



An exploration into the impact of augmented reality on EFL learners' Reading comprehension

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Abstract

This study investigated how Augmented Reality (AR) impacted EFL learners' reading comprehension and attitudes toward utilizing AR. A mixed-method was used with a sample composed of 64 upper-intermediate EFL learners in a state university in Iran. Independent and paired sample t-test were used to investigate the experimental group's reading comprehension and possible differences between groups' reading comprehension after utilizing AR. The quantitative findings indicated that the experimental group showed a significantly higher reading comprehension level than the control group. The thematic analysis of the semi-structured interviews revealed that students enjoyed using augmented reality and preferred it to traditional reading comprehension methods. Furthermore, AR increased students' interest in reading comprehension tasks and enhanced their willingness to use AR-based approaches in EFL classes.

Keywords Attitudes · Augmented reality · EFL · Reading comprehension · Reading textbooks

1 Introduction

Learners of English as a foreign language (EFL) learn in their native language environment and rarely use the target language in social situations, but learners of English as a second language (ESL) learn in the target language context and can use the language to communicate naturally. EFL learners seeking to master a new language can only do so if they acquire excellent reading skills (Lawrence, 2016). As McGee-Brown (1981) argues, comprehension is one of the most complex aspects of

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this skill. Reading comprehension is a highly complex process that involves several interactions between variables related to the text itself and readers, as well as what they bring to the text (Klingner et al., 2015). According to Shore and Sabatini (2009), EFL learners face several difficulties in reading comprehension, such as orthography, phonological awareness, vocabulary, and decoding. Other factors include: lacking of the ability to infer meaning from context, poor mastery over vocabulary, poor sentence structure and tenses, and a lack of interest from both teachers and students (Iqbal et al., 2015). Moreover, lack of learning opportunities in actual circumstances, lack of motivation, and limited practice time outside the classroom are the main factors that affect students' learning outcomes (Liu et al., 2008).

Iranian EFL learners suffer from a number of problems in reading comprehension skills. Khataee (2018) identifies these problems as unknown vocabulary, difficult or tedious content, failure in applying effective reading strategies, and shortage of time. According to a number of studies reported by Maasum et al. (2010), most Iranian EFL learners are word-by-word readers. They have difficulties with comprehending the text because of the rote-memorization and Grammar-Translation Method used in language education. Besides, anxiety is considered a barrier to Iranian EFL reading progress (Jafarigohar & Behrooznia, 2012).

To overcome such problems, teachers might employ visual aids to improve English Learners' comprehension and promote a more relaxed learning experience (Shabiralyani et al., 2015). To this end, teachers can employ AR tools that allow for the presentation of visual information and provide them with an immersion-like experience and an authentic learning environment.

Augmented Reality is described as “a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics, or CPS data” (Koch, 2016, p. 124). AR can be utilized to enhance all five senses, especially the visual” (Kipper & Rampolla, 2012). It can be seen as a bridge between classical education tools and media technologies which positively affects user performance (Bursali & Yilmaz, 2019). AR has shown to be advantageous in fostering motivation, engagement, creativity, imagination, and collaboration, to name but a few of its benefits (Radu, 2014; Yuen et al., 2011). It has been utilized in the reading comprehension section of Augmented Books (Cheng & Tsai, 2013) and other forms of reading activities that involve types of interactive virtual content. Advocates of AR reading activities have identified the ways to enhance students' reading skills, such as exploring elements beyond 2D illustrations in the reading to, innovative ways of presenting concepts, and enhancing active experimentation with them and a “sense of presence” which provides a meaningful learning environment (Ramli & Zaman, 2009). Moreover, researchers have proposed that AR books may provide interactive experiences with the text and illustrations, thereby enriching the learning process (Cheng & Tsai, 2014).

While augmented textbooks may be one of the most common approaches to use AR in education (Yuen et al., 2011), numerous researchers acknowledged that there are few empirical studies on AR-assisted reading comprehension. They recommended further studies to assist and improve learners' reading comprehension. Huisinga (2017) indicated that there are few studies on providing students with AR-based reading materials and visual aids. Thus, in an attempt to address this

drawback, Hadid et al. (2019) shed light on the potential value of using AR in language classrooms by providing a Reader Buddy model. Reader Buddy provides an example of using AR-based textbook supplements to improve language teaching and learning quality. They indicate that Reader Buddy offers the opportunity to experience the potential of AR-based teaching materials in enhancing the quality of language teaching and learning.

Hadid et al. (2019) pointed out that Reader Buddy AR contents are activated by Quick Response (QR) codes or triggers, which teachers can embed in printed textbooks at the beginning of every chapter. These glossaries, which introduce the meanings of new words by implementing videos, pictures and translations, help different EFL learners work at the same pace. Due to the lack of research on the implementation of AR in such projects, Hadid et al. (2019) recommended researchers plan to extensively use similar activities in future classrooms to determine better how AR supports EFL and how they can best apply it. Moreover, One of the primary goals of using AR in language learning is to provide learners with a meaningful learning environment and a real-life context not available for EFL students. As a result, the this study aimed at exploring the effects of using Augmented Reality on Iranian EFL learners' reading comprehension skills by implementing the Reader Buddy project.

