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The effects of using augmented reality on vocabulary learning and attitude of pre-school children in English education

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Abstract

The purpose of this study was to investigate the effects of Augmented Reality (AR) technology on vocabulary development and attitudes toward AR in pre-school English instruction. The study, which was grounded on a pretest–posttest control group quasi-experimental design, included 36 pre-school children aged from 4 to 5. While the participants in the control group used flashcards, matching cards, and puzzles to learn English equivalents of target vocabulary, the participants in the experimental group used the same materials presented through AR applications, enabling them to see 3D animated models and listen to English pronunciation. The results revealed significant differences between groups in terms of vocabulary learning, attitude, and enjoyment levels, with the experimental group performing better. Although there was no statistically significant difference in terms of emotions between the groups, the participants in the experimental group developed more positive feelings towards AR-supported activities than those in the control group. In addition, some participants with lower emotional levels in the control group had undecided and unhappy emotional states. As a result, it can be said that AR technology contributed to language learning in pre-school English classes and that this technology positively influenced the participants' attitudes and enjoyment.

Keywords Attitude · Augmented reality · English education · Pre-school children

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1 Introduction

Interacting with people from different countries is one of the most important requirements of the twenty-first century (Blyth, 2018). English has become a common means of communication in many countries (Evangelou, 2016) and a certain level of proficiency in English has become one of the most important requirements. Therefore, there has been an increasing emphasis on English language education around the world (Dixon et al., 2012; Gámez et al., 2019; MoNE, 2016). As early childhood from 0 to 6 years, when children can quickly pass through all developmental stages, is known to be critical for language learning (Becker & Roos, 2016; Garner & Waajid, 2012; Goh & Taib, 2006; Paquette & Rieg, 2008), a number of countries have lowered the age of foreign language education from primary to pre-school level, which covers the critical period (European Commission, 2012).

As pre-school language education is mostly based on listening and speaking skills (Nation, 2008), the development of listening and comprehension skills, involving the process of discriminating and making sense of sounds, is the key process (Albaladejo et al., 2018). As it is closely related to sounds, vocabulary development is an essential part of language development in pre-school education (Bromley, 2007; Llach, 2017). In the process of vocabulary development, children are expected to say the English equivalents of words (expressive vocabulary) and to know the meaning of words in their native language, referred to as receptive vocabulary (Gámez et al., 2019). However, students may feel anxious and develop negative attitudes towards vocabulary learning as forgetting words is one of the major obstacles in vocabulary learning (Chen & Chung, 2008; Hsu, 2017). Therefore, it is essential to stimulate students' interest in order to encourage the development of positive attitudes towards language learning in general and vocabulary development in particular (MoNE, 2016; Waddington et al., 2018). To achieve this, educators design and use multimedia materials (music, videos, animations, educational software, digital books) to increase students' willingness to learn English, aiming to benefit from the advantages of technology in language education (Blyth, 2018; Christ et al., 2018; Gómez Domínguez, 2018; Sasi et al., 2017; Segers & Verhoeven, 2003). Therefore, supporting vocabulary learning through audio or video materials is important for vocabulary development (Martínez et al., 2017). One of the latest technologies that can contribute to language education, with its particular advantages, is Augmented Reality (AR) applications. Thus, AR-supported multimedia materials (flashcards, matching cards, puzzles with audio, 2D and 3D model, and animation) were used in this study to help children see the visual of the selected vocabulary in addition to hearing its pronunciation. In this way, the children were expected to acquire and produce the words. Taking into account the characteristics of the pre-school learner profile, the present study investigated the impact of AR technology on the vocabulary learning and attitudes of pre-school students.

1.1 AR technology in education

In the twenty-first century, a new learning culture has emerged for learners who are surrounded by the internet and mobile applications (Wojciechowski & Cellary, 2013). Due

to certain characteristics of twenty-first century learners such as their preference for the use of digital audio-visual materials for learning (ISTE, 2016), the need to construct empirical learning contexts seems to have increased (Johnson et al., 2012). AR technology, which is increasingly used in educational contexts, consists of real objects or printed materials identified as markers, a tool that converts the information on the markers into digital data, and a screen presenting the digital data as 2D or 3D images that can be viewed from different angles (Azuma, 2016; Billinghurst et al., 2001; Kaufmann, 2004; Turkan et al., 2017). This technology allows students to interact with real and virtual objects simultaneously (Martínez et al., 2016; Wu et al., 2013; Yuen et al., 2011). AR technology supports a variety of virtual materials such as text, audio, images, 2D and 3D objects, video and animation (Taskiran, 2019; Wojciechowski & Cellary, 2013). AR applications, with which these materials can be used in portable smart devices, allow students to learn without temporal and contextual constraints (Castellanos & Pérez, 2017). As it does not require complex technology, AR can be considered advantageous due to its ease of use and user-friendliness (Blyth, 2018; Ismaeel & Al Mulhim, 2019; Solak & Cakir, 2016). Therefore, there has been an increase in its integration into formal and informal education (Lee, 2012; Wang et al., 2018).

Using AR technology, objects or situations which are difficult to observe in class and out of class can be explored in a 3D version as if they were real (Wu et al., 2013). This process is considered magical by students (Yilmaz, 2016). Concretising abstract or complex knowledge attracts students' attention to learning (Billinghurst et al., 2001; Wojciechowski & Cellary, 2013) and makes it easier for them to visualise abstract information in their minds (Castellanos & Pérez, 2017; Turkan et al., 2017). The observation of everyday events in real learning contexts (Cai et al., 2014) and the opportunities for visualisation and interaction are the features that distinguish AR-supported materials from other multimedia materials (Kaufmann, 2004; Lee, 2012; Martínez et al., 2016). These features activate students by giving them the chance to learn by doing while having fun (Dunleavy et al., 2008; Wang et al., 2018), increase students' interaction with each other, stimulate their motivation to learn (Chang et al., 2014; Dalim et al., 2020; Redondo et al., 2020; Taskiran, 2019), and allow them to learn at their own pace by providing contexts that facilitate learning (Wojciechowski & Cellary, 2013; Wu et al., 2013). Considering its pedagogical potential, Fig. 1 shows some of the AR-based studies in different fields.

As can be seen in Fig. 1, there are a number of studies conducted at different educational levels using various AR materials. This variety points at the popularity of AR in different fields. There are also studies on language education, however the number of studies on pre-school language education is quite limited. Focusing this study on teaching English vocabulary in pre-school aims to support and strengthen the existing studies in the literature. Figure 2 displays the variables examined in AR studies in the relevant literature.

