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A quasi-experimental study on the effectiveness of augmented reality technology on english vocabulary learning among early childhood pupils with learning disabilities

Un estudio cuasi-experimental sobre la efectividad de la tecnología de realidad aumentada en el aprendizaje del vocabulario inglés entre alumnos de educación infantil con discapacidades de aprendizaje

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ABSTRACT

This study addresses a gap in research by aiming to investigate the efficacy of augmented reality technology on vocabulary development for early EFL childhood pupils diagnosed with learning disabilities—a demographic known for significant learning challenges. A quasi-experimental design involving 30 pupils split into experimental and control groups was employed. The experimental group was taught using AR technology, while the control group received conventional instruction. Over a three-month period, both groups were assessed using a pre and post-test designed to measure vocabulary skills: recognition, recall, guessing, and production. Results revealed that the experimental group, exposed to augmented reality, outperformed the control group in all four vocabulary learning skills. This enhancement can be attributed to augmented reality's ability to engage the pupils' visual, aural, and kinesthetic senses, making learning more immersive and interactive.

KEYWORDS Augmented reality technology; EFL; early childhood; learning disabilities; vocabulary learning.

RESUMEN

Este estudio aborda una laguna en la investigación al proponerse investigar la eficacia de la tecnología de realidad aumentada en el desarrollo del vocabulario para alumnos de educación infantil EFL diagnosticados con discapacidades de aprendizaje, un grupo demográfico conocido por enfrentar significativos desafíos en el aprendizaje. Se empleó un diseño cuasi-experimental con 30 alumnos divididos en grupos experimentales y de control. Al grupo experimental se le enseñó utilizando tecnología de RA, mientras que el grupo de control recibió instrucción convencional. Durante un período de tres meses, ambos grupos fueron evaluados mediante una preprueba y una prueba posterior diseñadas para medir habilidades de vocabulario: reconocimiento, evocación, conjetura y producción. Los resultados revelaron que el grupo experimental, expuesto a la realidad aumentada, superó al grupo de control en las cuatro habilidades de aprendizaje del vocabulario. Este mejoramiento puede atribuirse a la capacidad de la realidad aumentada para involucrar los sentidos visuales, auditivos y kinestésicos de los alumnos, haciendo que el aprendizaje sea más inmersivo e interactivo.

PALABRAS CLAVE Tecnología de realidad aumentada; ILE (Inglés como Lengua Extranjera); educación infantil; discapacidades de aprendizaje; aprendizaje de vocabulario.

1. INTRODUCTION

Improving one's vocabulary in a foreign language is essential for language growth and learning. Teachers cannot frequently build effective vocabulary training programs because they strive to make classes entertaining and successful (Al-khresheh et al., 2022). According to researchers and educators working with first and second languages, a rich vocabulary is essential for linguistic maturity. Although acquiring a second language's vocabulary is comparable to learning the vocabulary of a first language, the two expand at varying times. Connecting with others through a common language has become increasingly important. A sizeable vocabulary is an essential component of one's level of language ability and is required for effective communication. A connection is made between the four different language skills through vocabulary (Sadikin & Martyani, 2020). Vocabulary is crucial for the development of the student's literacy skills. The direct teaching of a term, however, has been shown to aid vocabulary learning in children with developmental language impairment, Down syndrome, autism, and reading difficulties, according to several studies (Al-khresheh, 2020; Al-khresheh & Al-Qadri, 2021; Colenbrander et al., 2019; Kouvava, et al., 2022;). Notably, early childhood pupils with learning disabilities have difficulty building their vocabularies and remembering the terminology they have just been taught (Booton et al., 2021; Willoughby et al., 2017).

Early intervention is regarded as essential for young children's intellectual and emotional development, which influences the students' cognitive performance and academic achievement later on. Pupils with learning disabilities with recurrent failures in early childhood education probably suffer in later educational stages, particularly in intellectual capabilities. This is because of the nature of their learning problems. Therefore, researchers need to work on finding, testing and spreading ideas and strategies that support the cognitive and academic learning needs of students with learning disabilities (Al-Qadri et al., 2021; Balikci & Melekoglu, 2020; Kennedy et al., 2015).

Many researchers look at numerous elements that may help in learning English, considering vocabulary is essential to learning the language (Adlof et al., 2021; Ali, 2020; Mohamed, 2021). Furthermore, many scholars and English teachers are attempting to develop various multimedia techniques to enhance students' vocabulary development (Busra et al., 2021; Oh, 2020; Wang & Lee, 2021). Early childhood special education instructors now have various tools for teaching language to young pupils with learning disabilities. One of today's contemporary technologies that can fulfil this function is augmented reality (AR) technology. It can merge real images with virtual ones (Alkhattabi, 2017; Buchner & Kerres, 2023; Eldokhny & Drwish, 2021).

Incorporating AR technology in educating children with learning disabilities is essential. These pupils thrive in engaging and interactive learning environments, and AR apps have the potential to revolutionize their educational experience. By offering tailored support and interactive experiences, AR technology can significantly aid these young learners in language development, making the learning process enjoyable and effective. Chen and Chan (2019) and Sun et al. (2019) noted that well-designed AR applications can assist children with special needs, enhancing their language learning journey. The potential impact of this technology on their educational outcomes makes this an area of critical importance and great potential in special education. Therefore, this study aims to investigate AR technology's efficacy on vocabulary development in early EFL children with learning disabilities. This study makes a significant contribution to the existing body of research by documenting important information on the use of AR applications in assisting early childhood children who have learning disabilities to improve their vocabulary learning by answering the following question:

- What impact does AR technology have on the vocabulary learning process in early childhood pupils with learning disabilities?

