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Augmented Reality and EFL Learners' Vocabulary Acquisition and Digital Literacy Enhancement

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A B S T R A C T

Purpose: This study aimed to investigate the impact of augmented reality (AR) technology on EFL learners' vocabulary acquisition and digital literacy development and to explore learners' perceptions toward the use of AR in language classrooms.
Methods and Materials: The study adopted a mixed-methods quasi-experimental design using a pretest-posttest procedure. The participants consisted of 30 female secondary school EFL learners aged 13–14 who were selected through availability sampling and homogenized using the Cambridge Placement Test. The participants were randomly assigned to an experimental group (n=15) and a control group (n=15). The experimental group received AR-based vocabulary instruction through digital devices and interactive AR storybook applications, whereas the control group was taught using conventional teacher-centered vocabulary instruction. The intervention lasted 16 weeks. Data collection instruments included an 80-item vocabulary achievement test, a digital literacy questionnaire adapted from Ng (2012), and semi-structured interviews. Quantitative data were analyzed using descriptive statistics, Kolmogorov-Smirnov tests, paired-samples t-tests, and inferential statistical procedures, while qualitative interview data were thematically analyzed.
Findings: The inferential findings revealed a statistically significant improvement in the vocabulary achievement of the experimental group after receiving AR-based instruction, whereas the control group did not demonstrate significant progress. The paired-samples t-test showed a meaningful difference between the experimental group's pretest and posttest vocabulary scores ($p=.002<.05$). Furthermore, the results of the digital literacy questionnaire demonstrated a statistically significant increase in the digital literacy levels of the experimental group following the intervention ($p=.004<.05$), while the control group showed no meaningful difference ($p=.19>.05$). The qualitative findings additionally indicated that learners perceived AR-based learning as motivating, enjoyable, collaborative, and supportive of learner autonomy and self-directed learning.
Conclusion: The study supports the integration of AR technologies into EFL education as an effective pedagogical approach capable of addressing both linguistic and technological learning needs in contemporary educational settings.
Keywords: *Technology, Augmented Reality, Digital Literacy, Collaboration, Learning Enjoyment, EFL*

1. Introduction

The rapid expansion of digital technologies has transformed educational systems and redefined the processes through which language learning occurs. In the field of English as a Foreign Language (EFL), traditional teacher-centered approaches are increasingly criticized for their inability to address the communicative, cognitive, and motivational needs of contemporary learners. Conventional instructional methods often rely on rote memorization, decontextualized vocabulary presentation, and passive classroom participation, which may reduce learners' engagement and limit long-term retention of language items. Researchers have repeatedly emphasized that vocabulary acquisition constitutes one of the most fundamental dimensions of language proficiency because lexical knowledge directly influences learners' reading comprehension, oral communication, writing performance, and academic achievement (Korosidou, 2024; Topu et al., 2023; Yilmaz et al., 2022). Without sufficient vocabulary mastery, learners encounter serious challenges in expressing ideas, interpreting meaning, and participating effectively in communicative contexts. Consequently, language educators have increasingly explored innovative instructional technologies capable of enhancing vocabulary development while simultaneously improving learners' motivation, autonomy, and digital competencies. Among these emerging technologies, augmented reality (AR) has attracted considerable scholarly attention because of its capacity to integrate digital information with real-world environments and create immersive, interactive, and contextualized learning experiences (Bacca et al., 2014; Dunleavy & Dede, 2014; Schorr et al., 2024). AR-based learning environments allow learners to visualize abstract concepts, interact with multimedia objects, and experience authentic language exposure through animations, sounds, and virtual representations. Such characteristics are believed to increase cognitive engagement, reduce learning anxiety, and facilitate deeper processing of linguistic input, thereby making AR a potentially effective tool for EFL instruction.

Augmented reality refers to a technological system that overlays virtual elements such as images, sounds, videos, animations, and textual information onto the physical environment in real time. Unlike virtual reality, which immerses users entirely within a simulated environment, AR maintains learners' interaction with the real world while enriching their experiences through digital augmentation (Cuendet et al., 2013; Lindgren & Johnson-Glenberg, 2013). Educational researchers have argued that AR enhances situated learning because it enables students to connect abstract information with meaningful contextual experiences (Wen & Looi, 2019; Yoon et al., 2017). This contextualization is particularly valuable in language education where vocabulary learning often suffers from artificial presentation and insufficient real-life association. AR applications can provide learners with immediate visual and auditory representations of lexical items, helping them establish semantic relationships and improve retention. Furthermore, AR supports embodied learning principles by allowing learners to physically interact with instructional materials and engage multiple sensory channels simultaneously (Lindgren & Johnson-Glenberg, 2013; Skulmowski et al., 2016). Researchers have demonstrated that embodied and multimodal learning environments contribute significantly to cognitive processing, conceptual understanding, and learner satisfaction. Studies have also shown that AR-based educational systems improve motivation and participation because learners perceive the instructional process as enjoyable, innovative, and game-like (Di Serio et al., 2013; Wojciechowski & Cellary, 2013). In language classrooms, increased enjoyment and positive emotional engagement are especially important because affective variables strongly influence language acquisition processes. From the perspective of positive psychology, enjoyable learning experiences enhance learners' willingness to communicate, sustain attention, and maintain long-term engagement with language tasks (Wu & Kabilan, 2025). Therefore, integrating AR into EFL education may provide opportunities not only for linguistic development but also for fostering learners' emotional and psychological readiness for language learning.

