needs. This is supported by quotes taken from research respondents. Participants from Yekabado preschool noted that:

> *It is appropriate to handle excessive class sizes; children are extremely happy with the application. They use various colors to trace letters. It is learning with enjoyment. AR makes children curious. The application has assisted more children with disabilities. It is effective for small groups since it requires that all children be followed up on. If they learn via AR, it is simple to remember and say; it allows them to engage more; it increases child to child support. It improves children's ability for teamwork.*

FGD participant teachers from Miazia Preschool stated the following:

> *Children are inspired to use AR, which encourages them to interact and provides platforms for initiating a variety of activities. It also helps us meet the demands of globalization, and its multiple goals allow children a greater chance to speak up. Children are happy with AR, and they actively use it. Children get the chance to engage with it. It helps children learn real things with real illustrations. It is*

> *especially beneficial to children with special needs. It encourages discovery. It removes children's fear of speaking. It provides extra assistance, particularly for children with special needs. Children who are unable to talk are supported by AR to participate in learning, communicate, and be joyful. Children who are unable to speak are supported by AR to develop strong characters ("Tat Yetnkiral"). Children are exposed to technology that not all children, especially those in poverty, have access to, which benefits their spirit and gives us technological expertise. Children are encouraged to discover new things, but AR has its limitations and doesn't promote learning about how letters sound.*

The two preschool principals also elaborated on the benefits associated with AR application as follows:

> *We are seeing how AR helps children literally touch and see the material they desire to learn. Create platforms for collaboration. In addition, after being exposed to AR, children begin to communicate. It helps identify children's genuine desires; it creates platforms for interaction; it is beneficial to children. It inspires them to learn. They are eager and motivated to learn through AR (Principal Preschool, Yekabado).*

Participants from PIO and the AR designer also expressed the following:

> *When exposed to this training, non-speaking children begin to speak. This training is an additional resource for children. With learning disabilities are supported exposure of teachers to modern technology more opportunities for children to think, imagine, interact, and be engaged.*

Teachers' perspectives on the challenges of AR in preprimary education

The qualitative findings highlight various challenges encountered in applying AR and 3D technology in education. The participants identified several common obstacles, including pedagogical limitations, a lack of alignment between the curriculum and AR content, difficulties in utilizing AR for large groups, and limited availability of printed resources to support AR practices. Furthermore, the participants emphasized the significance of adhering to the curriculum, which primarily emphasizes English instruction, whereas AR may require additional time and attention from both teachers and students. Concerns were also raised regarding incomplete pilot implementations, the need for device recharging, and the exclusion of social skills, social norms, and local languages such as Amharic and *Afan* Oromo from AR applications. An FGD participant teacher from *Yekabado* preschool stated this concern as follows:

> *There are pedagogical restrictions, Amharic is not included, and there is no connection between what we teach and what AR wants to teach us (we use sounds like A (ኢ., E), C (ኪ, Ki), U (, E (, I (, and M (mi). This makes teaching quite simple. We don't have any printed resources*

> *to assist AR practices. It has to adhere to the curriculum. Children are required to study in English (for arithmetic, reading, and writing). It is frequently challenging to use since it takes more time. It is challenging to use for large groups. While concentrating on AR, certain children find it difficult to pay attention to their teachers.*

Moreover, *a* FGD participant teacher from *Miazia* Preschool stated as follows:

> *The pilot implementation has not been completed, AR does not align with our curriculum, and daily use is not feasible. You must recharge it. The children didn't pay much attention to our lecture. Social skills, social norms, Amharic, and Afan Oromo are not included in the application; it may last 15 minutes, but once AR was added, they participated for a longer period of time. We need our children to get away from technology and do other things.*

The two preschool principals, staff from Plan International, and AR designers identified various challenges related to augmented reality, which are hampering its proper implementation.

Participant principal from *Miazia* preschool:

> *Lack of time to practice AR, the teacher's dedication, poor use of AR, structure's impact on it, lack of alignment with AR, missing other subjects or contents, and AR not addressing our plan are all factors. The application does not include Afan Oromo or Amharic*

Participant principal from *Yekabado* preschool:

> *It is challenging to put into practice; it is not consistent with our curriculum; and the emphasis is on the English language (Amharic is the curriculum of the instruction). The material is implemented at all levels (AR contents were created for KG1 and applied to KG2).*

Participant from PIO and AR designer also described as follows:

> *Some instructional strategies are not addressed by AR (teachers' observations). Updated technology for us due to practice discrepancies, we were unable to stick to the budget plan. The Addis Ababa City Administration required some time to approve our project's launch. Integration into regular job takes some time.*

Discussion

The study aimed to assess teacher's perspectives towards fidelity, contributions, and challenges of AR to children's learning outcomes. According to the study's findings, using augmented reality as a teaching tool is appropriate for preprimary education. AR study awakes us the way our smartphones or technological devices support for pre-primary education. As a result, it calls to redesign to incorporate important contents by consulting veteran in the field of early childhood education.