In response to the posed research question, the study advances the following hypothesis: Vocabulary development in early childhood pupils with learning disabilities is significantly influenced when instruction is administered through AR technology, as opposed to conventional teaching methodologies.

2. LITERATURE REVIEW

2.1. Understanding Learning Disabilities: Language Barriers and Beyond

Learning disabilities, in their different manifestations, present various problems that pervade various aspects of educational endeavours (O'Connor et al., 2019). These disorders can be neurological, causing issues with information processing, reading, writing, reasoning, or even mathematical abilities (Peterson et al., 2021). Language competency becomes complex for learners navigating this terrain (Brown, 2015). According to Bao (2023), vocabulary emerges as a fundamental and often difficult pillar in this elaborate tapestry of language learning.

For pupils with learning disabilities, navigating the linguistic journey is far more complex than their typical peers, mainly due to cognitive processing differences (Woodeson et al., 2023). Dyslexic pupils, for instance, face challenges with phonological processing, making it difficult to recognize words. Furthermore, difficulties with working memory, as Bao (2023) highlighted, can hinder their ability to retain and recall new vocabulary. These cognitive challenges extend to understanding and interpreting idiomatic expressions, metaphors, and other complex linguistic nuances, significantly altering their language learning environment and experience. This situation underscores the need for specialized teaching approaches and tools that cater to their unique learning profiles.

On the other hand, vocabulary is more than just a collection of words; it provides the foundation for knowing, expressing, and connecting. An extensive vocabulary is equivalent to a complete communication toolset (Kai & Tan, 2021). However, deficiencies in this toolkit can cause many problems for people with learning difficulties. Given the frequent requirement to interpret unexpected words, their reading may lack fluidity. Without the correct language, expressing complex thoughts becomes difficult (VanUitert et al., 2020). Classroom conversations can be filled with misunderstandings, and even social encounters with peers can be loaded with communication stumbling blocks. In summary, the underlying problem is not simply obtaining words, but also effectively utilising them for meaningful communication.

2.2. The Importance of Vocabulary in Language Learning

Expanding one's vocabulary is integral to learning a foreign language and plays a crucial role in language instruction. However, teaching vocabulary can be challenging for teachers who may struggle to determine the most optimal strategies for vocabulary instruction (Al-Khresheh & Al-Ruwaili, 2020). Thornbury (2002) argues that while grammar is essential, vocabulary is the cornerstone of effective communication. A substantial vocabulary is necessary for language learners to express themselves proficiently (Cameron, 2001). Vocabulary can be defined as a collection of words specific to a language or a set of terms that a language speaker can use (Al-Ruwaili & Al-Khresheh, 2023). Linse (2005) defines vocabulary as an individual's word repertoire, while Hornby (2006) describes it as the words one employs or understands to convey a particular subject in a specific language. Bintz (2011) cites Neuman and Drawyer, emphasizing that vocabulary comprises the words required for effective communication. Therefore, a child's vocabulary consists of the words they understand in a given language, serving as a powerful tool for language development (Besthia, 2018; Elbro, 2010).

2.3. Key Skills in Vocabulary Learning

There are critical skills in vocabulary learning. Examining the critical skills involved in vocabulary learning is indispensable to fostering language proficiency and mastery. Word recognition is the foundational skill in vocabulary development, assuming that learners can identify and utilize sight words. Reading becomes possible as learners decode words into their constituent sounds. Exposure to various sources such as books, television, radio, newspapers, and magazines is vital in expanding vocabulary (Peterson et al., 2021). Therefore, learning new words extends away from reading books and encompasses reading newspapers, listening to the radio, and watching television.

Recall is another crucial skill in vocabulary development, requiring learners to thoroughly learn and store words in their long-term memory. Proficient recall necessitates a clear mental or auditory representation of the vocabulary term. Verbal-visual association tasks that involve sequential and phonological components can pose challenges for learners with learning impairments (Krishnan et al., 2017). Integrating innovative technologies into early childhood special education can enhance word recall and provide a more engaging learning experience (Ashoori, 2012).

Guessing the meaning of words from context is another critical skill in vocabulary acquisition. Contextual guessing involves making educated inferences about word meanings while reading or listening to enhance comprehension. Learners often rely on contextual clues, sentence structure, discourse, and situational context to deduce word meanings (Zhou, 2014). Early childhood special education teachers utilize contextual guessing, memorization, and repetition techniques to teach new English phrases and support vocabulary learning.

Word production is also another important skill that involves actively using vocabulary. Speaking a word aloud during the learning process enhances recall and strengthens associations with related concepts. Individuals with a rich vocabulary demonstrate improved reading comprehension, oral communication, and writing skills. Utilizing newly learned words facilitates better retention and comprehension (Al-khresheh & Al-Ruwaili, 2020).

2.4. Augmented Reality Applications in Education

The significance of vocabulary development in early childhood education, particularly for students with learning disabilities, is paramount. These students often face challenges in assimilating new English vocabulary. It is critical to nurture their vocabulary growth during this key developmental stage, as studies indicate children can acquire around nine to ten new words weekly (Brown, 2015; Peterson et al., 2021). Integrating advanced educational tools like Augmented Reality (AR) in teaching strategies can markedly enhance language acquisition and the broader learning experience for these students. This highlights the necessity of adopting specialized educational methodologies tailored to meet the distinctive learning requirements of students with learning disabilities.