A growing body of empirical research has investigated the effectiveness of AR in enhancing various dimensions of language learning. Many studies have specifically focused on vocabulary acquisition because lexical learning benefits greatly from contextual visualization and interactive repetition. Research findings consistently indicate that AR applications facilitate vocabulary retention, comprehension, and recall among learners of different ages and proficiency levels (Belda-Medina & Marrahi-Gomez, 2023; Binhomran & Altalhab, 2021; Khan et al., 2023). For instance, studies involving young EFL learners demonstrated that AR-based activities significantly improved vocabulary learning outcomes and increased learner motivation compared to traditional instructional approaches (Korosidou, 2024; Topu et al., 2023). Similarly, Yilmaz et al. reported that preschool

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learners who used AR technology achieved higher vocabulary retention levels and displayed more positive attitudes toward English learning than those receiving conventional instruction (Yilmaz et al., 2022). Solak and Cakir also found that vocabulary materials designed through AR improved students' lexical achievement and learning interest by presenting words through interactive visual contexts (Solak & Cakir, 2015). Additional evidence from Tsai indicated that AR applications enhanced both vocabulary performance and learner motivation because students experienced greater immersion and contextual understanding during instructional activities (Tsai, 2020). In another study, Belda-Medina and Marrahi-Gomez emphasized that AR environments increase learner engagement by combining physical interaction with multimedia-rich educational content (Belda-Medina & Marrahi-Gomez, 2023). Collectively, these findings suggest that AR has substantial pedagogical potential for improving vocabulary acquisition in EFL contexts.

Beyond vocabulary development, researchers have increasingly explored the broader educational implications of AR, including reading comprehension, oral proficiency, collaborative learning, and learner autonomy. Ebadi and Ashrafabadi found that AR-supported reading activities significantly improved Iranian EFL learners' reading comprehension and attitudes toward learning because the technology provided immersive and multisensory instructional experiences (Ebadi & Ashrafabadi, 2022). Similarly, Asadi and Ebadi demonstrated that integrating AR into reading instruction enhanced learners' comprehension abilities and fostered deeper engagement with textual content (Asadi & Ebadi, 2025). Wang examined the impact of AR applications on oral proficiency and concluded that AR-supported speaking activities improved learners' communicative confidence and fluency through interactive and authentic practice opportunities (Wang, 2024). Research has also shown that AR environments encourage collaborative learning by enabling students to interact with peers while jointly solving tasks and negotiating meaning (Gillies, 2016; Wen, 2020a). Wen argued that classroom-based collaborative AR activities increase socio-cognitive engagement and help learners generate meaningful contexts for language use (Wen, 2020a). Moreover, AR technologies are associated with learner autonomy because students can independently access multimedia content, repeat learning activities, and regulate their own pace of study (Mozaffari & Hamidi, 2023; Perry, 2021). These characteristics align with modern learner-centered pedagogies that emphasize active participation, self-regulation, and experiential learning. Consequently, AR is increasingly viewed not merely as a technological novelty but as a pedagogical framework capable of reshaping language education through interactive, contextualized, and student-driven learning experiences.

Another important dimension related to AR implementation concerns the development of digital literacy. In contemporary educational settings, digital literacy has become an essential competency because learners are expected to navigate digital platforms, evaluate online information, communicate through technological tools, and engage responsibly in virtual environments. Educational scholars define digital literacy as a multidimensional construct involving technical, cognitive, and socio-emotional skills associated with the effective use of digital technologies (Abedi & Tabatabaee-Yazdi, 2023). The integration of AR into language learning may contribute to digital literacy enhancement because learners are required to interact continuously with mobile applications, multimedia interfaces, and online resources. Through repeated exposure to technological environments, students may gradually improve their technical competence, confidence in using digital tools, and awareness of online communication practices. Although many AR studies have focused primarily on language achievement, relatively limited attention has been devoted to examining AR's role in promoting digital literacy among EFL learners. Existing evidence nevertheless suggests that technology-enhanced learning environments can positively influence learners' digital skills and attitudes toward educational technologies (Batista et al., 2020; Wen, 2020b). Abedi and Tabatabaee-Yazdi argued that digital literacy significantly contributes to learners' collaborative learning abilities in online educational contexts (Abedi & Tabatabaee-Yazdi, 2023). Likewise, Topsakal and Topsakal proposed that integrating AR, voicebots, and artificial intelligence technologies into language education may strengthen children's digital competencies while enhancing linguistic performance (Topsakal & Topsakal, 2022). Zhao and Wang also emphasized that AR multimedia systems can support technologically enriched educational platforms that integrate translation, communication, and instructional functions (Zhao & Wang, 2024). Such findings indicate that AR may simultaneously support language acquisition and digital literacy development, making it particularly valuable in technology-oriented educational environments.