Teacher's views of the fidelity of Augment Reality and 3D Visualization

The finding reveals a well-structured approach to implementing AR in pre-primary education. This approach encompasses meticulous participant selection, comprehensive training for stakeholders, external support from an organization, and the unwavering commitment of school leaders. The alignment of the intervention with curricula suggests the potential for positive outcomes in utilizing AR and 3D visualization in the context of pre-primary education (for further information, check the table below). The findings suggest that AR implementation varied across different participants, with some aligning it closely with their existing teaching methods while others approached it as a supplementary tool. Overall, while there was adherence to the planned sessions, there were gaps in incorporating new concepts, addressing content appropriateness, and establishing support systems, indicating room for improvement in the quality of AR implementation.

The contributions of AR in enhancing children's learning outcomes

This study aims to determine the attitudes of preprimary school teachers on the use of augmented reality technologies in preprimary school children learning activities. Results revealed that all preprimary school teachers believed that learning by using AR technologies increase children memory, motivation, active engagement, social interaction, digital literacy skills, and also enhance fine motor skill development. This was found to be consistent with other studies in which AR contributed to improving children memory capacity, remembering ability and visualization of contents (e.g., Piatykop et al., 2022; Chen et al., 2016; Garzón & Acevedo, 2019). As it is indicated in the current study, all preprimary school teachers' beliefs that AR based application increased children the speed of memorizing the learning material and helped to retain the child's attention. Similarly, a study conducted by Garzón and Acevedo (2019) indicated that AR application improve children long term memory retention of educational content.

A preprimary school teacher's response about the value of AR in children motivation has shown that AR-based learning activities fostered higher levels of learning interest, initiation, and satisfaction of children in this study. The finding in the current study is supported by prior researchers in the area. For example, according to Düzyol et al. (2022) findings have shown that AR based application drew more attention of the children and created a greater sense of reality. A similar study also indicated that AR increased motivation in preschool education (Masmuzidin & Aziz, 2018; Akçayır et al., 2016; Bursztyn et al., 2017; Chen et al., 2016), attract the attention and focus of children (Hassan et al., 2022; Wu et al., 2013); increases students' motivation and improves their concentration and thus teaches more (Aydoğdu, 2022).

In the current study preprimary school teachers reported that the AR technology increase children active engagement toward the learning activity. There are also empirical studies that support the findings of the current study. A study conducted by Chen et al. (2016) indicated that AR based application encouraged children to make use of meaningful and enriching experiences that facilitated their learning skills and helped them to recognize the learning content and understood the material provided more quickly. Another study also indicated that with the development of technology and its integration into school curriculum, AR is predicted to lead to enhanced engagement and motivation (Mundy et al., 2019). The obtained result in this study is also aligned with that reported by Kamarainen et al. (2013) and Lindgren et al. (2016) who revealed that students who received AR instruction showed positive learning outcomes compared to their conterparts.

The preprimary school teachers believed that AR based application improves children's interpersonal skills, self-expressions skills, and self-confidence. Preprimary school teachers had a belief that AR has the potential to enhance learning outcomes by providing a more engaging and interactive learning experience. They also viewed AR as a way to promote collaboration and social learning, which could help children develop important skills. There is an empirical study that supports the finding of the current study. In a related study, Saez-Lopez et al. (2020) shown that AR based application enables a range of interactions in the classroom among children. Another study also indicated that AR based application promotes communication skills, promoting all kinds of interactions in the classroom between teacher and students, students and students, students and families, families and families and teachers (Cascalesa et al., 2016). The findings indicated that AR techniques help in improving collaboration among group participants in preschool education. Chang et al. (2010) confirmed that collaboration among children in a group is highly increased when they share AR learning experiences compared to non-AR learning methods.

The preschool teachers agreed with the value of AR technology to enhancing and increasing children's knowledge of technology. The findings of the current study was consistent with results from previous studies (e.g., Rasalingam et al., 2014; Sidi et al., 2017) showing the value of AR based application in the development of preprimary school children's digital skills by using augmented reality tools. The results have also indicated that AR-based application improved children's eye-hand coordination and enhances children's motor skill development. Studies also consistently reported that Augmented Reality (AR) can potentially help preschool children to develop fine motor skills. This is because AR can provide a virtual environment where children's can practice and develop their fine motor skills in a safe and controlled setting. AR also can provide a more engaging and interactive learning experience that can motivate children to practice and develop their fine motor skills. Overall, by providing opportunities for practice, real-time feedback and social learning, AR has the potential to help develop a range of fine motor skills in preschool children.