The following research questions were investigated in the study:

1. To what extent does AR assist the development of the learners' reading comprehension skills?
2. Is there any significant difference between the learners who utilized AR and those who did not in terms of reading comprehension skills?
3. What are the participants' attitudes toward using AR in classroom activities?

2 Literature review

2.1 Augmented reality

Augmented reality began in the 1960s by creating Morton Heilig's Sensorama Simulator as the first real multi-sensorial simulator (Giganteh, 1993). Its basic premise is to apply computer-generated virtual information to the real environment following simulation, such as text, photos, 3D models, music, video, and so on. In this way, the two kinds of information complement each other, resulting in enhancing the real world (Hu et al., 2017). When the barcodes are scanned, virtual images, videos, and 3D objects are combined with real-world data on the screen of smartphones. AR enriches the learning experience, increases engagement, and leads to successful learning since it integrates virtual and real worlds and allows learners to interact in real-time (Hsu, 2013). It provides learners with the opportunity to see the virtual contents without moving away from the real world (Yilmaz & Goktas,

2017). Today, AR technologies are used with wearable technologies. However, they are primarily utilized with computers, tablets and smartphones.

2.2 AR in education and language teaching

Technology-enhanced learning has become increasingly accessible and popular as information technology has developed (Teng et al., 2018; Zou et al., 2019). According to Billinghamurst and Duenser (2012), “Decades of research have shown that computer technology in the classroom can enrich teaching and learning and boost student achievement, compared to teaching without such aids”(p.56). As one of the newly emerging computer technologies, AR has played an important role in enhancing e-learning (Ibanez & Delgado-Kloos, 2018). AR in different disciplines is becoming increasingly popular, not only because of its potential but also to improve the cognitive processes applied to teaching (Fructuoso et al., 2015). AR applications affect the academic achievement of students in a positive way (Akçayır & Akçayır, 2016) and make the learning process more interesting (Wojciechowski & Cellary, 2013).

According to Dunleavy et al. (2009), the main function of AR is its ability to combine digital and physical objects to create immersive hybrid learning environments, which facilitates the development of critical thinking and problem solving through collaborative interaction. Numerous studies have indicated that AR in educational setting enhances learning achievement and promotes students’ performance (Chang et al., 2015; Ferrer-Torregrosa et al., 2015). Lu and Liu (2015) stated that students had a positive attitude toward using AR in their classroom activities as they learned the subjects through play. They also perceived AR-enhanced learning as effective in terms of boosting their achievements. A systematic review study done by Akçayır and Akçayır (2017) has shown that the implementation of AR help students enhance their motivation and satisfaction and promotes their understanding. According to Chiang et al. (2014), AR can enhance students’ motivation by providing them with relevant and timely information rather than pushing them to search for information related to their subject matter. Concerning the importance of learners’ attitude and motivation in language learning, multiple studies have been conducted to enhance language learning in an engaging environment (Cheng & Tsai, 2014; Wu et al., 2013) and due to the potential of AR in providing such an environment, it has gained increasing research attention. AR allows real-time interaction and provides learners with real experiences, which can boost their attention and interest (Ibanez et al., 2014; Singhal et al., 2012). It facilitates providing ELs with visual information (Santos et al., 2014).

Some researchers have identified particular AR-enhanced learning effects, such as lowering students’ cognitive load. For example Bressler and Bodzin (2013) showed that students’ cognitive overload can be reduced by utilizing a well-designed AR system. Santos et al. (2014) found that augmented reality videos, images, virtual texts, and juxtapositions of real things reduce cognitive

burden in limited working memory. Kucuk et al. (2014b) pointed out that AR contributes to better learning since it helps learners decrease the cognitive load.

2.3 Theoretical framework

Augmented Reality is associated with the current theories of second language learning related to contextual and localized learning (Godwin-Jones, 2016). One evident theoretical foundation for AR technology is the Situated Learning Theory (Dunleavy & Dede, 2014). Situated learning theory holds that an authentic context should be provided for delivering knowledge to learners. They should be involved in real situations of daily practice and applying knowledge in productive ways (Pengiran et al., 2018). AR provides learners with a mixed-reality environment to implement what they have learned to other similar situations. Immersion in the culture of the target language is also an integral part of learning. AR merges a virtual layer onto reality, reflecting a sense of integration and immersion into the real world (Yang & Liao, 2014).