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Despite the growing literature on AR in language learning, several research gaps remain unresolved. First, many previous studies have concentrated primarily on vocabulary learning outcomes while neglecting broader learner-related variables such as digital literacy, emotional engagement, and learner perceptions (Ibanez & Delgado-Kloos, 2018; Schorr et al., 2024). Second, a substantial portion of AR research has focused on preschool or university contexts, whereas relatively fewer investigations have explored AR implementation among adolescent secondary school EFL learners (Kaenchan, 2018; Korosidou, 2024). Third, although collaborative and socio-cognitive dimensions of AR have been discussed conceptually, more empirical evidence is required to determine how AR influences learners' autonomy, enjoyment, and confidence within real classroom settings (Khatoony & Altinpulluk, 2021; Wen, 2020a). Furthermore, studies conducted in Middle Eastern and Iranian EFL contexts remain comparatively limited despite the increasing accessibility of digital technologies in these educational systems. Khatoony and Altinpulluk reported that faculty members generally expressed positive attitudes toward AR educational applications, yet they also identified challenges related to technical knowledge and implementation readiness (Khatoony & Altinpulluk, 2021). More recently, Khatoony et al. developed an AR mobile application for vocabulary instruction and demonstrated its effectiveness for improving school-age learners' lexical acquisition (Khatoony et al., 2025). Similarly, Khodabandeh et al. showed that AR integration within blended and flipped instructional models enhanced learners' language performance significantly (Khodabandeh et al., 2025). Nevertheless, further studies are needed to investigate how AR-based instruction affects both vocabulary learning and digital literacy simultaneously, particularly among adolescent EFL learners in authentic educational contexts. Moreover, qualitative exploration of learners' perceptions remains essential because students' attitudes toward technological innovation influence the success and sustainability of educational interventions (Khatoony, 2019; Wen, 2018). Understanding learners' experiences can therefore provide valuable pedagogical insights regarding the strengths, limitations, and practical applicability of AR technologies in language education.

Given the increasing importance of technology-enhanced language learning and the need for innovative instructional approaches that support both linguistic and digital competencies, the present study aimed to investigate the impact of augmented reality technology on EFL learners' vocabulary acquisition and digital literacy development while also exploring learners' perceptions toward the use of AR in language classrooms.

2. Methods and Materials

2.1. Study Design and Participants

The present research being a quasi-experimental study practiced a pretest-posttest pattern to collect the data. Moreover, as mixed-methods study, it implemented qualitative data collection procedures using semi-structured interview and quantitative data collection procedures using vocabulary tests and a questionnaire. The intervention lasted 4 months, 16 weeks, all together 48 hours.

The population of the study consisted of 38 school students, grade two. They were aged 13 to 14 years old, only females. To select the most appropriate subjects, availability sampling procedures was used.

Cambridge Placement Test was run to homogenize the subjects. Based on the result of the test, 30 ones established the subjects and the others whose scores were far from the mean were eliminated. Finally, a homogeneous group established the subjects of the study. As the next step, the selected subjects were randomly classified into groups of experimental (EG, n=15) who were received the treatment (AR-based teaching materials) and control (CG, n= 15) who were taught conventionally using the assigned materials. The EG were exposed to different AR applications using digital devices such as PCs, laptops, or tablets to do different activities. To regard the study morality and to deal with the selected students, it was required to achieve the consent of the school authorities for the following purposes:

1. To do the test of homogenization
2. To classify the learners into homogeneous groups
3. To practice extra materials and technological devices

2.2. Data Collection Tools

To collect the data of the study, three instruments were used: Digital Literacy Questionnaire, tests of vocabulary, and semi-structured interview.

2.2.1. Digital Literacy (DL) Questionnaire

The researcher used DL questionnaire to estimate the participants' DL knowledge before and after they received the treatment. Digitally literacy in this study meant

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possessing the technical and operational skills by the applicants to use ICT to fulfill their everyday needs and activities.

To estimate DL of the learners, the questionnaire designed and validated by Ng (2012) was used. It consisted of 17 items covering four dimensions listed below.

Table 1

Four Dimensions of Digital Literacy Questionnaire

	Dimensions	Items	Reliability index
1	Attitude	1, 2, 3, 4, 6, 13, 14	0.88
2	Technical use of AR	7, 8, 9, 10, 11, 16	0.92
3	Cognitive	12, 17	0.76
4	Social-emotional statements	5, 15	0.73

The questionnaire used a five-point Likert Scale ranging from strongly disagree to strongly agree. The first dimension sought to find participants' attitudes toward DL.

For the subjects to fully understand the questionnaire items, it was translated into fluent Farsi and the translated version of the questionnaire was submitted to the two groups of the EG and CG, once before at the beginning of the study, and next at the end of the experiment. Since the present questionnaire was already used in different studies for estimation of the same objective, i.e., foreign language learners' digital literacy (Abedi & Tabatabaee-Yazdi, 2023; Ng, 2012), it can be claimed that questionnaire was valid and could follow the goal of this study. However, since it was translated into Farsi and as a result the basic notions might have changed, it was back translated into English and then any problems of translation were altered. Moreover, the reliability of the questionnaire was estimated using Cronbach Alfa that came to be 0.89, high enough for this study.

2.2.2. Test of Vocabulary

To estimate the vocabulary knowledge of the subjects, a test of vocabulary was designed and run by the researcher. The test content was based on the material the participants had already been taught and practiced using AR applications. The list of the practiced words was long; however, a variety of vocabulary items were selected and used as test items. To construct the comprehensive test of vocabularies, two types of test items were constructed, using both recognition and limited production test types. The first type consisted of matching single words with pictures. In this case, the subjects were provided with a scrambles list of vocabulary items that they had to be matched with the related pictures. The second test types were filling the given blanks by writing the names of pictures. The questions consisted of both single items and the photos containing some kind of actions. The next section was made up of limited completion sentences so as to test the same ability using actions where the learners were required either to write the name of the actions or complete the blanks by writing the relevant action. All together 80 test items were designed. Since tests of recognition and limited production tests enjoy high objectivity of scoring and dependability, they are considered to be highly reliable (Brown & Abeywickrama, 2010; Brown, 2005; Hamp-Lyons, 2000) and as a result do not suffer from subjectivity of the scoring procedures. On the other hand, the content of the test was limited to the vocabulary items that had already been taught and practiced, so it is possible to claim the test was valid. However, to ensure the validity of the test, two experienced colleagues were asked to review the test content for any irrelevant items.