Challenges of the AR to practice in preprimary education

Inadequate time for practicing AR, insufficient teacher commitment, and a lack of alignment with the overall educational plan were factors mentioned by the principals. The participants further highlighted challenges related to instructional strategies, budget constraints, and the integration of AR into regular job responsibilities. Moreover, certain images and associated letters did not accurately reflect the Ethiopian context (e.g., A-Apple, G-gift, W-watermelon, and Y-yacht). Utilizing the letter and its associated picture not only provides a specific example for each letter but also offers opportunities for other developmental domains. For instance, associating the letter "H" with a house picture can introduce children to patterns (mathematics, cognitive development, and arts) and enhance their speaking skills, vocabulary, and fine motor skills. This example can be applied to all letters associated with their respective pictures, as seen in some of the images taken from the AR alphabet book. Overall, these findings illuminate the wide range of challenges encountered when implementing AR and 3D technology in educational settings.

Conclusions

The findings of the study highlight the importance of a well-structured approach to implementing AR in pre-primary education. The inclusion of participant selection, comprehensive training, external support, and commitment from school leaders are key elements for successful AR integration. This implies that careful consideration and planning are necessary to ensure effective implementation of AR in educational settings. One significant observation from the study is the alignment of AR interventions with curricula, indicating the potential for positive outcomes in utilizing AR and 3D visualization in pre-primary education though some concerns are not yet solved with it. This finding suggests that incorporating AR technology into the curriculum can enhance the learning experience and help children grasp concepts more effectively. However, the study also reveals variations in the implementation of AR among participants. While some integrated it closely with their existing teaching methods, others treated it as a supplementary tool. This discrepancy implies a need for standardized guidelines or best practices to ensure consistent and effective integration of AR in pre-primary education.

Recommendations

The following recommendations are forwarded on the bases of the study to improve the fidelity, contributions, and challenges of AR in preprimary education.

- Establish standardized guidelines and best practices for the integration of AR in pre-primary education. Address participant selection, comprehensive training, and alignment with curricula, content appropriateness, and support systems. Align AR interventions with the new integrated preprimary education curricula.

- Highlight the positive impact of AR-based applications on children's memories, visualization skills, motivation, interest in learning, and overall satisfaction. Also, emphasize the enhancement of problem-solving skills, social engagement, communication skills, and digital literacy abilities through AR. Overcome challenges associated with AR implementation, such as pedagogical limitations, lack of curriculum alignment, resource availability, time constraints, and budget limitations. Invest in ongoing research, collaboration, infrastructure, and training to address these challenges.
- Promote inclusivity: Utilize AR technology to create an inclusive learning environment. Provide additional assistance for children with special needs and address the diverse needs of students. Leverage the advantages of AR to handle large class sizes, make learning enjoyable, increase engagement and curiosity, and promote teamwork.
- Conduct further research and evaluation: Assess the long-term impact of AR on children's learning outcomes, including academic performance, critical thinking skills, considering of play based learning, and creativity. Gather data to evaluate the effectiveness of AR implementation and inform future improvements.

References

Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior*, *57*, 334-342.

Aladin, M. Y. F., Ismail, A. W., Salam, M. S. H., Kumoi, R., & Ali, A. F. (2020). AR-TO-KID: A speech-enabled augmented reality to engage preschool children in pronunciation learning. In IOP conference series: Materials science and engineering (Vol. 979, No. 1, p. 012011). IOP Publishing. https://doi. org/10.1088/1757-899X/ 979/1/012011.

Aydoğdu, F., & Kelpšiene, M. (2021). Uses of Augmented Reality in Preschool Education. *International Technology and Education Journal*, *5*(1), 11-20

Aydoğdu, F. (2022). Augmented reality for preschool children: An experience with educational contents. *British Journal of Educational Technology*, *53*(2), 326-348.

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., &Kinshuk, G. (2014). Augmented Reality Trends in Education: A Systematic Review of Research and Applications. *Educational Technology & Society*, *17* (4), 133-149.

Baragash, R. S., Al-Samarraie, H., Moody, L., & Zaqout, F. (2022). Augmented reality and functional skills acquisition among individuals with special needs: A meta-analysis of group design studies. *Journal of Special Education Technology*, *37*(1), 74-81.