In classroom settings, vocabulary instruction holds significant importance for children who enter school with limited word knowledge. Children with linguistic impairments are more prone to experiencing reading difficulties (Brown, 2015). However, traditional approaches to teaching word meanings may not be feasible for effectively instructing large numbers of students due to the time required for vocabulary acquisition and the number of words involved (Peterson et al., 2021).

Teaching English vocabulary poses a considerable challenge for educators, which is further intensified when teaching children with learning disabilities. To address this issue, the current study utilized augmented reality AR applications to explore their impact on teaching English vocabulary to a group of early childhood pupils with learning disabilities.

Information technology plays a pivotal role in catering to the needs of students with learning disabilities (Digón Regueiro et al., 2024). AR applications emerged as a technology encompassing various definitions. According to Mohamed (2022), AR apps can be described as “educational tools and digital displays that blend virtual graphics with physical reality, deliberately designed with educational goals in mind to be employed within an educational setting to offer learners happiness, pleasure, and facilitate the learning process” (p. 19). Unlike virtual reality, AR does not disrupt the user’s connection to the real world and enables the integration of virtual elements or perspectives into the actual environment (Khan et al., 2017; López-Belmonte et al., 2022). AR applications present novel approaches for engaging with the physical world and augmenting mixed-reality learning environments that combine virtual and real-world components. They facilitate the manipulation of virtual objects and enable the visualization of challenging-to-observe locations in the real world. AR offers an immersive educational journey, promoting critical thinking, deepening the understanding of challenging or intangible concepts, and rectifying misconceptions (Fernández Batanero et al., 2022).

AR technology seamlessly blends the virtual and physical worlds, augmenting the actual world rather than replacing it. Azuma (1997) identifies three pivotal characteristics of AR: the integration of actual and computer-generated elements, instantaneous communication, and the registration of real and virtual items with one another. AR aligns with three fundamental requirements, as outlined by Azuma: the fusion of actual and virtual worlds, genuine engagement, and precise recognition of three-dimensional objects (real and virtual).

Research suggests that AR applications hold great promise for the future of education (Khan et al., 2019; López-Belmonte et al., 2020; López-Bouzas & del Moral Pérez, 2022). Consequently, educational institutions should leverage this technology to benefit students, teachers, and institutions. Recent advancements in digital technologies, coupled with the capabilities of mobile devices, have made mobile AR applications readily accessible. The field of AR applications has expanded, and the utilization of AR apps has become simple and adaptable (Lv et al., 2021).

Utilizing AR technologies in early childhood education, particularly for pupils with learning disabilities, offers a distinct advantage by providing a technology-enriched learning environment. These tools can help reduce cognitive overload by integrating information from multiple sources, making learning more manageable and accessible. Furthermore, AR apps' immersive and interactive qualities actively engage students, boosting their enthusiasm and participation. This approach aligns with Khan et al. (2019) and Lv et al. (2021), who note AR's potential to create engaging, activity-driven, and realistic educational experiences, significantly enhancing student engagement and learning effectiveness.

Students can derive meaning from their interactions with AR applications through interactive exchanges and the analysis of mistakes. Moreover, learners can build upon existing knowledge and transfer newly acquired skills to unrelated settings. Teachers can monitor individual students and the social dynamics of the group, identifying areas of difficulty or success. The instructional process should be engaging, straightforward, enjoyable, and compatible with routine activities and the learning environment (Pivec & Dziabenko, 2004).

AR offers several advantages when incorporated into the classroom. Teachers can select from various ready-to-use AR options, simplifying technology integration into the learning environment. AR technology is widely used in textbooks, making it convenient for students who only need to bring their mobile devices to class (Lv et al., 2021).

For pupils with learning disabilities, engaging in task-based activities within the learning environment is essential. These activities can include various AR applications designed to make learning more enjoyable, fascinating, and fun while assisting students in word formation and usage across different contexts (Richardson, 2016). Studies have indicated that using AR applications improves students' academic performance, motivation, and vocabulary learning in EFL settings (Erbas & Demirer, 2019; Silva et al., 2013; Solak & Cakir, 2015).

Liu and Tsai (2013) examined how AR components enable young learners to access content actively and effectively, acquire language and subject matter knowledge, and develop writing skills. Silva et al. (2013) demonstrated that AR blocks could enhance young children's reading skills, employing quantitative and qualitative criteria to evaluate the tool's efficacy. The findings indicated that AR technology improves young children's academic achievement and reading skills, while instructors also expressed enthusiasm for its implementation. Santos et al. (2016) found that adopting AR applications can enhance system usability and language retention. Furthermore, Chen and Chan (2019) demonstrated how AR could facilitate young children's vocabulary expansion and language acquisition. By making learning English vocabulary more enjoyable, AR can aid students in understanding and remembering the language (Rozi et al., 2021). Similarly, Fernández Batanero et al. (2022) summarized the current state of AR research in special education and showcased how AR can enhance learning outcomes for children with exceptional needs. Other studies have highlighted the benefits of AR-assisted games, including active learning, improved cultural understanding, and heightened language awareness (Hasbi & Yunus, 2021; Lai & Chang, 2021; Mielgo-Conde et al., 2022).