A pre-test and post-test design was used by the researcher with intervention measurements to evaluate the impact of implementing AR-based educational applications on the participants' acquisition of the given and practiced vocabularies.

2.2.3. Semi-structured Interview

The next goal was estimating the learners' perceptions on the use of AR in their language class. In fact, by asking this question, the researcher meant to unfold the way the learners of EG who were exposed to the extensive use of AR felt about the use of AR applications and at the same time what they thought about it. Here the participants were supposed to express their ideas on the strong and weak points of the teaching techniques and if they had preferred it to the teaching procedures they had experienced before. To conduct the semi-structured interview processes, five participants from among the EG who had experienced AR teaching procedures were randomly selected and were asked to participate in the interview conducted by the researcher.

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Each candidate was asked to answer an open-ended question and freely speak about any aspect of the teaching procedures they wanted, how they felt about them, and what the advantages and disadvantages they had identified during the class activities. It took one complete session to carry out the interview. During the interview, the researcher recorded the voices and this made it possible for the researcher to refer to the learners' perceptions and classify them under definite themes and topics.

2.3. Teaching Procedure

For class practice, the AR technology was actively implemented. The most important advantage for this application is that the targeted words are supported by story animation, text and sounds that make learning a concrete and meaningful activity where the learners enjoy the form, the function, and the natural use of each new word in a suitable context.

Teaching EG primarily began by asking each learner to have their own tablets, iPods, or PCs and bring them to their classes each session or get ready to use them in the class situation and at home when necessary. As a prerequisite, and for choosing the required materials, the researcher chose to upload the storybooks using *Storybooks Alive Application* and upload them onto their tablets, iPads and other devices so as to give the chance of dealing with interesting and relevant stories that may lead to a better vision and engagement experience. These storybook series are available at https://apps.apple.com/us/app/storybooks-alive-ar/id1110894139. The site contains a collection of story books that designed for children. To introduce the sources, the site claims: "Storybooks Alive is our free 3D augmented reality mobile app that makes our printed book, Amos Alligator Arrives at the Airport, come alive." In introducing the app, it moreover adds, "This is the accompanying app that will make your Alive Studios' printed storybooks come alive and become interactive with the magic of augmented reality (3D without glasses). With your *Storybook Alive App* running, select your storybook."

The site contains a great number of storybooks and allow the applicants to have their own choices. To coordinate the class activities, definite and suitable stories that matched both the level and age of the students were chosen and recommended by the teacher. The researcher tried to choose the ones that could call the interest of the learners.

The control group on the other hand, were taught using a traditional approach (teacher- centered) employing two strategies of teaching vocabulary through reading, memorization of new terms and guessing the meaning of the new words. The teacher used definitions, synonyms, and pictures to make meaning clear for the CG. AR storybook series (Storybooks Alive, 2018) were used for the EG to practice vocabulary learning and *American English File, third edition*, was the teaching source assigned for the CG.

2.4. Data Analysis

The quantitative data collected through the vocabulary tests and digital literacy questionnaire were analyzed using descriptive and inferential statistical procedures in SPSS. Descriptive statistics including means and standard deviations were calculated to summarize learners' performances. Kolmogorov-Smirnov and Levene's tests were employed to examine the normality of data distribution and equality of variances. Paired-samples t-tests were conducted to compare the pretest and posttest scores of both the experimental and control groups and determine the effectiveness of augmented reality instruction on vocabulary acquisition and digital literacy development. In addition, the qualitative data obtained from the semi-structured interviews were analyzed through thematic analysis to identify the major perceptions and experiences of learners regarding the use of augmented reality in language learning.

3. Findings and Results

The goal for this section was estimating the extent the scores were normally distributed. In fact, the data can reveal the degree the scores that were achieved enjoyed an acceptable level of normality. To this purpose, Kolmogorov-Smirnov statistical analysis was employed.

Tables 1 to 4 present the data of normality of the pre and posttests of vocabulary for both EG and CG.

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Table 2

Test of Normality for (EG &CG)

Kolmogorov-Smirnov Tests (Normality)				Leven test (Equality of variance)		
	Statistic	df.	Sig.	Statistic	df	Sig.
Pretest CG	.164	14	0.125			
Posttest CG	.124	14	0.205	.95	38	0.85
Pretest EG	.112	14	0.301			
Posttest EG	.202	14	0.211			

Based on the data in table 1, the scores that were provided for the pre and posttests of the CG and EG were normally distributed, sig= 0.85> .05.

The first research question sought to explore the effect that implementing AR could have on the vocabulary acquisition of the EFL learners of the study. The data reflected here were the results of pre- and post-tests of vocabulary. As it was stated before, an 80-item vocabulary tests was run for both EG and CG. To this goal, the pre and posttest means and standard deviations were presented.