2.4 Reading comprehension

Reading comprehension necessitates using one's eyes, ears, and brain to see, comprehend, understand, and mentally generate meaning (Palani, 2012). Lev Vygotsky (1978) presented a reading perspective through the socio-cultural theory of learning. So reading is viewed as a social skill that requires active participation, interaction and involvement of learners (Ghafar Samar & Dehqan, 2013). Successful comprehension can be thought of as the ability to create and maintain a coherent and reasonably accurate situation model (Radvansky, 1999).

EFL learners may face a number of difficulties in reading comprehension, such as dealing with unknown vocabularies and rote memorization, boring content and lacking interest and motivation, anxiety, lacking the ability to infer the meaning of the text and shortage of practice time outside the classroom. A number of studies have supported the notion that mental visualization contributes to reading comprehension (Morrow et al., 1989; Perfetti & Stafura, 2014). Research has shown that students enjoy using AR and find the technology motivating and enjoyable (Billinghurst & Duenser, 2012). It decreased the students' anxiety levels while doing reading activities and boosted the process of word learning (Piriyasurawong, 2020).

2.5 AR in reading comprehension

Technology that can assist with reading can be divided into digital tools and digital devices. Tools include e-books, audiobooks, text-to-speech software, assistive technologies, word-by-word tracking, recording, mind mapping tools, and educational apps. Devices include eReaders, Tablets, smartphones, or laptops (Biancarosa & Griffiths, 2012; Hutchison et al., 2012). Research has shown clear benefits of using AR apps and digital texts for readers, particularly when aligned

with appropriate reading strategies (Huisinga, 2017). AR provides the opportunity to experience information through channels other than printed text (Billinghurst & Duenser, 2012). For instance, incorporating 3D models can engage struggling readers and promote deeper comprehension (Billinghurst & Duenser, 2012; Green et al., 2014). Kun-Hung Cheng (2017) explored learners' cognitive load, motivation, and attitudes using AR technology in reading activities. With quantitative surveys using three questionnaires, this study analyzed the relationships between motivation, perceived cognitive load and attitudes of perceived control, perceived utility, and learning behavior of 153 students participating in an AR reading activity. The results showed less cognitive load, greater motivation and more positive attitudes perceived by students experiencing reading an AR book. The students were also willing to learn with the help of AR technology in the future after this experience.

ChanLin (2018) studied the effect of augmented reality on children's reading skills. He developed the AR storybook library using HP Reveal to link triggers with the stories in the story database. The method used was a mixed method using questionnaires and observations with a sample of 137 children. The study observed that most children reacted positively toward using AR in reading experiences. They were fascinated by the visual element and engaged in the guided reflection process in reading. Qualitative observations indicated the engagement of the children in the reading activity. The researchers recommended the Adults' support for children's AR story reading as it played an important role in providing them with exploration experiences. Utilizing AR provided learners with a rich and vivid reading experience helping them enhance their reading and cognitive literacy.

Bursali and Yilmaz (2019) investigated the effect of augmented reality on the permanence of high school students learning and reading comprehension by examining their attitudes. The mixed method was applied with a sample of 89 5th grade students (46 boys, 43 girls). The experimental group that participated in the study used AR applications in reading activities, while the control group used traditional methods. Results indicated that the experimental group students, experiencing satisfaction for their participation in interactive reading activities based on AR, improved their reading comprehension level, and the qualitative results revealed that AR applications could be used effectively as educational aids.

A study was done by PiriyaSurawong (2020) on scaffolding augmented reality to enhance deep reading skills found that SC-AR Model (Scaffolding Augmented Reality) effectively improves learner's Deep Reading (DR) skills. This Model can also be applied to strengthen DR skills in all foreign languages. Research by Kucuk et al. (2014a) on 5th-grade students indicated the students' desire to use AR applications in their English language courses. It also revealed a decrease in students' anxiety levels. An experimental study by Çakır et al. (2016) concluded that university students in an experimental group who used AR technology in learning English vocabulary showed more significant motivation levels and performed better than students in the control group exposed to traditional teaching methods. Akcayir and Akcayir (2016) found that using an AR application developed for a Foreign Languages course improved the permanency of learned words and boosted students' word learning. Alsowat (2017) investigated the effect of Augmented Reality on EFL learners' reading comprehension, autonomy, self-efficacy and attitudes. The study

indicated the positive impact of AR in English language learning that comes from its potentials in offering dynamic interaction, real-life situations, any-time learning resources, and visual and auditory objects. Wu (2019) reported that incorporating mobile-AR games into EFL classrooms had a good impact on students' learning satisfaction, motivations, and achievements. According to Teng et al. (2018), AR-enhanced learning improves learners' perceptions of their learning experience and system usability by providing interactivity and visual representation.