Becker, S. A., Brown, M., Dahlstrom, E., Davis, A., DePaul, K., Diaz, V., & Pomerantz, J. (2018). *NMC horizon report: 2018 higher education edition*. Louisville, CO: Educause.

Bursztyn, N., Shelton, B., Walker, A., & Pederson, J. (2017). Increasing undergraduate interest to learn geoscience with GPS-based augmented reality field trips on students' own smartphones. *GSA Today*, *27*(5), 4-11.

Cascalesa-Martínez, A., Martínez-Segura, M. J., Pérez-López, D., &Contero, M. (2016). Using an augmented reality enhanced tabletop system to promote learning of mathematics: A case study with students with special educational needs. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(2), 355-380.

Chang, G., Morreale, P., & Medicherla, P. (2010). Applications of augmented reality systems in education. In *Society for Information Technology & Teacher Education International Conference* (pp. 1380-1385). Association for the Advancement of Computing in Education (AACE).

Chen, C. H., Chou, Y. Y., & Huang, C. Y. (2016). An augmented-reality-based concept map to support mobile learning for science. *The Asia-Pacific Education Researcher*, *25*, 567-578.

Chen, R. W., & Chan, K. K. (2019). Using augmented reality flashcards to learn vocabulary in early childhood education. *Journal of Educational Computing Research*, *57*(7), 1812-1831. https://doi.org/10.1177/0735633119854028

Dobrovská, D., &Vaněček, D. (2021, February). Implementation of Augmented Reality into Student Practical Skills Training. In International Conference on Intelligent Human Systems Integration (pp. 212-217). Springer, Cham.

Düzyol, E., Yildirim, G., & Özyilmaz, G. (2022). Investigation of the effect of augmented reality application on preschool children's knowledge of space. *Journal of Educational Technology and Online Learning*, *5*(1), 190-203.

Fan, M., Antle, A. N., & Warren, J. L. (2020). Augmented reality for early language learning: A systematic review of augmented reality application design, instructional strategies, and evaluation outcomes. *Journal of Educational Computing Research*, *58* (6), 1059-1100.

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains. *Educational Research Review*, *27*, 244-260.

Gecu-Parmaksiz, Z., & Delialioğlu, Ö. (2020). The effect of augmented reality activities on improving preschool children's spatial skills. *Interactive Learning Environments*, *28*(7), 876-889. https://doi.org/10.1080/10494820.2018.1546747

Gecu-Parmaksiz, Z., & Delialioğlu, Ö. (2020). The effect of augmented reality activities on improving preschool children's spatial skills. *Interactive Learning Environments*, *28*(7), 876-889. https://doi.org/10.1080/10494820.2018.1546747

Godoy Jr., C.H. (2020) 'Augmented Reality for Education: A Review', *International Journal of Innovative Science and Research Technology*, *5*(6), pp. 39–45. Available at: https://doi.org/10.38124/ijisrt20jun256.

Hassan, S. A., Rahim, T., & Shin, S. Y. (2022). Child AR: An augmented reality-based interactive game for assisting children in their education. *Universal Access in the Information Society*, *21*(2), 545-556.

Jaiswal, D., Kaushal, V., Kant, R., & Singh, P. K. (2021). Consumer adoption intention for electric vehicles: Insights and evidence from Indian sustainable transportation. *Technological Forecasting and Social Change*, *173*, 121089.

Kamarainen, A. M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M. S., & Dede, C. (2013). EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips. *Computers & Education*, *68*, 545-556.

Kelpšienė, M. (2020). The usage of books containing augmented reality technology in preschool education. *Pedagogika*, *138*(2), 150-174. https://doi.org/10.15823/p.2020.138.9

Kirner, T. G., Reis, F. M. V., &Kirner, C. (2012). Development of an interactive book with augmented reality for teaching and learning geometric shapes. In *7th Iberian Conference on Information Systems and Technologies (CISTI 2012)* (pp. 1-6). IEEE.

Lindgren, S., Wacker, D., Suess, A., Schieltz, K., Pelzel, K., Kopelman, T., & Waldron, D. (2016). Telehealth and autism: Treating challenging behavior at lower cost. *Pediatrics*, *137*(Supplement_2), S167-S175.

Masmuzidin, M. Z., & Aziz, N. A. A. (2018). The current trends of augmented reality in early childhood education. *The International Journal of Multimedia & Its Applications (IJMA), 10*(6), 47.

Madanipour, P., & Cohrssen, C. (2020). Augmented reality as a form of digital technology in early childhood education. *Australasian Journal of Early Childhood*, *45*(1), 5–13. https://doi.org/10.1177/18369 39119 885311.