Table 3

Descriptive Statistics of Vocabulary Test

Groups	N	Mean	Std. Deviation	Std. Error Mean
Pretest (EG)	15	14.66	0.4252	.7234
Posttest (EG)	15	18.88	1.4952	.6456
Pretest (CG)	15	15.5	0.0512	.5632
Posttest (CG)	15	16.25	2.7841	.6588

As the data in table 2 shows, the mean score for the EG pretest was estimated to be 14.66 that changed to 18.88 for the posttest and after they were exposed to AR teaching procedures. The data for the CG indicate that the mean for their pretest was calculated to be 15.5 that after the teaching period changed to 16.25. Both groups showed that they had improved their vocabulary knowledge after being exposed to the teaching procedures. However, the EG showed more improvement and benefitted from the intervention.

Table 4

Independent Samples Test (CG)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre- and posttest scores (CG)	-.2495	0.5198	.12441	-.5271	.2412	-1.022	14	.271

Table 3 presents the inferential data belonging to pre and posttest of vocabulary belonging to the CG. according to the data, the data does not support the effectiveness of traditional vocabulary teaching for the CG, p=.271>.05.

Table 5

Independent Samples Test (EG)

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		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre and posttest (EG)	-2.6732	2.5178	.78421	-1.5524	-1.6481	-8.254	14	.002

The data in table 4 shows the t test result for the EG. As it is clear, there is meaningful difference between the pre and posttest of vocabulary for the EG, p=.002<.05. In fact, it indicates the effectiveness of using AR technology of teaching vocabulary on the vocabulary acquisition of the EG.

The second research question sought to explore the effect that implementing AR could have on the digital literacy of the EFL learners. To this goal, the researcher employed Digital Literacy Questionnaire. It is a 17-item questionnaire covering four dimensions of learners' attitudes on the use of digital devices, their technical ability, cognitive aspect of using digital technology, and finally socio-emotional qualities. Table 5 presents that data of responses to the questionnaire.

Table 6

Descriptive Data of Pre- and post-administrations of DL Questionnaire (CG)

Items	No.	Mean : Pre	Std. D.	Mean: Post	Std. D.
1. I like using ICT for learning	15	2.0167	.78542	2.3212	.85458
2. I learn better with information and communication technologies (ICT)	15	3.2917	.56790	3.2141	.73852
3. ICT makes learning more interesting	15	1.7083	.94089	2.6131	.91281
4. I am more motivated to learn with ICT	15	1.6667	1.10880	3.0213	.85702
5. I frequently obtain help with my university work from my friends over the Internet (e.g., through Skype, Facebook, Blogs)	15	2.1667	.56790	3.8125	.76685
6. ICT enables me to be a self-directed and independent learner	15	2.5833	.72225	3.5412	.98139
7. I know how to solve my own technical problems	15	3.0833	.75018	3.0909	.83421
8. I can learn new technologies easily	15	1.5000	.51177	2.2352	.67967
9. I keep up with important new technologies	15	2.4583	.83355	3.8636	.64690
10. I know about a lot of different technologies	15	2.7917	.92113	2.8435	.83265
11. I have the technical skills I need to use ICT for learning and to create artefacts (e.g., presentations, digital stories, wikis, blogs) that demonstrate my understanding of what I have learned	15	2.8750	.95005	2.4367	.93765
12. I am confident with my search and evaluation skills in regard to obtaining information from the Web	15	1.5151	.54312	2.7727	.89242
13. There is a lot of potential in the use of mobile technologies (e.g., mobile phones, PDAs, iPods, smartphones etc.) for learning	15	2.0287	1.2518	2.9213	.96811
14. Teachers/lecturers should use more ICT in their teaching of my classes	15	2.8842	2.4512	2.6818	.84762
15. ICT enables me to collaborate better with my peers on project work and other learning activities	15	2.9433	.94231	2.3142	.92387
16. I have good ICT skills	15	4.2443	1.37891	3.1273	.93476
17. I am familiar with issues related to web-based activities (e.g., cyber safety, search issues, plagiarism)	15	1.142	1.9213	2.0261	.96967
Total		41.2		48.4	
Valid N (listwise)	15				

Table 5 offers the descriptive data of pre and post administration of the DL questionnaire. According to the data, the higher means reflect higher agreement with the given statement about attitudes on DL. As an example, the mean score for item 16 is 4.2 indicating the subject in the CG believed that they have had good skill at using technology, but for the post administration of the same item changes to 3.1. Table 6 presents a comparison of the means of pre and post administration of DL questionnaire.

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Table 7

Paired Samples Statistics (CG): pre- and post-administrations of DL Questionnaire

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-ad. CG	2.42	15	10.5234	4.2198
	Post-ad. CG	2.84	15	11.5841	3.4972

Based on the data in table 6, the mean for the pre-administration of DL was calculated to be 2.42 while it changed to 2.84 for the post administration of the same questionnaire. The second administration shows a minor degree of improvement among the CG and their DL skill.

Table 8

Descriptive Data of pre and post administrations of Four Dimensions of DL Questionnaire (CG)

	Dimensions	N.	Means for pre-administration	Means for post-administration
1	Attitude	15	3.321	3.9214
2	Technical use of AR	15	4.218	4.964
3	Cognitive	15	1.432	1.940
4	Social-emotional statements	15	2.0437	2.994

The data in table 7 clearly presents the means for each subcategory. However, the highest mean belongs to the subjects' attitudes on the use of different aspects of DL and the lowest level belongs to the cognitive aspect of DL: 1.43.