A few studies are investigating the impact of utilizing AR technology on EFL learners' reading comprehension. Most of the studies have explored AR in learners' native language. Moreover, few attempts have been made to investigate other crucial elements for enhancing reading, such as background knowledge which has been considered an important factor in enhancing learners' performance in reading comprehension (Pritchard, 1990; Nelson, 1987; Bensoussan, 1998) in an AR-based context. As a result, the purpose of this study was to corroborate the findings of a few earlier studies by looking at the impact of AR on the factors that influence EFL learners' reading comprehension.

Another aspect that hasn't been examined in previous studies is the relevance of student interaction. Situated learning theory holds that there should be interaction among learners and that this interaction defines the level of learning quality (Brown et al., 1989). According to Hadid et al. (2019), the more learners participate in group work activities and communicate with one another, the higher their learning level becomes. Thus, this study investigated the impact of AR on providing learners with background knowledge and an interactive environment in EFL reading comprehension.

3 Method

3.1 Design

The study employed the sequential explanatory mixed-methods design (Creswell et al., 2003). Participants' Reading proficiency and the questionnaire results were analyzed quantitatively, and then qualitative data collected through semi-structured interviews were analyzed to substantiate and explain quantitative findings.

3.2 Participants

A total of 75 EFL learners at a state university's language institute were invited to enroll in this study. The participants' proficiency level had already been assessed through the institute's placement test. Because this study required a certain level of English proficiency, the participants were given a Dialang test to determine their exact level. Dialang is an online diagnostic assessment system designed to measure the learners' proficiency in 14 European languages based on the Common European Framework of Reference for language (CEFR). Among all the participants, 64 upper-intermediate EFL learners, parallel to B2 in CEFR taxonomy, were chosen

as the participants and 11 other learners whose proficiency levels were considered lower than B2 were excluded. All the participants were Persian-native speakers (aged from 22 to 30). 32 participants were randomly assigned to the experimental group (EG group) and 32 to the control group (CG group). Care was taken to ensure that EG students were of similar cultural and technological profiles. They had never experienced AR technology before. All participants were informed about the entire process and ensured that all data would be kept confidential. Figure 1 illustrates the distribution of participants in experimental and control groups.

3.3 Instruments

A reading comprehension test was administered using the Dialang system as the pre-test to measure the learners' level of reading proficiency before the treatment. The same test was administered as the posttest at the end of the intervention to assess the learners' improvement. Finally, semi-structured interviews were conducted after the treatment. The researcher's six open-ended questions were used to explore the students' attitudes toward the whole process. The interview questions were finalized and refined after receiving feedback from area experts. Member Checking (also known as respondent validation) technique was applied to investigate the credibility of results.

Two AR-based applications named CXOCARD and ROAR were utilized in this study. They are accessible and user-friendly applications available for both iOS and Android users. CXOCARD can be freely downloaded and used to create AR-based audio-visual materials. Because CXOCARD cannot create AR-based texts, a separate program was required to fill the gap. As a result, the ROAR app was also used to provide text materials to students.

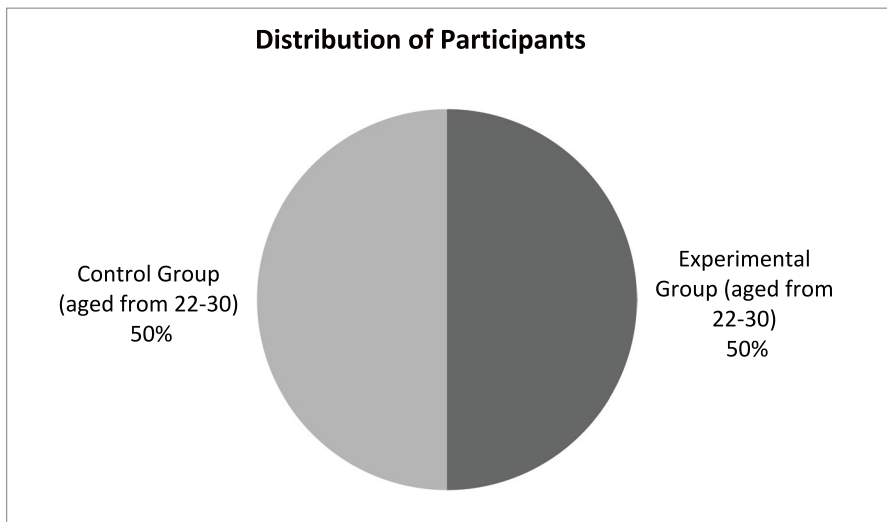


Fig. 1 Distribution of participants

The whole process of data collection lasted for ten sessions in an online Web-based class using BigBlueButton software. BigBlueButton (BBB) is a free software web conferencing system and its intended use is online learning. Due to the pandemic of Covid-19, education systems have been obliged to be online and on digital platforms. As a result, students have already had enough experience using BBB utilized in the educational system of the institute.