AR can be implemented through various devices and in diverse ways, catering to various students and learning styles. The gamified learning environment fostered by AR promotes student engagement, as learners tend to grasp concepts more effectively when interested. Games facilitate the integration of prior knowledge, organize learning experiences, and provide immediate feedback. Furthermore, contextual learning within games allows students to apply their knowledge to real-life situations. Students can acquire knowledge through games, personal experiences, problem-solving, and trial and error (Acquah & Katz, 2020; Ibrahim et al., 2018; Liu et al., 2016; Madanipour & Cohrssen, 2020).

Despite the growing body of research on the benefits of AR applications in educational settings, there remains a research gap regarding their specific impact on teaching English vocabulary to early childhood pupils with learning disabilities. While studies have demonstrated the efficacy of AR in enhancing academic achievement, motivation, and vocabulary learning, there is limited research that specifically focuses on its application in the context of learners with special needs. Therefore, this study aims to address this research gap by investigating the effects of AR apps on vocabulary development in a group of early childhood pupils with learning disabilities, thereby contributing to the existing literature on the effective integration of AR technology in inclusive educational practices.

3. MATERIAL AND METHOD

This study aimed to determine AR applications' effectiveness in improving the vocabulary of early childhood pupils with learning disabilities. In light of this, the study proposed the following hypothesis: The AR technology strategy affects vocabulary learning for pupils with disabilities.

3.1. Research Design

The quasi-experimental technique was used in this study to demonstrate a cause-and-effect relationship between a dependent and independent variable. A quasi-experimental design is a research approach where participants are not randomly assigned to conditions. It is used when controlled, random assignment is impractical, allowing for causal inferences with some limitations due to non-randomization (Gay & Airasian, 2005). A quasi-experiment does not employ random assignment in contrast to an actual experiment. Instead, individuals are divided into specific groups based on non-random criteria. Without randomization, this experimental study design can simulate an experiment and provide a high level of evidence.

It allows the researchers to control the variables (Babbie, 2005). This method was chosen because it helps observe the independent variable effect (AR technology) on the dependent variable (Vocabulary Learning) while adjusting other related variables. Pre- and post-testing were mainly carried out on 30 students chosen purposely and divided into experimental and control groups. The experimental group was subjected to teaching using the AR technology strategy (See Appendix 1). The control group received the conventional approach, a traditional way of teaching vocabulary using flashcards, photographs, wall charts, relia, and translation techniques. As previously stated, an AR app integrates numerical visual material (audio and other categories) into the user's real-world surroundings. The research utilized an augmented reality application developed expressly for the examined curriculum. When a learner places his smartphone's camera on a book page, the text is animated into a video, interactive exercise, and game-based activity that allows him to practice in-text vocabulary. These elements may facilitate vocabulary development for early childhood with learning disabilities. Such programs are believed to generate a joyous and pleasant ambience in the pupils' hearts. After the experiment, the two groups were statistically compared.

The quasi-experimental design depends on two variables. The independent variable is the element or causes used to determine its impact on the result. The study's independent variable is the use of AR technology. The outcome is the dependent variable, which is used to evaluate the impact of the independent variable. The dependent variable in this study is vocabulary learning skills.

3.2. Participants

A purposive sampling strategy was utilized to choose a sample of 30 pupils diagnosed with learning disabilities by the school's special needs section, where all necessary data is available. Pupils with learning disabilities were purposively chosen from two separate schools. It is known that the purposive sampling method enables researchers to examine the ramifications of their results for the entire population (Gay & Airasian, 2005). Identifying pupils with learning disabilities was facilitated through dedicated resource rooms in each participating school. These rooms hold detailed educational profiles for students with special needs. A thorough examination of these records and consultations with educational experts in these environments enabled a precise selection of pupils who stood to gain significantly from integrating AR technology into their vocabulary learning. This method ensured a focused and effective application of AR resources, targeting those most likely to benefit. The participants have the same socioeconomic background. Their native language is Arabic. English is a required course for all pupils. They have been learning it for over five years. They have been taught vocabulary as part of the English curriculum. They were all nine years old on average. In this study, individual phone calls to parents were a procedural step for obtaining consent and an opportunity to engage them in the study's objectives. This engagement likely influenced the results, as parental understanding and support could have impacted pupils' responses and participation. Parental agreement may have provided a more conducive environment for the pupils, potentially affecting their enthusiasm and engagement with the AR technology. Recognizing the influence of parental attitudes and support in educational research is crucial, as it can shape the children's experiences and responses within the study context.

3.3. Instrument

A test was developed and used to achieve the main study's objective. The test was constructed based on the literature to cover primary vocabulary skills, recognition, recall, guessing, and production. Each skill was assigned a set of questions. The terminology for the test came from the students' textbooks. Four questions were developed to assess pupils' vocabulary achievement considering their learning disabilities. The first question assesses their recognition skill. Therefore, the question required pupils to look at the photographs and unscramble the words, which included six items. The second question had four items that required students to look, listen, and number. Looking at the picture provided and listening to their pronunciation help them remember and recall their meanings. The third question had five items, and pupils had to match the text to the proper photographs in each item. Photographs were viewed as hints to aid in deciphering the meaning and matching it with the appropriate word. The last question consisted of six items. Pupils were instructed to look at the photographs and fill in the blank letters in each item. Filling in the blanks reflects production skills. The total exam score was (40) (See Appendix 2 & 3). The test was the most effective way to evaluate the participants' vocabulary knowledge. Ary et al. (2018) defined a test as a set of stimuli shown to an individual to elicit responses from which a score may be assigned. The same pupils were tested before and after adopting the AR teaching technique (pre and post-test). The pupils were given explicit instructions (See Appendix 2 & 3).