Table 9

Paired Samples Test for two administrations (CG)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre and post administration (CG)	-3.5198	3.54214	.52033	-4.39216	-.82450	2.993	14	.19

Table 8 offers the inferential data of the two administrations of DL questionnaire for the CG. As it is clear, the p value was calculated to be .19 indicating that there is not any meaningful difference between the performance of the learners of the CG, before and after and experiment. In fact, it can be claimed that the use of AR had no impact on their DL. Of course such a result was expected to have happened since the CG were not exposed to the use of technology and thus the conventional teaching of vocabulary had no impact on this quality of the subjects of CG.

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Table 10

Descriptive Data of Pre-administration of DL Questionnaire (EG)

Items	No.	Mean	Std. D.	Mean	Std. D.
1. I like using ICT for learning	15	2.942	.16465	3.95	1.4598
2. I learn better with information and communication technologies (ICT)	15	2.5187	.92181	2.927	.99841
3. ICT makes learning more interesting	15	2.4591	1.4597	2.998	.95891
4. I am more motivated to learn with ICT	15	2.8121	2.4597	3.912	1.4589
5. I frequently obtain help with my university work from my friends over the Internet (e.g., through Skype, Facebook, Blogs)	15	3.8462	.81276	3.9692	2.1497
6. ICT enables me to be a self-directed and independent learner	15	2.8156	.023234	2.6215	1.5479
7. I know how to solve my own technical problems	15	3.0517	2.1874	3.129	1.0478
8. I can learn new technologies easily	15	1.8315	1.2386	2.096	1.0542
9. I keep up with important new technologies	15	1.8134	.40237	1.521	1.2178
10. I know about a lot of different technologies	15	1.4179	.74001	1.284	.99452
11. I have the technical skills I need to use ICT for learning and to create artefacts (e.g., presentations, digital stories, wikis, blogs) that demonstrate my understanding of what I have learned	15	1.9184	.91270	2.996	1.4582
12. I am confident with my search and evaluation skills in regard to obtaining information from the Web	15	2.5546	.86465	2.4521	1.5147
13. There is a lot of potential in the use of mobile technologies (e.g., mobile phones, PDAs, iPods, smartphones etc.) for learning	15	1.9241	1.2518	1.3195	2.4659
14. Teachers/lecturers should use more ICT in their teaching of my classes	15	2.9174	2.4512	3.841	0.7846
15. ICT enables me to collaborate better with my peers on project work and other learning activities	15	3.0549	.94231	3.8432	1.4855
16. I have good ICT skills	15	3.7841	1.37891	2.8432	0.7459
17. I am familiar with issues related to web-based activities (e.g., cyber safety, search issues, plagiarism)	15	2.0145	1.9213	2.1254	0.4512
Total		43.1		47	
Valid N (listwise)	15				

Table 9 presents the data of pre- and post-administrations of DL questionnaire for the EG. The means for both administrations can be compared. The higher is the mean, the more agreement it indicates with the given item. The total mean of the responses for the pre-administration was calculated to be 43.1 while the mean for the second administration increased to 47. The increase shows some degree of development in the DL skill of the learners of EG. As a result, the increase can indicate the effect of frequent exposure to AR among this group.

Table 11

Paired Samples Statistics (EG): pre- and post-administrations of DL Questionnaire

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-ad. EG	2.53	15	4.94658	3.2149
	Post-ad. EG	2.80	15	7.29854	4.5463

Table 10 presents the means of pre and post-administration of DL for the EG. The difference between the means of the two performances indicated DL improvement of the learners in the EG that was undertaken as a result of their being exposed to AR.

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Table 12

Descriptive Data of pre and post administrations of Subcategories of DL Questionnaire (EG)

	Dimensions	N.	Means for pre-administration	Means for post-administration
1	Attitude	15	3.125	3.851
2	Technical use of AR	15	3.802	3.967
3	Cognitive	15	2.56	3.154
4	Social-emotional statements	15	2.01	2.947

The data in table 11 presents the means of each subcategory separately. The highest mean belongs to the subjects' attitudes on the technical use of AR and the lowest level belongs to the Social-emotional statements.

Table 13

Paired Samples Test for two administrations (EG)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre and post administration (EG)	-2.9284	4.87212	1.5412	-5.9233	-1.9324	2.815	14	.004

Table 12 shows the inferential data of the two administrations of DL questionnaire belonging to the EG. The p value was calculated to be .004<.05, indicating that with 95% of certainty, there is meaningful difference between the responses of the learners of the EG, before and after they received the treatment.

4. Discussion and Conclusion

The present study investigated the impact of augmented reality (AR) technology on EFL learners' vocabulary acquisition and digital literacy development while also exploring learners' perceptions toward the implementation of AR-based instruction in language classrooms. The quantitative findings demonstrated that learners in the experimental group significantly outperformed the control group in vocabulary achievement after receiving AR-supported instruction. In contrast, the control group, which experienced traditional vocabulary teaching procedures, did not demonstrate statistically meaningful improvement. These findings strongly suggest that AR-based educational environments can facilitate vocabulary acquisition more effectively than conventional teacher-centered methods. The observed improvement may be attributed to the contextualized and multimodal nature of AR learning environments, where learners interacted simultaneously with visual, auditory, and textual representations of lexical items. Such interaction appears to have promoted deeper cognitive processing and more meaningful semantic associations. These findings are consistent with previous research emphasizing the effectiveness of AR in vocabulary development among EFL learners (Belda-Medina & Marrahi-Gomez, 2023; Khan et al., 2023; Topu et al., 2023). Similar outcomes were also reported by Yilmaz et al., who concluded that preschool learners exposed to AR technology achieved significantly higher vocabulary retention levels compared with those receiving traditional instruction (Yilmaz et al., 2022). Likewise, Binhomran and Altalhab demonstrated that AR-based vocabulary instruction enhanced lexical acquisition among young EFL learners by creating engaging and immersive learning experiences (Binhomran & Altalhab, 2021). The current findings therefore reinforce the argument that AR technologies facilitate vocabulary learning through contextualization, interactivity, and multisensory engagement.