During the first session, two Dialang tests were administered as the pretest to place the participants' level of general English and their reading proficiency. Learners whose proficiency levels were considered lower than B2 were excluded. Starting from session two, the EG participants were instructed on employing the two AR applications (CXOCARD and ROAR) in their reading activities. They were first directed to download the applications to their phones and create the necessary accounts. Then students were allowed to work with the applications and follow the teachers' directions step by step, asking any questions they had along the way to ensure they were all capable of using the applications without difficulty in future sessions. All the instructions were given in Persian to avoid any misunderstanding. They were also assigned into groups of two or three to provide them with the opportunity of exchanging ideas and discussing the lessons in the class. Breakout rooms were available in BBB for group discussions.

Seven readings of Inside Reading (Book 2) were chosen to achieve the research objective; Cooper Pedy, The power of Branding, Product Placement, Weather, climate, or both? Fat for Brains, the Minnesota Starvation Experiment. Inside Reading 2 was designed for upper intermediate students and the difficulty level of all the readings corresponds to B2 in CEFR language proficiency levels. These units were chosen specifically as they contained events and situations illustrated and explained using AR. The reading content of these units was taught using augmented reality by providing learners with background knowledge of each text via AR-based videos, vesting their insight into the subject matter via AR-based sounds of various characters discussing the subject matter, and directing them to discuss what they've learned from the content. The meaning of difficult vocabulary and example sentences of each were presented through AR. ROAR was used to provide learners with Persian translations and example sentences for complicated terms, while CXOCARD was used to construct audio-visual AR teaching materials.

The book's author has previously highlighted the difficult vocabulary in the passages. The ROAR app scanned the words to act as AR-embedded triggers. The Persian translation and an example sentence were provided and infused into the app and attached to its scanned trigger. The learners installed the ROAR app on their smartphones, so when they pointed their phones at the AR-embedded words, they saw the Persian translation and example sentences (see Fig. 1). Students were allowed to use smartphones during the whole process.

The contents of the readings were analyzed to choose the appropriate videos and sounds. These sounds and videos were uploaded to the CXOCARD website and attached to their triggers (the topics of the readings trigger related videos and some added pictures provided to act as the triggers for related sounds). The learners installed CXOCARD app on their smartphones, so when they pointed their phones at the topics and pictures, the related videos and sounds popped up (see Figs. 2, 3).



Fig. 2 Scanning a challenging word using ROAR app

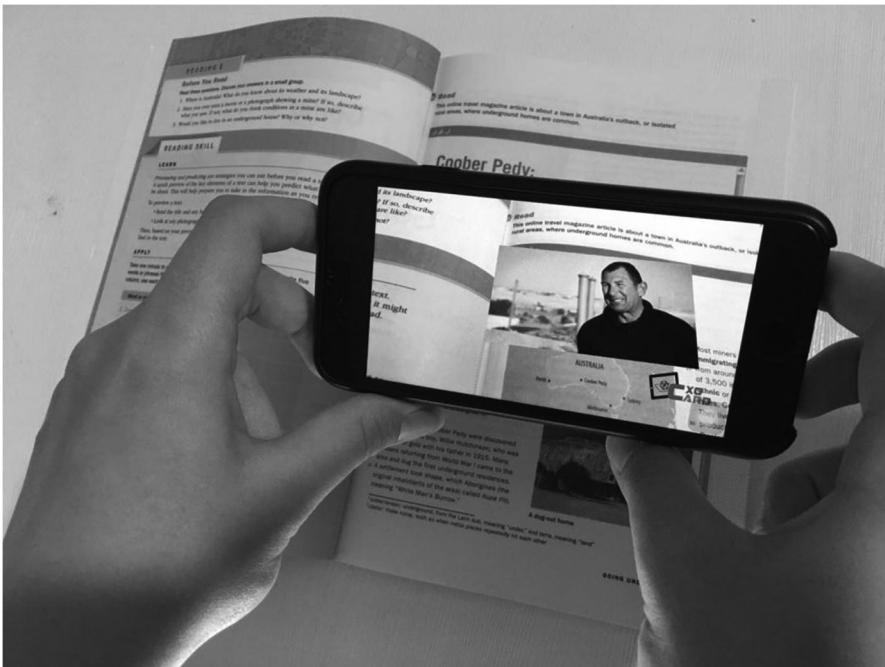


Fig. 3 Scanning lesson topics using CXOCARD app

The CG learners were taught using the traditional teaching method, while the students in the EG group were taught utilizing the Reader Buddy project. We had the opportunity to use a couple of activities proposed by the project. These activities went

through the steps of pre-reading, during reading and post-reading. The pre-reading phase is aimed at providing ELs with background knowledge of the text. To this end, starting from session 3, learners were provided with videos about the topics of the readings using AR. When they pointed their devices at the topic, the related video was activated to introduce the title of the reading and learn about its content. Afterward, the students were directed to discuss what they have learned about the topic in groups.