As stated earlier, the experimental group was instructed via the AR application. Vuforia software was used to construct this application, which can be viewed on smartphones and iPad tablets. Vuforia was chosen for its sophisticated AR features, such as strong tracking and real-time rendering, which made it well-suited to the study's aims. Its broad compatibility and user-friendly interface also played a role in the selection, allowing for the fast creation and execution of the AR applications utilized in the study. Utilizing the program's three-dimensional visuals, audio, and animated movements, pupils may learn new vocabulary words. The AR application stimulates the pupils' senses and gives them new linguistic experiences and information. Before letting students utilize the AR program on their smart devices to learn new vocabulary, teachers reviewed how the AR application functioned with the class.

3.4. The Test's Validity

The pre/post-test was given to a jury of curriculum and teaching experts to examine the appropriateness of its items in order to verify its content validity. The jury, comprising curriculum and special education specialists, was carefully selected based on their profound knowledge of language teaching and AR technologies. Their comprehensive evaluation of the test's content, focusing on its applicability and relevance for students with learning disabilities, ensured its content validity. This rigorous validation by seasoned professionals affirmed the test as a dependable tool for assessing vocabulary development. For each question, a set of 35 objects was presented. The jury was tasked with selecting the most relevant ones. As a result, 20 items were chosen from the four primary assessed vocabulary skills. Table 1 shows the percentage of the jury's agreement and disagreement on the adequacy of the test content.

TABLE 1. The Percentage of Agreeing and Disagreeing on the Test Suitability

Question no.	Agreeing on suitability	Disagreeing on suitability
1	90%	10.0%
2	100%	0.0%
3	80%	20.0%
4	100%	0.0%

The coefficient validity was also tested for more accuracy. Calculating the correlation coefficients between the test questions and the overall score, then calculating the correlation coefficients between each sub-skill and the total score for this skill, determines the test's coefficient validity. The reciprocal correlation coefficients are computed between each sub-skill of the test and its overall score in the third phase. Consequently, Table 2 displays the results of the first phase, and Table 3 displays the results of the second step. The findings of the third phase in calculating internal consistency are shown in Table 4.

TABLE 2. Correlation Coefficients between each Test Question and the Total Test Score

Questions	The correlation between the test scores	Questions	The correlation between the test scores
1	0.84**	11	**0.81****
2	0.80**	12	**0.39***
3	0.47**	13	**0.87****
4	0.52**	14	**0.81****
5	0.58**	15	**0.39***
6	0.37*	16	**0.76****
7	0.87**	17	**0.81****
8	0.45**	18	**0.46****
9	0.41**	19	**0.44****
10	0.80**	20	**0.82****

Note:**. The difference is significant at the 0.01 level.
Note:*. The difference is significant at the 0.05 level.

The preceding table demonstrates the significance of the correlation coefficients between the test questions and the test's total score. These coefficients were mainly significant at levels (0.01) and (0.05). This means that the test has passed the first step of internal consistency validity. Table 3 displays the values of the correlation coefficients between the test questions and the overall score for the primary skills to which they belong.

TABLE 3. Correlation Coefficients between each of the Test Questions and the Total Score for the Main Skills

Recognition		Recall		Guessing		Production	
Item No	Correlation Coefficients	Item No	Correlation Coefficients	Item No	Correlation Coefficients	Item No	Correlation Coefficients
1	0.85**	1	0.88**	1	0.87**	1	0.76**
2	0.83**	2	0.49**	2	0.86**	2	0.61**
3	0.56**	3	0.45**	3	0.79**	3	0.74**
4	0.56**	4	0.83**	4	0.61**	4	0.84**
5	0.59**			5	0.91**	5	0.64**
6	0.46**						

Table 3 demonstrates that the correlation coefficients were significant at the level (0.01), indicating that the test passed the second stage of internal consistency validity. Table 4 demonstrates that all the correlation coefficients between the four sub-skills of the test and between them and the total test score were significant at the significance level (0.01). This marks the completion of the third level of the vocabulary achievement test's internal consistency. These findings thoroughly support the validity of the vocabulary achievement test in assessing what it was designed to measure, lending confidence to its use in the current study.

TABLE 4. The Matrix of Correlation Coefficients between the Sub-skills of the Vocabulary Achievement Test and Its Total Score

SKILLS	Recognition	Recall	Guessing	Production	Total Score
Recognition	-	0.86**	0.93**	0.91**	**0.97****
Recall		-	0.83**	0.96**	**0.95****
Guessing			-	0.97**	**0.94****
Production				-	**0.96****

3.5. The Test's Reliability

Ahead of the main study, a pilot study was carried out to ensure the test's reliability. Twenty pupils were tested twice at different times. They are a representative sample of the main study's participants. They were excluded from the main study. Cronbach's alpha was used to determine the reliability coefficient value, one of the most significant reliability coefficients (0.842). This implies that the test is reliable and trustworthy, allowing the researcher to apply it confidently to the study's primary sample. The reliability coefficients for each skill are displayed in Table 5. Furthermore, during the piloting, the researchers could determine the time required to complete the exam by adding the time taken by the first student to the time spent by the last one and dividing the total time by two. The average time required to complete the exam was (40) minutes.