Figure 2 shows that most of the studies compared AR applications with traditional teaching techniques in terms of different variables. While most of the results were in favor of AR technology (Akçayır et al., 2016; Dalim et al., 2020; Gattullo et al., 2019; Ismaeel & Al Mulhim, 2019; Küçük et al., 2016; Pan et al., 2021; Redondo et al., 2020), there are also some studies that show no difference between AR and traditional applications (Chen & Chan, 2019; Hsu, 2017; Turkan et al., 2017). At

Fig. 1 AR-based studies in different fields

this point, it is seen that the results in the literature on the effect of AR-supported technologies in education compared to traditional methods are inconsistent. There are many AR studies at different educational levels from primary school (Hsu, 2017, 2019; Solak & Cakir, 2016; Tosik Gün & Atasoy, 2017) and high school (Liou et al., 2017; Sırakaya & Kılıç Çakmak, 2018; Wojciechowski & Cellary, 2013) to university level (Akçayır et al., 2016; Küçük et al, 2016; Sirakaya, & Kilic Cakmak, 2018; Taskiran, 2019; Turkan et al., 2017). Though not many in number, there are also some AR studies conducted with pre-school children who are in need of concretization of information because of their age (Çevik et al., 2017; Chen & Chan, 2019; Gecu-Parmaksiz & Delialioglu, 2019; Huang et al., 2016; Pan et al., 2021; Redondo et al., 2020; Yilmaz, 2016; Yilmaz et al., 2017). However, among these studies, there are few that focus on teaching English vocabulary (Çevik et al., 2017; Chen & Chan, 2019; Pan et al., 2021; Redondo et al., 2020).

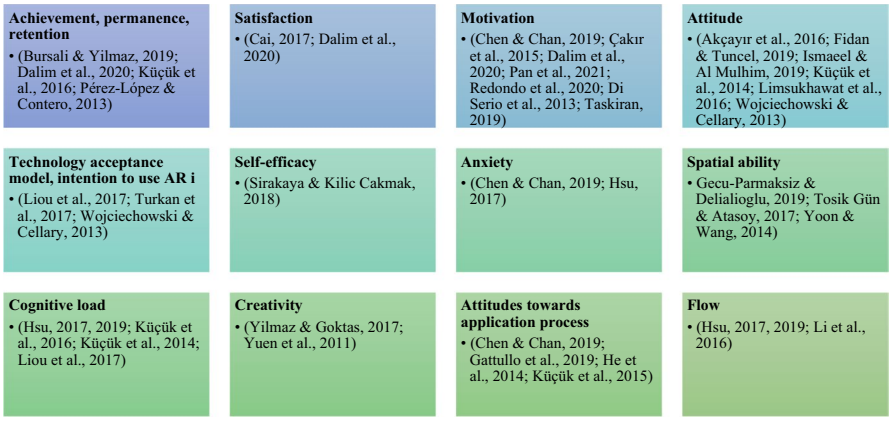


Fig. 2 Variables examined in AR studies

1.2 AR integration in pre-school English education

Vocabulary development is essential in pre-school language education. However, this process may not be easy for every child (Chen & Chan, 2019; Dixon et al., 2012). Therefore, AR technology can support vocabulary development by enriching flashcards with QR codes, written formats, and images. Multimedia materials such as text, audio, images, 2D and 3D objects, videos and animations can be integrated into these markers to address linguistic and visual intelligence through different learning channels (Lee et al., 2019; Li et al., 2016; Martínez et al., 2016, 2017; Pan et al., 2021; Safar et al., 2017). This opportunity allows students to remember the vocabulary items more easily by making a connection between what they hear and see (Chen & Chan, 2019; Wu et al., 2013).

When evaluating the literature on studies in this field, the process of learning English with AR-supported and traditional methods has been compared in the literature, and it has been found that AR applications provide more positive results. According to the studies, students' level of learning and word recall improved (Akçayır & Akçayır, 2016; Barreira et al., 2012; Castañeda et al., 2018; Ho et al., 2017; Ibrahim et al., 2018) and their motivation was high (Çakır et al., 2015; Solak & Cakir, 2016). Hsieh and Lee (2008) found that students' reading, comprehension, listening, and speaking skills can progress more in AR-supported English teaching compared to traditional teaching. However, other studies did not reveal positive results.

Studies using AR in English language teaching are categorised by educational level and summarised in the Appendix. In an AR implementation with primary school students, Chen and Wang (2015) found that neither learning style nor prior language proficiency affected students' motivation to learn. Martínez et al. (2017) found that although the use of AR applications with pre-school children had positive results in terms of motivation and performance, there were also several difficulties during the implementation process. The researchers noted that the large number of students required more technical materials such as tablets and Wi-Fi devices, that the AR

application sometimes caused problems in recognising the markers, that it was difficult to hear the sounds in the AR application due to noise in the classroom, and that students should listen to the sounds from the tablets in small groups. Chen and Chan (2019) found that the teaching of English to pre-school children using flashcards with and without AR support produced positive results in both groups. There was no significant difference in vocabulary teaching between the groups, although the students liked the AR application. Pan et al. (2021) compared AR-supported 3D materials with traditional materials for teaching English alphabet to pre-school children and found that children using AR could name letters quickly, but the motivation increased at a similar rate in both groups. In their systematic review study, Akçayır and Akçayır (2017) found that such AR-supported practices are mostly used in K-12 and universities. There are only a few studies investigating different variables related to the effectiveness of AR in pre-school education (Çevik et al., 2017; Dalim et al., 2020; He et al., 2014; Martínez et al., 2017; Pan et al., 2021; Redondo et al., 2020). In addition, some studies are related to the usability of developed AR applications (Chen et al., 2017; Hsieh & Lee, 2008; Lee et al., 2019; Li et al., 2016), which seems to highlight the need for research examining the effects of practical AR implementation.

Considering the importance of pedagogical implications suggested by academic studies (Chen & Chan, 2019), this research is expected to reveal practical suggestions regarding the implementation of AR-supported instruction in pre-school language education. In this design, pre-school children were taught English vocabulary and attempted to develop their vocabulary using AR-supported flashcards, matching cards and puzzles. In addition, the process of developing and implementing AR-supported materials is described in detail, which is also intended to guide teachers and practitioners.