One possible explanation for the effectiveness of AR in vocabulary learning lies in the situated and embodied nature of AR-supported educational experiences. Traditional vocabulary instruction frequently relies on memorization and isolated presentation of words, which may reduce learners' motivation and long-term retention. In contrast, AR applications provide contextual learning opportunities where learners interact with animated objects, stories, and real-life simulations connected to target vocabulary items. According to embodied learning theory, learning becomes more effective when learners physically and cognitively engage with instructional content through multiple sensory modalities (Lindgren & Johnson-Glenberg, 2013;

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Skulmowski et al., 2016). The findings of the present study support this perspective because the experimental group demonstrated stronger vocabulary gains after experiencing interactive AR activities. These findings also align with the arguments proposed by Wen, who emphasized that AR-enhanced learning environments increase learners' cognitive engagement and promote self-generated contextual learning (Wen, 2020a). Similarly, Wu et al. found that AR-based instructional designs improved learning achievement and learner satisfaction while reducing cognitive load through visually supported interaction (Wu et al., 2018). The integration of storybooks, animations, and multimedia elements in the current study may therefore have enabled learners to process vocabulary items more efficiently and remember them more successfully. Moreover, the game-like and immersive nature of AR likely increased learners' attention and sustained engagement throughout the instructional process.

Another important finding of the study was the positive impact of AR implementation on learners' digital literacy. The results of the digital literacy questionnaire revealed meaningful improvement among learners in the experimental group, whereas the control group showed no statistically significant change. This finding indicates that frequent interaction with AR technologies and digital devices contributed not only to language development but also to learners' technological competence and confidence. The learners in the experimental group regularly used tablets, smartphones, and AR applications during classroom activities and homework assignments. Such repeated exposure appears to have improved their technical skills, attitudes toward technology, and awareness of digital learning practices. This outcome supports the argument that technology-enhanced learning environments can facilitate the development of essential digital competencies among learners (Abedi & Tabatabaee-Yazdi, 2023). Abedi and Tabatabaee-Yazdi emphasized that digital literacy is closely associated with learners' ability to collaborate, communicate, and engage effectively within technology-mediated educational contexts (Abedi & Tabatabaee-Yazdi, 2023). Similarly, Batista et al. concluded that virtual learning environments and AR-supported systems improve learners' technological interaction, content absorption, and motivation (Batista et al., 2020). The findings of the present study therefore extend previous literature by demonstrating that AR-based instruction can simultaneously support language learning and digital literacy enhancement.

The improvement observed in learners' digital literacy may also be interpreted through the lens of learner autonomy and self-directed learning. AR technologies require learners to navigate digital interfaces, solve technical problems, search for information, and independently manipulate multimedia content. These processes naturally encourage learners to become more confident and autonomous in their interaction with technology. The interview findings further supported this interpretation because many participants reported feeling more independent and self-reliant while using AR applications. They perceived the learning process as less teacher-dependent and more learner-centered. Such findings correspond with previous studies suggesting that AR environments foster learner autonomy and active engagement (Mozaffari & Hamidi, 2023; Perry, 2021). Furthermore, Topsakal and Topsakal argued that integrating AR and artificial intelligence tools into language education could contribute significantly to children's digital competence and technological adaptability (Topsakal & Topsakal, 2022). The present study similarly indicates that AR-supported educational practices can help learners become more digitally competent individuals capable of functioning effectively in contemporary technology-oriented educational settings.

The qualitative findings of the study additionally revealed that learners generally held positive attitudes toward the use of AR in language classrooms. Most participants described AR-based instruction as enjoyable, motivating, and innovative. They emphasized that learning vocabulary through stories, animations, sounds, and 3D representations made the instructional process entertaining and engaging. These findings support earlier research demonstrating that AR environments positively influence learner motivation and emotional engagement (Di Serio et al., 2013; Tsai, 2020). Korosidou also found that AR significantly enhanced young learners' motivation and willingness to participate in language learning activities (Korosidou, 2024). In the present study, learners expressed that AR activities resembled digital games and therefore reduced boredom commonly associated with traditional vocabulary instruction. This positive emotional response may have contributed substantially to the learners' improved performance because enjoyment and motivation are strongly associated with successful language acquisition. From a positive psychology perspective, emotionally positive learning experiences increase learners' persistence, confidence, and willingness to communicate (Wu & Kabilan, 2025). Consequently, the enjoyable and interactive

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nature of AR may have strengthened learners' psychological readiness for vocabulary learning and facilitated more effective language acquisition.