The other activity done in this phase was to provide the pictures of different characters by the teacher to act as triggers. When the ELs pointed their smartphones at a character, they heard narration that extended their insight into the text's content. After listening to different narrations, they discussed the people's opinions about the text in groups. During the reading phase, ELs pointed their devices at any challenging word to receive the Persian translation and an example sentence so that they could construct meaning while reading. At the end of the lesson in the post-reading phase, ELs recorded themselves briefly explained what they learned from the lesson. For ethical reasons, ELs were not forced to record themselves and it was done voluntarily. Those who didn't volunteer were asked to explain and discuss the lesson without recording themselves. This activity represents an opportunity for them to voice their opinions on what they discussed and learned in their lesson (Hadid et al., 2019). At the end of each session, the participants were assigned easy and motivational homework that helped them relate what they learned to themselves. The experiment went on for seven sessions.

A post-test of reading comprehension was administered to assess both groups' achievements after the treatment. And the final session was devoted to interviewing. To avoid any misunderstanding on the part of the learners, they completed the Persian version of the questionnaire and the interview was conducted in Persian. Member Checking technique (Dörnyei, 2007) was used to explore the credibility of the interview results.

3.4 Data analysis

The data elicited were analyzed using Standard Packages of Social Sciences (26 SPSS). A paired t-test measure was conducted to investigate the EG participants' reading comprehension before and after the treatment. An independent sample t-test was used to explore possible differences between the EG and CG participants' reading comprehension after the process. Also the qualitative thematic analysis was utilized to analyze the collected data from the interview. The results were analyzed through four steps. Firstly the gathered data from audio recordings were transcribed. Secondly, interesting features were drawn from the transcription for coding the data. Third, researchers sorted codes into themes and then review and refine the themes to discard or combine any candidate themes if necessary. Lastly, the themes are drawn from the interview related to the three subscales of the IMI scale. Any other themes were discussed separately.

Table 1 Paired sample t-test for EG participants' pretests and posttests of reading comprehension

Paired Differences							
95% Confidence Interval of the Difference							
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df Sig. (2-tailed)
EG	-2.75000	1.45912	0.25794	-3.27607	-2.22393	-10.661	31 0.000*

Table 2 Descriptive statistics for differences between EG participants' pretests and posttests

	Mean	N	Std. Deviation	Std. Error Mean
EG's pretest	13.0000	32	2.66398	0.47093
EG's posttest	15.7500	32	3.20282	0.56618

4 Results

A paired sample t-test was carried out, investigating the effect of using AR on the reading comprehension development of EG participants to address the first research question. As Table 1 shows, the use of AR technology has significantly impacted the participants' reading proficiency. Table 2 indicates the mean differences between the EG participants' pretests and posttests of reading comprehension.

An independent sample t-test was conducted to investigate the second research question regarding the impact of using AR on the possible differences between EG and CG participants' pretests and posttests of reading comprehension. As Table 3 indicates, there was no significant difference between the results of EG and CG participants' pretests of reading comprehension ($p = .0640$). Still, a statistically significant difference was found between the two groups in the reading comprehension post-tests ($p = 0.001$). Tables 4, 5 presents the descriptive statistics for differences between the EG and CG participants' pretests and posttests.

Students' attitudes toward utilizing AR in their classroom activities were also collected using a semi-structured interview. On the whole, the findings revealed EFL learners' positive attitude toward using AR in classroom activities. The participants believed that AR affected their reading comprehension significantly by providing them with good background knowledge, an interactive environment, and lowering their cognitive load. They all perceived it as beneficial and thought that AR was beneficial and highly developed their reading skills. Participants enjoy using AR and prefer it over traditional ways of teaching. They mainly were relaxed while using AR, but some were anxious due to a lack of confidence in voicing their idea in the target language, poor internet connections, exposure to new technology and possible technical problems of AR apps.

Table 3 Independent sample t-test for EG and CG participants' results of pretests and posttests t-test for equality of means

Levene's test for equality of variances		t		Sig. (2-tailed)		Mean Difference		Std. Error Difference		95% Confidence Interval of the Difference	
F	Sig.	t	df	Sig.	Mean Difference	Std. Error Difference	Lower	Upper	Lower	Upper	
0.005	0.946	0.470	62	0.640	0.31250	0.66514	-1.01710	1.64210	-1.01710	1.64210	
2.030	0.159	3.439	62	0.001*	2.53125	0.73607	1.05986	4.00264	1.05986	4.00264	

*p < 0.05

Table 4 Descriptive statistics for differences between EG and CG participants' pretests and posttests

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Pretest	EG	32	13.0000	2.66398	0.47093
	CG	32	12.5714	2.65716	0.46972
Posttest	EG	32	15.7500	3.20282	0.56618
	CG	32	13.2143	2.66076	0.47036