1.3 Attitude towards AR integration in pre-school English education

Attitude can guide individuals to adopt certain behaviours. Within the specific case of technology integration, an individual's perception of the ease and usefulness of the technology is thought to have positive or negative impact on their attitude (Yilmaz, 2016). In this sense, the effectiveness of technology integration in the classroom is determined by students' attitudes towards new technologies (Wojciechowski & Cellary, 2013). It can be concluded that the increasing popularity of AR integration is based on students' positive attitudes towards this technology (Sırakaya & Kılıç Çakmak, 2018). As AR technology combines tactile, auditory and visual channels of learning, it has been reported to increase children's willingness, enthusiasm and motivation (He et al., 2014). The interactive experiences that students have in adopting such technology contribute to higher levels of motivation, as well as the creation of enjoyment and positive emotions in the classroom, compared to traditional approaches (Redondo et al., 2020). However, practical problems experienced in the implementation process can also discourage children and negatively affect their attitudes (Ismaeel et al., 2019; Wu et al., 2013). Therefore, to avoid creating negative attitudes among students, AR technology should be integrated through effective planning and meaningful design (Fonseca et al., 2014; Yilmaz et al., 2017).

Literature on attitudes towards AR technology covers such educational fields as science (Akçayır et al., 2016; Cai et al., 2017; Fidan & Tuncel, 2019), mathematics and geometry (Atasoy et al., 2017), engineering (Turkan et al., 2017), instructional technologies (Ismaeel & Al Mulhim, 2019), Turkish language education (Bursali & Yilmaz, 2019; Yilmaz et al., 2017), geography (Liou et al., 2017; Sırakaya & Kılıç Çakmak, 2018) and chemistry (Wojciechowski & Cellary, 2013). The majority of these studies showed that students using AR-based materials developed positive attitudes towards the course, with further interest and attention in and enjoyment of the course.

In the specific field of English language education, there is a lack of research on attitudes towards English language teaching with AR support. Limsukhawat et al. (2016) conducted a study on the attitudes of first grade students, Küçük et al. (2014) on fifth grade students, Li et al. (2016) on language teaching experts, and Hsieh (2016) on both teachers and students. However, there are limited studies investigating pre-school students' attitudes towards AR technology in teaching English. There are only a few studies on teachers' attitudes towards integrating AR in pre-school English teaching (Chen & Chan, 2019; He et al., 2014). Setting out from this gap, this study was designed to investigate pre-school children's performance in learning English vocabulary using AR while examining their attitudes, positive/negative emotions and enjoyment regarding the AR-supported language education process.

1.4 Purpose of the study

The reviewed studies generally investigated the effect of AR flaschcards on pre-schoolers' English vocabulary learning, mostly revealing positive results (Çevik et al., 2017; Pan et al., 2021; Redondo et al., 2020). Chen and Chan (2019) found that although children enjoyed the AR flashcard activities, there was no significant difference between groups regarding vocabulary learning. Given the inconsistency in the literature comparing AR and traditional teaching, and the limited number of studies on English language teaching supported by AR technology in pre-school education, this study focuses on the use of AR in pre-school English teaching. In this study, matching cards and puzzles were used as AR-supported materials in addition to flashcards. These materials were supported by an AR application that included audio, 2D—3D models and animation. In this way, the children were able to see the visual representation of the word as well as listening to its English pronunciation.

In order for young children to be enthusiastic about English language learning, it is important to organise activities that encourage them to have positive feelings about the lesson and to have fun during the lesson (Küçük et al., 2014; Redondo et al., 2020). AR-based English learning can also stimulate pre-schoolers' desire, excitement and enthusiasm by combining tactile, auditory and visual senses (He et al., 2014). As AR technology provides a student-centred learning context, it is essential to examine the attitudes of students towards this particular technology (Wojciechowski & Cellary, 2013; Yilmaz et al., 2017). As attitudes towards AR have an impact on the effective and efficient use of such activities in the classroom (Redondo et al., 2020; Sırakaya et al., 2018). According to Küçük et al. (2014), students are more successful when they have

a positive attitude towards activities supported by AR. They also stated that those who are satisfied with such activities are less anxious when using the AR application, and have a higher desire to continue using such applications in the future.

However, in the study by Chen and Chan (2019), the teachers stated that although the children enjoyed the AR-supported flashcard activities, there were some difficulties in the use of such materials in the kindergarten. Furthermore, technical infrastructure issues and malfunctioning AR applications may cause a lack of interest and dissatisfaction (Redondo et al., 2020). Despite these positive and negative findings in the literature, the lack of studies on attitude, emotions and enjoyment variables in AR-assisted language teaching in preschool is remarkable (Redondo et al., 2020; Yilmaz, 2016; Yilmaz et al., 2017).

Therefore, by providing a new learning experience, this study aimed to investigate the vocabulary learning levels of pre-school students through AR-supported flashcards, matching cards, and puzzles, as well as their attitudes towards the implementation process, positive/negative emotions, and enjoyment. This study will have a significant impact on the effectiveness of AR materials in pre-school English language learning. This study is believed to have the potential guide future research on AR integration in pre-school language education, where the high energy and interest of the learner profile can be directed to the language content with the help of the AR-supported language meterials. In line with these considerations, this study was guided by the following research questions:

In pre-school vocabulary teaching in English with AR technology and without AR technology;

Is there a statistically significant difference between the students' word/concept learning?
Is there a statistically significant difference between the students' attitudes?
Is there a statistically significant difference between the students' emotions?
Is there a statistically significant difference between the students' enjoyment?

2 Method

2.1 Research design

Based on a quasi-experimental design, this study investigated the effects of AR technology on pre-school children's word/concept learning, attitudes, emotions and enjoyment in experimental and control groups. A pre-test was used to assess the knowledge levels of both groups. There was no significant difference between the groups in terms of pre-test scores ($p > 0.05$), indicating that the knowledge levels of both groups were similar at the beginning of the study. Over a four-week period, students in the experimental group received AR-supported materials (flashcards, matching cards and puzzles) prepared according to the course programme while students in the control group received printed versions of the same materials without AR integration. A word/concept test was administered after having applied the AR-based materials. Detailed information on the research design is given in Fig. 3.