TABLE 5. Reliability coefficients for all skills

SKILL	RELIABILITY COEFFICIENTS
Recognition	0.802
Recall	0.713
Guessing	0.762
Production	0.793
Overall Cronbach's alpha	0.842

3.6. Data Collection and Analysis

The study took place throughout the second academic semester of the academic year 2021-2022. The main study was conducted fifteen days following the pilot study. Permission was obtained from the two schools where the pilot and primary studies were carried out.

The test administration to pupils with learning disabilities was methodically tailored with specific adjustments to address their unique needs. The process involved employing straightforward language, allowing additional time, and creating a distractions-free environment. Specialist educators were integral in overseeing the testing, ensuring a comfortable and supportive setting for effective participation by each pupil. These strategic accommodations were vital in aligning the data collection with the specific educational requirements of the pupils, thereby preserving the validity and reliability of the test outcomes.

Two experienced teachers were involved in this study. They have an outstanding track record of teaching performance reviews. They were both familiar with the use of AR. Because the AR application was optional, most teachers did not use it throughout the lesson. During the three-month teaching period, the researchers paid weekly visits to the teachers, monitored their performance, and ensured that this application was used in the experimental group. The supplementary English classes were held three times a week for 45 minutes. These extra classes were exclusively offered to students who had learning disabilities.

In this research, the control group was taught using conventional instructional methods, serving as a benchmark for evaluating the AR technology's impact. This traditional educational approach was maintained without specific alterations for the study, encompassing regular classroom teaching and standard curriculum materials. This methodological decision was pivotal in establishing a clear comparative framework with the experimental group utilizing AR, thereby allowing for an objective evaluation of AR's effectiveness in aiding vocabulary development for pupils with learning disabilities.

The additional sessions are divided into three primary parts: a warm-up, an AR lesson presentation, and an understanding assessment. The teacher always starts the instructional sessions to grab the pupils' attention and introduce the lesson topic and objectives. Pupils are then instructed to open their books to the page where the AR application will be used. Pupils can use their smart devices to acquire new vocabulary and participate in interactive activities by pointing their cameras at the lesson page. Depending on the instructions, pupils may complete the assignment individually, in pairs, or groups. In order to gauge how well the pupils understand the new language, the teacher gives out a worksheet. When feasible, he gives feedback and praises the pupils' accomplishments (See Appendix 4).

After marking the tests, the SPSS 28 program was used to analyze the data. There was a pre-test and a post-test. The following statistical methods were used:

- The Mann-Whitney test for comparison between two independent groups to test the hypothesis related to the study of the statistically significant differences between the mean scores of individuals (the experimental group and the control group), whether before or after applying the experiment.
- Rank Biserial correlation to calculate the effect size.
- Wilcoxon Test" for two related samples and its statistical significance for the differences between the mean scores of the experimental group in the pre and post-test.
- Pearson correlation coefficient to verify the validity of the test.
- Cronbach's Alpha equation in calculating the test reliability coefficient.

Given this, the tabulation method was used in this study for data presentation.

3.7. Ethical Considerations

This study adhered to strict ethical guidelines. We obtained informed consent from both schools involved and the parents of all participating pupils, ensuring full awareness of the study's aims and methodology. The rights of participants, especially regarding confidentiality and voluntary engagement, were upheld. Special attention was given to the sensitivities of working with children with learning disabilities, guaranteeing respectful and considerate interactions. Data management, including test results and observations, was conducted with utmost confidentiality and security, prioritizing participant privacy throughout the research process.

4. RESULTS

The vocabulary achievement test was administered to the two groups before the experiment began to ensure that the two groups (experimental and controlled) were equal. The researchers adjusted the tests and computed the scores to confirm that the two groups were alike in the study variables. As indicated in Table 6, the Mann-Whitney test and its statistical significance for the differences between the experimental and control groups' mean scores in the pre-test were used.

TABLE 6. **Results of the Mann-Whitney Test for Finding Differences between the Control and Experimental Groups on the Pre-Test**

SKILLS	Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z-Score	Asymptotic Sig. (2-tailed
Recognition	Experimental	15	15.53	233.00	112.00	-.022	0.982
	Control	15	15.47	232.00			
Recall	Experimental	15	15.97	239.50	105.50	0.306-	0.759
	Control	15	15.03	225.50			
Guessing	Experimental	15	15.77	236.50	108.50	-0.173	0.863
	Control	15	15.23	228.50			
Production	Experimental	15	15.87	238.00	107.00	-.241	0.810
	Control	15	15.13	227.00			
Total	Experimental	15	15.57	233.50	111.50	-.042	0.967
	Control	15	15.43	231.50			

Table 6 shows no statistically significant differences at the significance level (0.05) between the experimental and control groups' mean scores in the level of all vocabulary learning skills before applying the AR technology strategy. Thus, it could be stated that there is parity between the two groups (controlled and experimental) before applying (using) the AR technology strategy.

To answer the study question, the researchers validated the study's hypothesis, which suggests statistically significant differences at the level of statistical significance (= 0.05) between the mean scores of the control group taught traditionally and the experimental group taught by AR technology. To test the hypothesis, the researchers utilized the Mann-Whitney test and its statistical significance for the differences in mean scores between the experimental and control groups in the post-test, as shown in Table 7 (next page).