Masmuzidin, M. Z., & Aziz, N. A. A. (2018). The current trends of augmented reality in early childhood education. *The International Journal of Multimedia & Its Applications (IJMA)*, *10*(6), 47.

Mowafi, Y., & Abumuhfouz, I. (2021). An interactive pedagogy in mobile context for augmenting early childhood numeric literacy and quantifying skills. *Journal of Educational Computing Research*, *58*(8), 1541-1561.

Mundy, M. A., Hernandez, J., & Green, M. (2019). Perceptions of the effects of augmented reality in the classroom. *Journal of Instructional Pedagogies*, *22*.

Ozdamli, F., & Karagozlu, D. (2018). Preschool teachers' opinions on the use of augmented reality application in preschool science education. *Croatian Journal of Education: HrvatskiČasopisZaOdgoj I Obrazovanje*, *20*(1), 43–74. https://doi.org/10.15516/ cje.v20i1.2626

Pan, Z., López, M., Li, C., & Liu, M. (2021). Introducing augmented reality in early childhood literacy learning. *Research in Learning Technology*, *29*.

Piatykop, O., Pronina, O., Tymofieieva, I., & Palii, I. (2022). Early literacy with augmented reality. *Educational Dimension*, *58*, 131-148.

Preka, G., & Rangoussi, M. (2019). Augmented Reality and QR Codes for Teaching Music to Preschoolers and Kindergarteners: Educational Intervention and Evaluation. In *CSEDU (1)* (pp. 113-123).

Radosavljevic, S., Radosavljevic, V., & Grgurovic, B. (2020). The potential of implementing augmented reality into vocational higher education through mobile learning. *Interactive Learning Environments*, *28* (4), 404-418.

Radu, I., & MacIntyre, B. (2012). Using children's developmental psychology to guide augmented-reality design and usability. In *2012 IEEE international symposium on mixed and augmented reality (ISMAR)* (pp. 227-236). IEEE.

Rapti, S.; Sapounidis, T.; Tselegkaridis, S. (2023). Enriching a Traditional Learning Activity in Preschool through Augmented Reality: Children’s and Teachers’ Views. Information 2023, 14, 530. https://doi.org/10.3390/ info14100530

Rasalingam, R. R., Muniandy, B., & Rass, R. (2014). Exploring the application of Augmented Reality technology in early childhood classroom in Malaysia. *Journal of Research & Method in Education (IOSR-JRME), 4* (5), 33-40.

Redondo, B., Cózar-Gutiérrez, R., González-Calero, J. A., & Sánchez Ruiz, R. (2020). Integration of augmented reality in the teaching of English as a foreign language in early childhood education. *Early Childhood Education Journal*, *48*(2), 147-155.

Roopa, D., Prabha, R., & Senthil, G. A. (2021). Revolutionizing education system with interactive augmented reality for quality education. *Materials Today: Proceedings*, *46*, 3860-3863.

Sáez-López, J. M., Cózar-Gutiérrez, R., González-Calero, J. A., & Gómez Carrasco, C. J. (2020). Augmented reality in higher education: An evaluation program in initial teacher training. *Education Sciences*, *10*(2), 26.

Santos, M. E. C., Lübke, A. I. W., Taketomi, T., Yamamoto, G., Rodrigo, M. M. T., Sandor, C., & Kato, H. (2016). Augmented reality as multimedia: The case for situated vocabulary learning. *Research and Practice inTechnology Enhanced Learning*, *11*(1), 1–23. https://doi.org/10.1186/s4103 9-016-0028-2

Sidi, J., Yee, L. F., & Chai, W. Y. (2017). Interactive English phonics learning for kindergarten consonant-vowel-consonant (CVC) word using augmented reality. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, *9* (3-11), 85-91.

Sobral, S. R., & Menezes, N. D. C. A. P. (2012). Motivação de alunos com e semutilização das TIC emsala de aula. In *Conferênciaanual da Associação Portuguesa de Sistemas de Informação: actas do CAPSI'12*, *Guimarães*. http://hdl.handle.net/11328/ 2299

Sommerauer, P., & Müller, O. (2018). Augmented Reality for Teaching and Learning-a literature Review on Theoretical and Empirical Foundations. In *ECIS* (p. 31).

Tuli, N., & Mantri, A. (2020). Usability principles for augmented reality-based kindergarten applications. *Procedia Computer Science*, *172*, 679-687.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, *62*, 41-49.

Zhu, M., Sun, Z., Zhang, Z., Shi, Q., He, T., Liu, H., & Lee, C. (2020). Haptic-feedback smart glove as a creative human-machine interface (HMI) for virtual/augmented reality applications. *Science Advances*, *6* (19), eaaz8693.