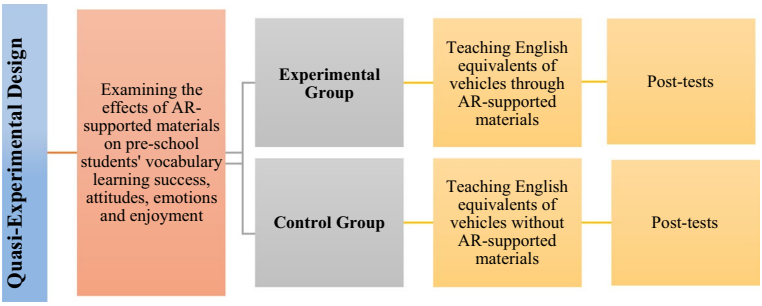


Fig. 3 Research design

Table 1 Distribution of sample in experimental and control groups

	Experimental Group	Control Group	Total
Girls	7	9	16
Boys	12	8	20
Total	19	17	36

2.2 Sampling

The sample of the study consisted of 36 pre-school children aged 4–5 years (19 in the experimental group, 17 in the control group). Convenience sampling was used in accordance with the criteria of accessibility and willingness to participate. Information on the distribution of the sample is given in Table 1.

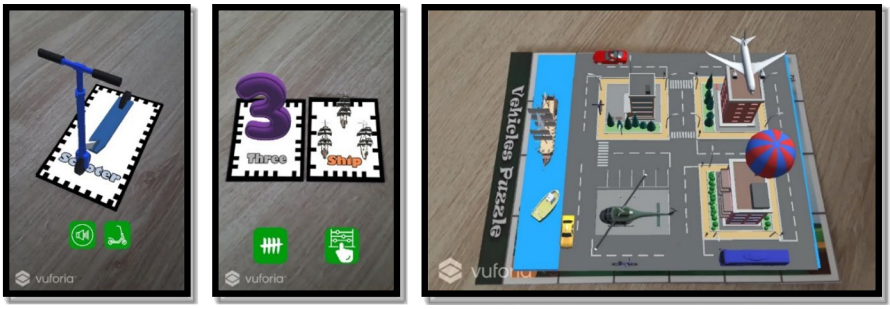
In order to test the similarity of the experimental and control groups, an independent samples t-test was carried out for the pre-test. The analysis showed that there was no significant difference between the two groups in terms of English vocabulary knowledge ($p > 0.05$) and the groups had similar characteristics as shown in Table 2.

2.3 Research material and process

For the purposes of this study, AR-based materials (flashcards, matching cards and puzzles) were designed to teach vehicle names in English to pre-school children. Printed designs of the cards and 3D models of 10 different vehicles were created. Combined in Unity programme, the AR application was prepared. When this application is run in mobile phones, the camera opens and the pre-identified markers turn into 3D models. In this way, the children can see the 3D models of the objects they see in the printed version, listen to the English pronunciation of the objects they see, and interact with

Table 2 Difference in pre-test success levels

Group	n	M	SD	*df*	*t*	*p*
Experimental Group	19	10.00	15.634	34	.960	.344
Control Group	17	5.88	8.702			



AR Flashcard Application **AR Match-card Application** **AR Puzzle Application**

Fig. 4 Screenshots of mobile AR application used in the study

the materials through the touch screen. Figure 4 shows the markers, the AR application targets and the 3D models in the materials (flashcards, matching cards and puzzles).

Prior to the implementation, ethics committee approval was obtained and the necessary permission documents were obtained from the Ministry of National Education. In addition, consent forms were signed by students' parents to obtain their permission. After all ethical procedures were completed, the practices were started in the school. Two experimental groups and two control groups were selected on the basis of random sampling in the classroom where the implementation took place. Over a four-week period, an English teacher taught the selected vehicle names using the AR-supported materials (flashcards, matching cards and puzzles) in the experimental group and printed cards without AR design in the control group. The same English teacher conducted the entire procedure in both groups. A pre-test was done to assess the children's word/concept knowledge of vehicles before the application. The analysis of the pre-test showed no significant difference between the groups ($p > 0.05$). After the analysis, the implementation process started, 2 h per week for a period of 4 weeks. A total of 8 h of AR activities were conducted in both groups. A PowerPoint presentation was used in the first week in both groups. Flashcards were used in the second week, matching cards in the third week and puzzles in the fourth week in the experimental group who did the activities using tablets. In the control group, the activities were done with the printed versions of the same materials without tablets. After the implementation, a word/concept test and an attitude test involving emotions and enjoyment were administered. Figure 5 shows the pictures related to the implementation process.

2.4 Data collection tools

2.4.1 Word/concept test

A ten-item word/concept test was developed by the researchers, two experts in CEIT and one in ELT, in relation to vehicles. The test involved two parts. The first part aimed to assess the participants' ability to say the English equivalent of the item in the visual,

Fig. 5 Images showing the AR material in use by pre-school children

and listen to the Turkish version and say the English equivalent. The second part asked the participants to tell the Turkish meaning of the English item, say the Turkish meaning of the item they listened to in the sentence in English and choose, from among the cards, the related visual of the item the English pronunciation of which they listened to. Two English teachers in the application school were consulted for the clarity, understandability and appropriateness of the test. No problem was reported related to the test. Cronbach Alpha coefficient of the word/concept test was calculated 0.721, revealing the reliability of the test. To make the implementation process easy, a PowerPoint presentation was prepared with instructions. The details of the word/concept test are as follows:

- In the first three questions, the visual of the related item is placed on the right side of the screen. There is an instruction for the practitioner on the left side. (*Ex: Ask the English equivalent of the item in the visual.*)

- In the 4th and 5th questions, the written version of the item in Turkish is on the right side of the screen. There is an instruction for the practitioner on the left side. (*Ex: Say the word "scooter" aloud in Turkish and ask the English equivalent.)*
- In the 6th and 7th questions, all the visuals related to the topic are placed on the right side of the screen. On the left side, there is a sound button with the English pronunciation of the sentence presented in the flashcards. The participants are asked to tell the item they hear in the English sentence. Then, they are asked to choose the related visual from among the cards. There is also an instruction for the practitioner. (*Ex: Ask the child to show the vehicle the English pronunciation of which they listen to.*)
- In the 8th, 9th and 10th questions, on the right side of the screen, there is a sound button with English pronunciation of the item. The participants are asked to push the sound button and tell the Turkish equivalent of the item they listen to in the English sentence. There is also an instruction for the practitioner. (*Ex: Ask the child to say the Turkish equivalent of the item s/he listens to in the English sentence.*)

This test aimed to assess the participants' ability to say the English equivalent of the item they see in the visual, say the English equivalent of the item they listen to in Turkish, understand the item in the English sentence, say the Turkish equivalent of the item they listen to in English and show the related visual. In this way, learning vehicle-related items was checked through different criteria. Besides, checklists were prepared for the practitioners. The answers each participant gave in the test were noted in these checklists. Each true answer in the test was 10 points, and the total score was 100.