TABLE 7. Results of the Mann-Whitney test for Finding Differences between the Control and Experimental Groups on the Post-Test

SKILL	Class/Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	*Z-Score*	Asymptotic Sig. (2-tailed
Recognition	Experimental	15	22.47	337.00	8.00	4.385-	0.000*
	Control	15	8.53	128.00			
Recall	Experimental	15	21.47	322.00	23.00	3.776-	0.000*
	Control	15	9.53	143.00			
Guessing	Experimental	15	19.37	290.50	54.500	2.445-	0.014*
	Control	15	11.63	174.50			
Production	Experimental	15	22.70	340.50	4.500	4.520-	0.000*
	Control	15	8.30	124.50			
Total	Experimental	15	22.93	344.00	1.000	4.687-	0.000*
	Control	15	8.07	121.00			

Note: **The difference is significant at the 0.01 level of significance.

Table 7 demonstrates significant differences (0.05) concerning the experimental and control groups' post-test scores in all vocabulary skills (recognition, recall, guessing, and production) and the overall skill level. These differences favour the experimental group, with significance levels of (0.000, 0.000, 0.014, 0.000, 0.000) respectively. This value is less than the significance threshold (0.05), indicating that it is statistically significant. The average dimensional measurement scores of the experimental group pupils in the (Vocabulary Achievement post-test) were significantly higher than those of the control group students. This suggests that the use of AR technology in education affected the improvement and growth of the skills (recognition, recall, guessing, and production) and the overall level of skills of the participants in the experimental group.

In order to determine the impact of the teaching method according to the AR technology strategy on the development of (recognition, recall, guessing, and production) skills and on the level of skills as a whole, which is the complementary aspect of statistical significance (Rank biserial correlation ( )) was calculated as in Table 8 below.

TABLE 8. The Effect Size of AR Technology

SKILLS	r_{rb}	EFFECT SIZE
Recognition	0.93	**very high**
Recall	0.80	**High**
Guessing	0.52	**Moderate**
Production	0.96	**very high**
Total	0.99	**very high**

Looking at the impact size data in Table 8, it is evident that the effect size ranged from medium to very high. This demonstrates the efficacy of the AR technology technique for increasing vocabulary skills (recognition, recall, guessing, and production). This also demonstrates that the difference between the experimental and control groups is a fundamental difference caused by using the AR technology technique in education. The study's hypothesis can now be accepted in light of this finding.

The efficiency of the AR technology in developing (recognition, recall, guessing, and production) skills among experimental group students was assessed by statistical analyses of pre and post-test data for the experimental group only. Table 9 shows the "Wilcoxon Test" and its statistical significance for differences in the mean scores of the experimental group in the pre-and post-tests.

TABLE 9. Analysis of Experimental Group Pre-Test and Post-Test Scores

SKILL		N	Mean Rank	Sum of Ranks	z	Asymptotic Sig. (2-tailed)
Recognition	Negative Ranks	0	0.00	0.00	-3.426	0.001*
	Positive Ranks	15	8.00	120.00		
	Ties	0				
Recall	Negative Ranks	0	0.00	0.00	-3.421	0.001*
	Positive Ranks	15	8.00	120.00		
	Ties	0				
Guessing	Negative Ranks	0	0.00	0.00	-3.436	0.001*
	Positive Ranks	15	8.00	120.00		
	Ties	0				
Production	Negative Ranks	0	0.00	0.00	-3.425	0.001*
	Positive Ranks	15	8.00	120.00		
	Ties	0				
Total	Negative Ranks	0	0.00	0.00	-3.415	0.001*
	Positive Ranks	15	8.00	120.00		
	Ties	0				

As shown in Table 9, there are statistically significant differences at the level of significance (0.05) between the experimental group's mean scores in the pre and post-test on the four vocabulary skills (recognition, recall, guessing, and production) and on the overall level of skills in favour of the post-test. This also indicates that the differences in achievement were not due to chance but rather to the influence of the teaching technique based on AR technology.

5. DISCUSSION

Participants showed a difference in pre- and post-assessment scores between the traditional and AR technology of teaching vocabulary. Traditionally, participants did not show a noticeable variation between their pre- and post-assessment ratings. In contrast, utilizing the AR method consistently improved average pre- and post-assessment scores. This solid improvement was apparent in the high scores achieved by the experimental group in the four subs skills of vocabulary: recognition, recall, guessing, and production. The experimental group scored higher on the post-test because incorporating new methods into the school curriculum, such as integrating AR technology, enhances students' learning, aids in language development, and boosts students' learning, knowledge, motivation, and achievement. The visual aspects of AR technology play a crucial role in engaging users and maintaining their focus. This aspect of AR aligns with the observations of Santos et al. (2016), who noted that AR's capabilities in information visualization allow users to form meaningful connections between the content and their environment. This interactivity enhances the learning experience by making it more immersive and contextually relevant. The learners' auditory and visual senses may be stimulated only using traditional vocabulary teaching methods. Nevertheless, when students use AR apps to help them study, their visual and aural senses are stimulated by 3D videos and images. Their kinesthetic senses are enhanced by operating their smartphones and tablets and connecting with their peers. This observation is consistent with the findings of Lai & Chang (2021) and Bonetti et al. (2018), who found that learning via AR often occurs near-spontaneously as learners are immersed in new language contexts within their AR environments. This immersive experience, providing first-hand exposure to new language items, facilitates a deeper and more intuitive understanding, underscoring the effectiveness of AR in language acquisition.