The interview data also demonstrated that learners valued the authenticity and contextualization provided by AR applications. Participants reported that vocabulary items became easier to understand because words were presented within meaningful stories and realistic visual contexts rather than isolated lists. Such contextualization likely contributed to stronger semantic associations and better retention. Previous studies have similarly emphasized that AR provides authentic and situated learning opportunities that improve conceptual understanding and meaningful learning (Wen & Looi, 2019; Yoon et al., 2017). Danaei et al. also concluded that AR-enhanced multimedia storybooks significantly improve comprehension because learners can visualize complex concepts and events more effectively than through text-only materials (Danaei et al., 2020). In the present study, learners repeatedly mentioned that AR allowed them to understand vocabulary naturally without depending heavily on translation or rote memorization. This finding suggests that AR-based vocabulary instruction may support more implicit and contextualized language learning processes.

Another significant aspect emerging from the qualitative findings concerns learners' perceptions of collaboration and social interaction. Participants stated that AR activities increased peer interaction and collaborative engagement during classroom tasks. The learners often shared devices, discussed vocabulary meanings, and cooperated while completing AR-supported exercises. This finding aligns with the work of Gillies, who emphasized the importance of cooperative learning environments for promoting learner interaction and knowledge construction (Gillies, 2016). Similarly, Wen argued that collaborative AR environments enhance socio-cognitive engagement and encourage meaningful interaction among learners (Wen, 2020b). In the current study, collaborative learning may have strengthened learners' confidence and reduced language anxiety because students interacted in supportive and technology-rich environments. The social dimension of AR learning therefore appears to be another important factor contributing to vocabulary development and learner satisfaction.

Despite the overall positive findings, the participants also identified several challenges associated with AR implementation. Some learners initially experienced technical difficulties while using AR applications and required additional support to operate digital devices effectively. Others reported limited access to technological equipment such as tablets and laptops outside the classroom. These challenges are consistent with previous studies identifying technical infrastructure, accessibility, and teacher readiness as significant barriers to AR integration in educational settings (Khatoony & Altinpulluk, 2021; Schorr et al., 2024). Furthermore, some participants noted that AR applications focused primarily on vocabulary learning and provided fewer opportunities for developing productive language skills such as speaking and writing. This observation suggests that although AR is highly effective for vocabulary instruction, its pedagogical design should be expanded to support broader communicative competencies. Another challenge involved teachers' technological preparedness. Some learners believed that instructors required more professional training to use AR effectively within classroom environments. This finding corresponds with previous research emphasizing that successful integration of educational technology depends heavily on teachers' technological competence and instructional readiness (Dunleavy & Dede, 2014; Khatoony & Altinpulluk, 2021). Therefore, while AR demonstrates substantial educational potential, its implementation requires adequate technical infrastructure, teacher preparation, and pedagogical adaptation.

Overall, the findings of the present study provide strong evidence supporting the educational value of augmented reality in EFL instruction. AR-based learning environments significantly improved learners' vocabulary acquisition, enhanced their digital literacy, and fostered positive attitudes toward language learning. The combination of contextualized multimedia presentation, interactivity, learner autonomy, and collaborative engagement appears to create highly effective instructional conditions for vocabulary development. The study additionally contributes to the growing body of literature emphasizing the multidimensional benefits of AR technologies in education. Beyond linguistic achievement, AR appears capable of supporting learners' emotional engagement, technological competence, and self-directed learning capacities. These outcomes are particularly important in contemporary educational systems where digital literacy and technological adaptability have become essential learner competencies. Consequently, integrating AR into language classrooms may provide educators with innovative opportunities to address both linguistic and technological learning objectives simultaneously.

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One important limitation of the present study concerns the relatively small sample size and restricted participant population. The study involved only thirty female secondary school students within a single educational context, which may limit the generalizability of the findings to broader populations, different age groups, or mixed-gender settings. Another limitation relates to the duration of the intervention. Although the treatment lasted several weeks, longer-term implementation might provide more comprehensive insights into vocabulary retention and sustained digital literacy development. Additionally, the study focused primarily on vocabulary acquisition and did not examine other language skills such as speaking, listening, writing, or grammar development. Technical challenges also represented a limitation because some learners experienced difficulties accessing digital devices or operating AR applications effectively during the initial stages of instruction.

Future research should investigate the long-term effects of augmented reality on vocabulary retention and broader language proficiency across diverse educational contexts. Researchers are encouraged to examine AR implementation among learners of different age groups, proficiency levels, and sociocultural backgrounds to determine whether similar outcomes emerge across populations. Further studies may also explore the effectiveness of AR for developing productive language skills such as speaking and writing, as well as its impact on learner anxiety, creativity, and communicative competence. Comparative studies investigating different types of AR applications, instructional models, and collaborative learning designs may additionally provide deeper understanding regarding the most effective pedagogical approaches for technology-enhanced language learning.

Language teachers and educational institutions should consider integrating augmented reality technologies into EFL classrooms in order to create more interactive, engaging, and learner-centered instructional environments. Teachers can employ AR-supported storybooks, vocabulary games, and multimedia applications to contextualize lexical items and increase learner motivation. Educational policymakers should additionally provide schools with sufficient technological infrastructure and professional training programs so that instructors can effectively implement AR-based teaching practices. Curriculum designers may also benefit from incorporating AR-supported activities into language materials to enhance learners' digital literacy alongside language development. Finally, encouraging learners to interact independently with AR applications may foster greater learner autonomy, collaboration, and enthusiasm toward language learning.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

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Ethical Considerations

All procedures performed in studies involving human participants were under the ethical standards of the institutional and, or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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