2.4.2 Attitude scale

The basis of the attitude scale used in this study was on Macklin and Machleit's (1989) and Giannakos' (2013) studies. There are five questions with visuals in Macklin and Machleit's (1989) attitude scale for pre-school children. The Cronbach Alpha coefficient of the scale was calculated 0.97 in this study. Along with the attitude scale, visuals, as a commonly used tool, enabling children to express their emotional states from among visual representations were used (Giannakos, 2013; Read & MacFarlane, 2006; Yilmaz et al., 2017). As can be seen in Fig. 6, visuals range from very happy (5) to very unhappy (1).

These visuals were involved in the part where demographic information was presented. As regards the children's enjoyment states, questions with "yes/partly/no"

Fig. 6 Visual representations showing children's happiness state

answer options presented in the study of Yilmaz et al (2017) with 0.752 Cronbach Alpha coefficient were also involved in this part. To assess the effectiveness of the practice through tablets, such questions as "Did the practice through the tablet attract your attention?", "Did you have fun in the practice through the tablet?", "Did you like the practice through the tablet?", "Would you like to do the practice through the tablet again?" and "Did you have difficulty in the practice through the tablet?" were asked. The Cronbach Alpha coefficient was 0.759 for the related items.

2.5 Data analysis

The skewness and kurtosis values of each variable were analyzed for the normality of distribution. As displayed in Table 3, data sets except attitude and enjoyment variables had normal distribution.

Paired sample t-test was used to determine the difference between pre-test and post-test scores in both groups. Since the data had normal distribution, independent sample t-test was used to determine the difference between the groups in terms of word/concept learning levels and their emotions during applications. Since the data did not have normal distribution, Mann Whitney U test was run to determine the difference in relation to the attitudes and enjoyment levels.

3 Findings

3.1 Difference between groups in terms of English word/concept learning level

Descriptive statistics were used to analyze the pre-test and post-test scores in relation to word/concept learning of groups in which AR applications were used and not used. The results are presented in Table 4.

When Table 4 is analyzed, it is seen that post-test scores in the experimental group were higher than those in the control group. Whether there was a significant difference between both groups in relation to pre-test post-test word/concept learning levels was also determined. The results of the paired sample t-test are shown in Table 5.

Table 5 shows that there is a significant difference between pre-test and post-test scores in relation to word/concept learning in the experimental group ($t(18) = -17.474$, $p < 0.05$). A significant difference was also found between pre-test and post-test scores in relation to word/concept learning in the control group ($t(16) = -12.158$, $p < 0.05$). The difference was in favor of the post-tests in both groups.

Table 3 Skewness and kurtosis values of each variable

	Vocabulary Test		Attitude		Enjoyment		Emotion	
	Group-1	Group-2	Group-1	Group-2	Group-1	Group-2	Group-1	Group-2
Skewness	-.583	.552	-3.367	.659	-3.933	-.872	-1.545	-1.629
Kurtosis	-.572	2.414	12.474	.003	16.165	1.198	.419	2.558

Table 4 Pre-test post-test results of the groups in relation to word/concept learning

	Experimental Group (n = 19)		Control Group (n = 17)	
	M	SD	M	SD
Pre-test	10.00	15.634	5.88	8.703
Post-test	85.00	12.247	55.88	13.019

Table 5 In-group pre-test post-test differences in relation to word/concept learning

Groups (Pre test-Post test)	M	SD	*df*	*t*	*p*
Experimental Group	-75.00	18.708	18	-17.474	.000
Control Group			16	-12.158	.000

Independent sample t-test was conducted to understand whether there is a significant difference between both groups in terms of post-test scores. The results are presented in Table 6.

As displayed in Table 6, there is a significant difference in post-test scores of both groups in terms of retention ($t(34) = 6.913$, $p < 0.05$). The mean score of the experimental group ($M = 85.00$, $SD = 12.247$) was higher than that of the control group ($M = 55.882$, $SD = 13.019$).

3.2 Differences in the attitude between the groups in relation to implementation process

Figure 7 shows the attitude levels in both groups towards the implementation process.

Figure 7 indicates that attitude levels in both groups are positive considering the sub-dimensions; happy, like, great, satisfaction and excited, and the experimental group had higher levels compared to the control group.

Mann Whitney U test was conducted to understand whether there was significant difference between both groups in terms of attitudes towards the implementation process, which is shown in Table 7.

As displayed in Table 7, there was a significant difference between the attitude levels of both groups in relation to the implementation process ($U = 36.500$, $p < 0.05$) in favor of the experimental group.

Table 6 Differences between post-test scores of both groups in relation to word/concept learning

	n	M	SD	*df*	*t*	*p*
Experimental Group	19	85.00	12.247	34	6.913	.000
Control Group	17	55.882	13.019			

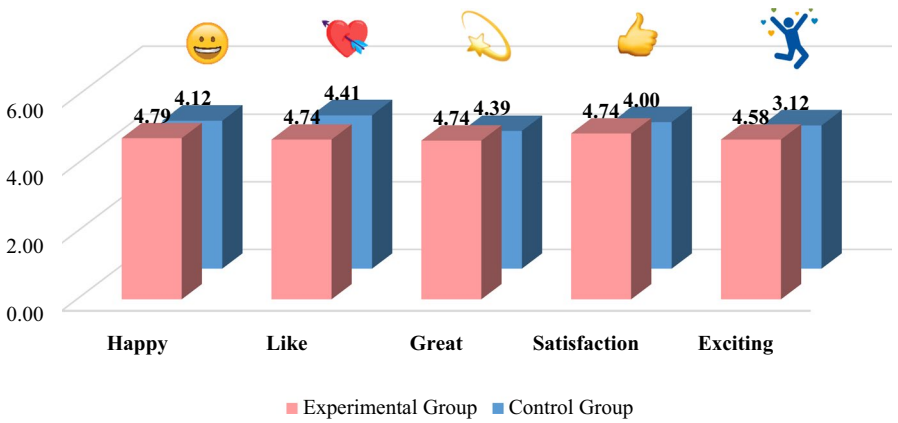


Fig. 7 Attitude levels in relation to sub-dimensions

3.3 Differences in the emotions between the groups in relation to the implementation process

Figure 8 presents the emotion levels in both groups in relation to the implementation process.