The current study created an AR application to support language learning in early childhood with learning disabilities. Images, films, and animation were among the multimedia components of the AR application. Students could stay motivated and interested in what they were learning since their regular sources of distraction were lessened. This was demonstrated by using digital games AR in the classroom to increase student motivation and enhance learning outcomes. Mobile phones, frequently a significant distraction source for students, become an engaging tool when used as a teaching tool to immerse students in their AR world. Students could better concentrate on their lessons by using their phones as a tool and minimizing distractions. Additionally, distractions from the classroom or peer pressure were minimized because students' VR headgear covered everything to save their AR surroundings. Students could recognize, recall, guess, and produce words when fully engaged in their AR surroundings.

Likewise, pupils utilizing AR applications showed enhanced performance for reasons such as the AR content being tailored to their interests and needs and the technology's support in learning at an individual pace. This customizability and adaptability of AR contributed to their learning efficacy. These outcomes are in line with the research of Binhomran and Altalhab (2021), Busra et al. (2021), Kellems et al. (2020; 2021), and Sadikin and Martyani (2020) affirming the positive impact of AR in meeting diverse educational requirements of pupils.

The findings revealed that AR technology significantly enhanced the learning experience, making it more interactive, enjoyable, and meaningful for pupils. The technology's facilitation of active engagement and collaboration was notable, particularly in activities featuring animations. This enhanced group interaction and cooperative learning approach align with Hasbi and Yunus's (2021) assertion on the efficacy of collaborative learning in classrooms. It underscores the role of AR in promoting social interaction, student-centred activities, and learner autonomy, thereby transforming the educational process into a more dynamic and inclusive experience. The researchers were intrigued by the fact that young children could utilize their cell phones, which are often distracting, as an educational tool to immerse themselves in their AR environment. This transformed their distraction into an instrument that piqued their interest in studying. Students were better able to pay attention to what they were studying due to using their phones as tools and reducing distractions. Instead of being taught a term to memorize, students might utilize the meanings to create real-world examples and connections. These findings align with Tyson's (2021) research, suggesting successful technology integration in learning. However, a notable contrast arises with Kathryn et al. (2004), who observed challenges in children with learning disabilities using similar technology. The discrepancy highlights the variability in technology's effectiveness across different learner groups and emphasizes the need for tailored approaches in educational technology implementation, particularly for learners with specific needs.

This study also found that students' learning performance dramatically increased, indicating that AR helped them learn more effectively. This outcome defies the conclusions made by Lai and Chang (2021). They found that adding AR to the learning process did not significantly alter students' learning performance compared to conventional learning methods. They concluded that the experiment needed to be broadened to assess how the use of AR applications affected students' learning performance.

Acknowledging the focused scope of this research, the findings provide a preliminary understanding of the efficacy of AR technology in special education settings. While the results offer valuable insights, they also underscore the need for more expansive studies in various educational environments. Such extended research is critical to fully appreciate the potential and limitations of AR technology in enhancing learning experiences for diverse groups of students, especially those with unique educational needs.

5.1. Implications

The study underlines the pivotal role of AR in supporting early childhood pupils with learning disabilities. AR does not merely enhance vocabulary learning; it potentially paves the way for enriched reading comprehension. The immersive quality of AR captivates learners, cultivating a more profound interest in English. This interactive learning environment enriches the educational experience and fosters a positive attitude and heightened self-assurance among students, as reflected in their improved post-test outcomes. The broader ramifications suggest that AR's potential extends beyond vocabulary to encompass other facets of English language instruction. Ramping up educator training focused on AR's educational applications is imperative to harness this potential fully. Recognizing AR's transformative impact, curriculum developers should proactively integrate it into language instruction modules. While illuminating in its findings, this research also beckons further exploration into how AR can revolutionize the educational landscape for young learners with disabilities.

6. CONCLUSIONS

This study underscores the transformative potential of AR in enhancing vocabulary instruction for early childhood pupils with learning disabilities. A marked improvement was observed in the post-assessment scores of the experimental group, exposed to AR-based learning, compared to the control group. The integration of AR not only minimized distractions but also amplified student engagement, leading to enhanced word recognition, recall, and linguistic production. Given these outcomes, curriculum designers are urged to embed AR applications with vibrant visuals in early childhood textbooks. Concurrently, educators should prioritize vocabulary retrieval strategies to bolster the expressive skills of students with learning disabilities, with the study suggesting tailored AR applications as a potent tool in this endeavour.

6.1. Limitations and future lines of research

The research presents certain limitations due to its methodological approach and participant selection. The sample, derived exclusively from two schools and comprising a limited number of early childhood pupils with learning disabilities, restricts the sample size and, consequently, the generalizability of the findings. While insightful, the study's focus on vocabulary learning does not encompass other critical areas, such as speaking and reading comprehension. Moreover, by concentrating solely on early childhood pupils with a specific type of disability, the study does not represent a broader range of disabilities.

Recommendations for future research include broadening the scope to incorporate larger and more diverse samples and extending study durations to provide a more holistic understanding of AR technology's impact. There is also a pressing need for developing and implementing innovative technologies that facilitate early identification and continuous support for early childhood pupils with diverse learning disabilities, thereby potentially enhancing educational outcomes and experiences.

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