5 Discussion, conclusion and suggestions for further research

Regarding the first and the second research questions about the impact of using AR on EFL reading comprehension, the findings showed that utilizing AR and implementing the Reader Buddy project in EG participants' reading course improve their reading skills compared to the traditional teaching method. Additionally, the reading comprehension post-tests revealed a statistically significant difference between the two groups. AR may assist EFL learners in improving their reading skills more effectively than reading without it. The findings align with Alsowat's (2017) research which indicated the usefulness and effectiveness of using AR in enhancing reading skills. He stated that AR offers visual and auditory materials, dynamic interactions and real-life situations. Majid and Salam (2021) also reported vocabulary acquisition as a significant learning outcome in AR implementation in language learning. The findings are also consistent with Akcayir and Akcayir's (2016) study, which found that using an AR-based application improved the permanency of learned words and boosted the process of students' word learning in the EFL context. Kucuk et al. (2014a) also corroborate that AR helps learners improve their reading comprehension by lowering their cognitive load. However, this contradicts Radu (2014) and Akcayir and Akcayir (2017), who found that AR can increase learners' cognitive load. According to Akcayir and Akcayir, one probable cause for this increased cognitive load is that AR makes the learning task more complicated. This complexity was significantly decreased in this study due to the adoption of user-friendly AR applications and the students' mastery of their implementation. The findings are also consistent with Wu's (2019) findings, which found that integrating AR into ESL courses improves students' learning achievement.

The audio and visual multimedia AR components that made the learning process meaningful by offering a rich and vivid reading environment contributed to the EG participants' progress in this study. The videos and narrations were informative and provided them with good background knowledge of the content, which has been considered an essential factor in improving learners' reading comprehension. Audiovisual materials also provided students with a sense of presence and immersive environment. It lowered the EFL learners' cognitive load by invoking their vision as well. AR enabled students to repeat the process of learning over the challenging parts as many times as they needed without the guidance of their instructor. Moreover, AR helped the learners deepen their understandings of the contents of the subject matter by enriching their textbooks with the translation and example sentences for challenging words. This feature allowed students to better organize their time

Table 5 Themes of the participants' attitudes toward using AR in classroom activities

Themes	Example
The effectiveness of AR on learners' reading comprehension by	
Providing learners with background knowledge	S16: Watching videos before going through the text provided me good knowledge and a vast insight into the topic.
Lowering learners' cognitive load	S7: After exposing to all audiovisual materials, I didn't have much trouble memorizing the meanings of new words. AR made the learning process easier for me.
	S10: It was a good idea to use different characters talking about the reading text. Understanding the content without them would be more challenging.
Providing learners with an interactive environment	S26: Learning in such an interactive environment was amazing. Discussing the topic after watching videos gave me good background knowledge and made me curious about the content.
	S9: Voicing my opinion about the reading at the end of each session helped me reinforce my learning of the content and new words; thereby, I had less trouble recalling them after a while.
Preference for AR over traditional ways of practicing reading	S2: I prefer AR-based classes over the traditional ones. I spent much less time at home memorizing the new words and grappling with reading. I learned all I needed in the course through the audio-visual materials provided by AR.
	S31: I enjoyed working with AR. It was a fascinating technology and I didn't feel bored for a moment in the class. It was more fun than sitting in traditional reading classes with no visual materials and interactions."
Perceived value/usefulness	S17: I think that the process was so beneficial to me, I learned a lot and now I'm more confident in reading. I want AR in my future classes.
	S14: AR made a great difference to my reading proficiency which impressed me a lot. I would like to utilize AR in my future reading classes.
Interest/ enjoyment	S22: When I pointed my smartphone at the topic, a video popped up. It was so interesting for me to be introduced to the title of reading by a video on my device.
	S5: Activating videos and narrations by pointing my cellphone at the book was a first-time event that attracted my attention. My reading book became fascinating and fun for me."

Table 5 (continued)

Themes	Example
Felt pressure and tension	<p>S22: not only was I relaxed while using AR, but it also helped me relieve my other stresses. When I encountered a word I'd forgotten the meaning, I simply pointed my device at it, and its translation popped up. I didn't worry about being judged by classmates and my teacher to ask repeatedly about the meanings of words anymore.</p> <p>S14: The video was shaking and that was a little bit annoying. It made me anxious about not understanding the content."</p>

by getting instant translations of vocabularies and seeing how they were used in the correct context rather than searching them in dictionaries or continually questioning their teacher. In general, AR facilitates vocabulary learning by providing access to the words' meanings and functions. By increasing their vocabulary knowledge, learners could better comprehend the text and have less difficulty analyzing and decoding the content, which is identified as one of the major problems in the EFL reading comprehension. Learners engaged in motivating and interacting activities such as making guesses about the reading content after watching videos and hearing narrations and discussing their ideas with classmates about their lessons. That is, AR increased students' participation and their level of engagement. This project provides opportunities for learners to engage in group work activities rather than the solitary act of reading as in traditional methods.