When Fig. 8 is analyzed, it is seen that while the participants in the experimental group had positive feelings towards the application, the level for the same variable was lower in the control group. There were also some students with undecided and unhappy emotional states in the control group.

Independent sample t-test was conducted to understand whether there was a significant difference between the emotion levels in both groups in relation to the implementation process, which is displayed in Table 8.

Table 8 shows that there was not a significant difference between both groups in relation to emotion states regarding the implementation process ($t(22) = 1.629$, $p > 0.05$).

3.4 Differences in the enjoyment levels between the groups in relation to the implementation process

Figure 9 presents the enjoyment levels of both groups in relation to the implementation process.

Table 7 Differences in relation to the implementation process in both groups

	n	Mean Rank	Sum of Ranks	*U*	*Z*	*p*
Experimental Group	19	25.08	476.50	36.500	-4.092	.000
Control Group	17	11.15	189.50			

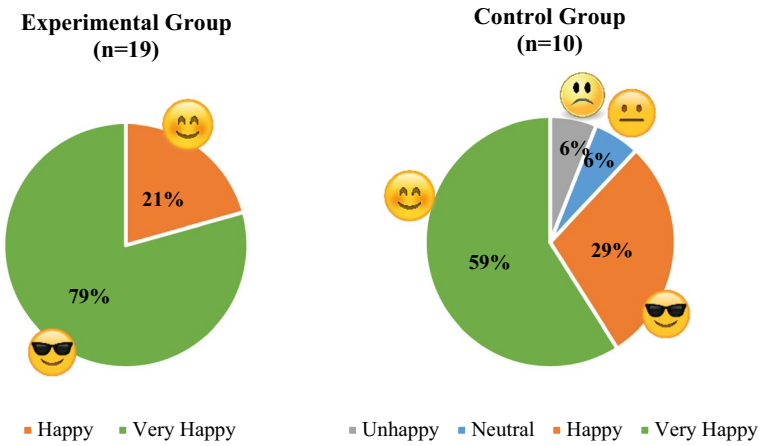


Fig. 8 Emotion levels in the groups in relation to the implementation process

Table 8 Differences between the groups in relation to emotions regarding the implementation process

	n	M	SD	*df*	*t*	*p*
Experimental Group	19	4.79	.419	22.462	1.629	.117
Control Group	17	4.41	.870			

Figure 9 points at the higher level in the experimental group, compared to the control group, in terms of enjoyment with its interesting, fun, like using, willing to use and perceived difficulty dimensions.

Independent sample t-test was conducted to determine whether there was a significant difference between the groups in terms of their enjoyment level during the application. The results are presented in Table 9.

Table 9 shows that there was a significant difference between the groups in relation their enjoyment levels in the implementation process ($U = 72.500$, $p < 0.05$), in favor of the experimental group.

4 Discussion

4.1 English word/concept learning

In terms of English word/concept learning, there was a significant difference between the pre-test and post-test scores of both groups. This case shows the positive contribution of the flashcards, matching cards, and puzzles, with or without the AR design, to the English word/concept learning of pre-school children. Çelik and Yangın Ersanlı (2022) found that the foreign language achievement of students who participated in the gamified AR activities was higher than that of the control group. Chen and Chan (2019) reported that learning English with flashcards increased the success of both groups. Materials such as flashcards presenting connections between vocabulary words and their meanings through simple images can be considered

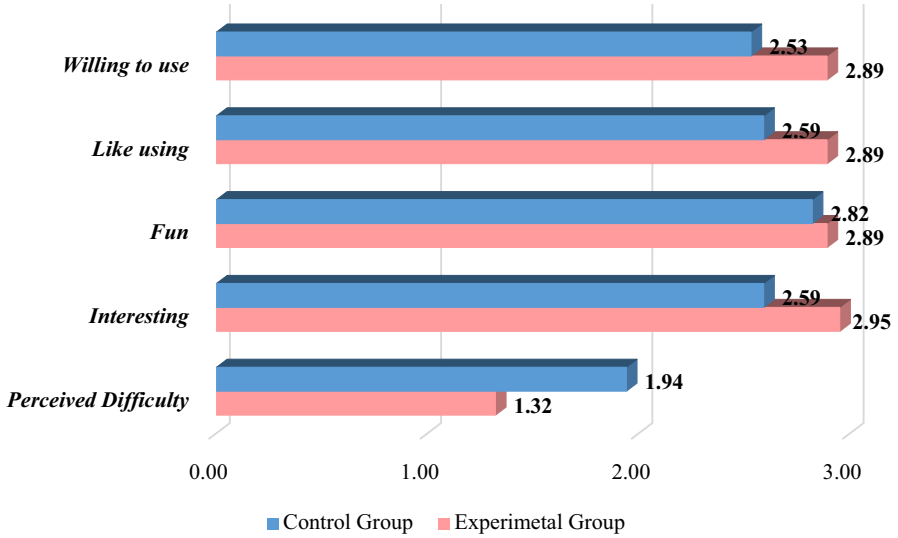


Fig. 9 Enjoyment levels of the groups in relation to sub-dimensions

important in English learning (Ibrahim et al., 2018; Liu, 2009; Liu & Tsai, 2013). Thus, in this study, the reference to different learning channels stimulated with AR technology can be thought to help children learn the selected items more effectively.

In this study, there was a significant difference between the experimental and control groups in terms of word/concept learning, in favor of the experimental group. Ustun et al (2022) stressed that AR-supported language learning contributed to better comprehension, emphasising that AR-integrated activities can help develop language skills such as pronunciation and listening. This result indicates that AR applications in which flashcards, matching cards and puzzles were used enabled children to use the markers themselves, touch the tablets, see the 3D image of the vehicles on the tablets and listen to the English pronunciation of the items; and these chances increased their success in word/concept learning. Because the combination of auditory, visual, and tactile elements attracts children's attention in learning, the construction of concrete meaning can be facilitated (Cheng, 2017; Liu, 2009; Liu & Tsai, 2013). Pointing at its positive effects, Pan et al. (2021) also noted that AR applications help children name the English alphabet faster. Similar conclusions were also reported by Chen et al. (2017), Çevik et al. (2017) and Safar et al. (2017). Therefore, it can be said that AR-supported flashcards can enrich children's language learning experience by referring to visual and auditory channels (Chen & Chan, 2019). In other words, such materials can increase the permanence of learning

Table 9 Differences in the enjoyment levels between the groups in relation to implementation process

	n	Mean Rank	Sum of Ranks	*U*	*Z*	*p*
Experimental Group	19	23.18	440.50	72.500	-3.105	.002
Control Group	17	13.26	225.50			

by addressing different learning channels (Martínez et al., 2017). They can also help children make connections between what they see and hear, thereby increasing their retention (Gattullo et al., 2019; Ho et al., 2017; Liu, 2009; Wu et al., 2013). Thus, based on the results of this study, it can be inferred that the AR-supported flashcards, matching cards and puzzles in our study can also be used as educational tools to improve pre-school children's cognitive and listening skills, as also reported by Yilmaz et al. (2017), who used augmented reality picture books in their study.

4.2 Attitude towards the AR implementation process

The results revealed the positive attitudes with happy, like, great, satisfaction and exciting sub-dimensions, towards AR-supported English learning, and the experimental group had higher scores compared to the control group. Çelik and Yangın Ersanlı (2022) found that students developed positive attitudes towards gamified AR activities in foreign language learning and were satisfied with such activities. Ustun et al. (2022) found that AR significantly improved students' attitudes towards English language courses and increased their self-efficacy beliefs in English language learning. Bursali and Yilmaz (2019) also revealed that students were not anxious about the use of AR materials; instead, they were satisfied with the use of AR applications, and this situation had a very positive impact on their attitudes. A similar result is also reported by Castañeda et al. (2018), who found that the AR application provided a fun learning environment and increased the learning motivation of primary school students. It can be stated that AR-supported learning offers more interactive chances for students and stimulates their participation. Since AR-supported applications attract students' attention and increase their willingness to participate (Kim & Kim, 2018; Wu et al., 2013), the participants in the experimental group of our study may have felt more satisfied and motivated (Lee et al., 2019; Zhang, 2018).

In this study, there was a significant difference between the attitudes of both groups, in favor of the experimental group, towards the implementation process. Sharing similar results, Redondo et al. (2020) found that children having interactive experiences with AR flashcards had more positive attitudes than the traditional group. Limsukhawat et al. (2016) expressed that first-grade students developed positive attitudes towards AR applications in learning English phonetics. Since the participants of our study experienced a new learning situation different from the traditional mode and interacted with the educational content, they may have developed positive attitudes towards the application.

Relevant literature presents studies on learner attitudes towards AR-supported English education (Hsieh, 2016; Küçük et al., 2014; Limsukhawat et al., 2016). Most of these studies were conducted with different learner profiles other than pre-school students and examined attitude as a sub-dimension of the usability variable. As regards the attitude variable, there are some studies examining the attitudes of practitioners such as teachers towards AR applications (Chen & Chan, 2019; He et al., 2014). However, since AR applications also affect student attitudes and performance (Wojciechowski & Cellary, 2013; Yilmaz et al., 2017), examining students' attitudes towards these applications is critical (Küçük et al., 2014). Therefore, desiging AR

applications to promote pre-school children's willingness and motivation to learn English is essential (Blyth, 2018; Gómez Domínguez, 2018). Min and Yu (2023) found that students at different grade levels generally had positive attitudes towards AR tools in their bibliometric analysis of language learning. However, depending on the results and conclusions in our study, it is recommended that further studies should be conducted to verify the contribution of AR-based flashcards, matching cards and puzzles to pre-school English learning.

4.3 Emotion in the AR implementation process

Most of the participants in the experimental group had positive feelings towards the AR application. Similarly, Redondo et al. (2020) found that students using the AR application developed more positive emotions than the traditional group. Similar results were reported by Taskiran (2019), who also found that students' interaction with AR materials increased interest in English language learning and enjoyment of the course. As also reported by Yilmaz et al. (2017), AR technology, which is considered magic by children, may have encouraged the children to have positive feelings towards the application since it gave them the chance to see the 3D models and listen to the sounds.

The participants in the control group had lower positive emotional levels compared to those in the experimental group, there were also undecided and unhappy participants in the control group. However, no statistically significant difference between the groups in terms of their emotions towards the implementation process was reported. Therefore, it can be concluded that flashcards, either designed with or without AR technology, contribute to learning with an emphasis on the vocabulary item and its meaning (Ibrahim et al., 2018; Redondo et al., 2020), and matching cards and puzzles promote students' active participation, increasing positive feelings. Yet, Cheng (2017) also noted that AR-supported practices may negatively affect the learning process since some students may focus on having fun instead of learning, which refers to the negative characteristic of such tools as potential sources of distraction. Therefore, future studies can be conducted to identify further advantages and disadvantages of AR-supported practices to create and maintain effective and successful learning enironments.

4.4 Enjoyment in relation to the AR implementation process

There was a significant difference, in favor of the experimental group, in relation to the enjoyment levels regarding learning English. Higher levels in terms of the sub-dimensions of enjoyment (interesting, fun, like using, willing to use and perceived difficulty) in the experimental group attract attention. In line with this result, Ustun et al. (2022) stated that AR-supported foreign language teaching increases interest and participation in the lesson and makes the lesson more enjoyable. Redondo et al. (2020) also noted that AR applications can be used to improve the perceived enjoyment of learning, in other words, to create a fun learning atmosphere. The study by Dalim et al. (2020) also indicated that children have fun in AR-supported activities and become more willing to learn. Similarly, Chen and Chan (2019) reported that teachers of pre-school children

favor AR-supported English teaching since the materials attract children's attention and enrich their learning experience. Martínez et al. (2016) stated that AR-supported matching cubes increased children's curiosity to learn. Relevant literature shows that AR technology can make vocabulary learning, which is an important part of English language development, enjoyable and effective (Akçayır et al., 2016; Dalim et al., 2020; Küçük et al., 2014), and create a fun learning context that attracts children's attention and affects their learning performance (Giannakos, 2013; Limsukhawat et al., 2016; Pan et al., 2021; Wojciechowski & Cellary, 2013; Zhang, 2018). In line with these conclusions, AR-supported English learning contexts are to be created considering the potential contributions of the technology (Castañeda et al., 2018; Lee et al., 2019).

The results of this study showed that the vocabulary learning levels of the students in the experimental group were higher compared to those in the control group, as also reported by (Giannakos, 2013; Redondo et al., 2020). This situation may have resulted from the high enjoyment levels in the experimental group. Thus, future research can examine the relationship between enjoyment and success levels as there seems to be some mutual relationship between these variables.