The interview results regarding participants' attitudes toward using AR in classroom activities showed that participants perceived AR as effective in terms of enhancing their reading comprehension by providing them with background knowledge, an interactive learning environment and lowering their cognitive load. They believed videos and narrations were informative and helped them gain more knowledge about the content. As one EG participant said: "The narrations from different characters were very informative. Each character talked about a new aspect of the reading and I learned a lot." Another participant highlighted the positive effect of the interactivity of the learning atmosphere using AR: "I didn't feel that I am in a reading class at all. We were watching videos, hearing different stories and discussing with classmates all the time. We interacted a lot and learned more about the content." The participants also reported that AR-based reading tasks made the learning process easier. This positive perception might be due to being exposed to audio visual materials that lowered their cognitive load and make the learning process easier for them. Learners also enjoyed using AR technology in their reading activities. Activating videos by pointing their smartphones at the book attracted their attention and made their reading books fascinating and fun. They were eager to repeat the activity at home so that they could get more practice with the material. AR also made learning vocabulary more interesting. Using their phone to look up the translation and effective use of vocabularies made the difficult task of learning

new words more enjoyable and manageable. They found AR-based reading activities to be fun and engaging, which increased their enthusiasm to read in class, and they plan to use them again in the future. The learners stressed the importance of using AR because it can improve their reading skills significantly. Students also preferred AR-based reading classes over the traditional ones. They didn't have the challenges associated with the conventional reading classes, such as the boring learning environment, the time-demanding process of vocabulary learning and memorizing, and the lack of the opportunity to be in an immersive learning environment. Instead, audio-visual AR materials provided them with a fascinating, motivating, dynamic and immersive learning environment that removed the extra cognitive load of learning and increased their engagement. As an EG participant recounted: "I could see real scenes and hear real stories and narrations about the content. It helped me get a closer insight into the content. Traditional reading classes hadn't provided me with such an opportunity."

Parmaxi and Demetriou (2020) point out that many researchers confirmed the success of AR in offering an enjoyable, engaging and motivating environment for learners. The findings of this study corroborate Ghasemi and Javidan's (2014) study in which their presented model of AR had a positive impact on students' interest and motivation toward learning English. In another study, Kucuk et al. (2014a) concluded that EFL learners were pleased with using AR in learning English and wanted it to be used in their future courses. The findings also are in line with Also-wat's (2017) research findings in which using AR motivated EFL learners helped them develop their reading skills and stimulate their curiosity. The findings also corroborated Çakır et al. (2016) study concluding that university students using AR technology in learning English vocabulary showed greater motivation levels and performed better than students exposed to traditional teaching methods. Chen et al. (2020) also confirmed the positive attitude of learners toward using AR. This technology appears to interest students, as evidenced by their increased curiosity, engagement, and motivation. The interview results revealed that some individuals felt anxious when using AR. However, this may not be true for everybody because they were generally unconcerned and did not feel obligated to participate in AR activities. Some participants may have felt pressured due to their exposure to new technology, poor internet connections, a lack of confidence in expressing their ideas in the target language, and possibly technical issues with AR apps.

The study's findings give future researchers a chance to expand their understandings of the factors contributing to the better application of AR in reading classes. This study also assists teachers and students in becoming more acquainted with AR and moving closer to implementing it in their EFL lessons. It shows how integrating AR-based resources in the pre-reading phase gives learners a good background knowledge of the content and creates an interactive environment for pre- and post-reading discussion. During the while-reading stage, students may observe the translation of new words while also becoming familiar with their function in example sentences, reducing their cognitive load when learning difficult vocabularies. According to the findings, language institutes are recommended to utilize AR technology in their classes. They are advised to integrate AR into their curriculum to provide a motivating and enriched learning environment. Textbook authors are

also recommended to design AR-based books to make using this technology more straightforward and accessible.

A limitation of this study was related to the problems some participants encountered due to the poor internet connections and some technical problems of AR apps that could affect their level of anxiety. Another limitation was due to the relatively small sample size ($N=64$). Care should be exercised in generalizing the findings to other groups of learners. Further studies with larger sample sizes should be conducted for more generalizable results. Most research to this date has explored the impact of AR on reading in L1 classes. Future research could focus on the effects of AR on learners' self-efficacy and autonomy in EFL reading comprehension.

Appendix 1

Interview questions

1. Do you think that AR benefited you in terms of enhancing reading skills? How?
2. Did you find AR helpful in terms of making the learning process more accessible? How?
3. Do you prefer AR over traditional ways of practicing reading? Why (not)?
4. Did you feel any pressure or tension while using AR?
5. Did AR make the lessons enjoyable and interesting for you?
6. Are you going to use AR in your future classes?

Declarations

Conflict of interest None

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