5 Conclusion and recommendations

The results of this study revealed that children in the experimental group using AR-supported materials performed better than those in the control group in vocabulary learning in English. In addition, the attitudes, emotions and enjoyment states of the children in the experimental group were higher than those of the control group children. Cao and Yu (2023) found that students' learning outcomes were significantly higher and their attitudes towards AR-supported education were more positive than those who did not use AR technologies in their meta-analysis of the use of AR in education. Though the significant place of learners' attitudes towards courses and course materials has been underlined in the literature (Dalim et al., 2020; Liou et al., 2017; Wojciechowski & Cellary, 2013), it is surprising that there is limited research on children's attitudes towards AR-supported language learning. Thus, future research is suggested to focus on pre-school children's attitudes towards AR technology in language education.

Yet, the possible negative effects of the problems in using AR applications, learner differences and complexity in application interface should also be taken into account (Bujak et al., 2013). At this point, careful planning of AR-supported applications and effective management of the educational process can be suggested. Given that children's positive attitudes are influenced by the feelings they experience during activities, it is possible to create efficient designs with an easy-to-use interface that will attract children's attention while developing AR applications. In addition, it is advised that realistic, colorful, and animated 3D models be used in material design in accordance with children's levels because seeing and hearing 3D models using AR technology helps children feel better and pleased. It has been also noted that when children see the tablets, they become overly excited, and they sometimes fail to listen to their teachers. It is critical to be aware of these concerns and take precautions when using AR applications.

Appendix 1

Table 10 Literature on AR integration in English education

Level	Study	Participants	Research Design and Purpose	Variables	Results
Under/graduate	Gattullo et al. (2019)	22 students	Case study Examining AR-supported vs. PDF-supported technical English learning in engineering	Usability of AR application Vocabulary learning Interview	AR-supported material offered more effective visuals and promoted retention compared to pdf supported material
	Taskiran (2019)	83 students	Quantitative research Examining EFL students' motivation in learning English through AR mobile games	Intrinsic Motivation Inventory	EFL students considered AR mobile game motivating and enjoyable
	Ibrahim et al. (2018)	52 students	Quasi-experimental research Comparing AR-supported and traditional flashcards in vocabulary learning	Vocabulary learning Retention/Recall Perceptions of AR	AR group had higher retention rates compared to the group using traditional flashcards. Most of the teachers considered AR application more enjoyable
	Ho et al. (2017)	90 participants (18–30 years old)	Quasi-experimental research Comparing English learning performances of students with different learning strategies and cognitive styles	Vocabulary learning strategies (enforcing, semi-enforcing, and non-enforcing instructions) cognitive styles (field-dependent/independent)	Learning strategies and participants' cognitive styles affected learner performance in using AR application The field-dependent students using enforcing learning strategy used the AR application more effectively and had better learning performance compared to field-independent students
	Akçayır and Akçayır (2016)	91 students	Quasi-experimental research Comparing AR-supported vs. traditional vocabulary learning	Vocabulary learning Retention	AR group was more successful in vocabulary learning and higher retention compared to the traditional group

Table 10 (continued)

Level	Study	Participants	Research Design and Purpose	Variables	Results
	Li et al. (2016)	6 English language professors	Qualitative Research Examining AR-supported application in English teaching in line with the flow theory	Usability of AR application	It was found that the AR application was effective and innovative in teaching English, but the videos should be clearer and more understandable
	Çakır et al. (2015)	60 students	Quasi-experimental research Comparing AR-supported vs. traditional vocabulary learning	Vocabulary learning Motivation in AR	AR group performed better in vocabulary learning than the traditional group. The students had higher levels of motivation in using AR
	Li et al. (2014)	5 students	Quantitative research Examining AR-supported vocabulary learning in line with ARCS motivation theory	Motivation in vocabulary learning Interview	AR-supported vocabulary learning increased the students' motivation
	Liu & Tsai (2013)	5 students	Mixed research Analyzing students' writing skills after attending trips and answering questions	Composition skills Student experience	The mobile AR application developed the EFL students' ability to express and compose writing through visual interaction. In this way, the students developed their grammar knowledge and writing skills and created meaningful texts
High school	Hsieh (2016)	69 students (7^{th} grade) 3 teachers	Quantitative research Examining students' and teachers' perceptions of ARELS application	Students' Interests in, Acceptance and Attitude toward, Desire for use of and Teachers' Viewpoints, Advantages, Weaknesses in ARELS	Students and teachers mostly had positive attitudes towards the ARELS application
	Solak and Cakir (2016)	61 students (5^{th} grade)	Quasi-experimental research Comparing AR-supported vs. traditional vocabulary learning	Vocabulary learning Retention Motivation	AR group had higher levels of achievement and retention compared to the traditional group. In addition, AR technology was shown to decrease the achievement difference between high-motivated and low-motivated students

Table 10 (continued)

Level	Study	Participants	Research Design and Purpose	Variables	Results
	Küçük et al. (2014)	122 students (5^{th} grade)	Causal-comparative research Examining attitudes and cognitive load of learners participating in AR application in learning English and examining the relationship between the variables	Vocabulary learning Attitude Cognitive load	The students with higher achievement levels had more positive attitudes towards AR applications compared to those with lower achievement levels. The students using the AR application enjoyed classes and had lower levels of anxiety and cognitive load
	Liu (2009)	64 students (7^{th} grade) 3 teachers	Quasi-experimental research and Case study Comparing HELLO English Learning AR application and traditional ways in developing English listening and speaking skills	Listening and speaking skills Interview	Achievement levels of the AR group were higher than the traditional group. The students maintained that AR increased their motivation and stimulated their language development
Primary school	Hsu (2019)	20 students (3^{rd} grade)	Quasi-experimental research Comparing the application of collective game-based and sequential-mission gaming design in terms of gender, achievement, flow experience and cognitive load	Vocabulary learning Flow experience Cognitive load	Both groups had similarly high levels of learning. The students in the collective game-based design had higher flow experience and lower cognitive load than those in the sequential-mission game. Male students had higher flow experience than female students
	Castañeda et al. (2018)	163 students (1^{st} and 3^{rd} grades)	Quantitative research Comparing AR-supported gamification and traditional English teaching in terms of learner performance	English learning performance before and after the application	Learning performances of the AR group were better than the traditional group
	Hsu (2017)	38 students (3^{rd} grade)	Quasi-experimental research Comparing learning experiences of students with different learning styles in self-directed vs. task-based AR-supported applications	Flow experience Cognitive load Foreign language learning anxiety Learning effectiveness Learning styles	Though the flow experience of the self-directed group was higher than that of the task-based AR group, both groups had similarly high levels of learning effectiveness. Learners with serial learning style had lower cognitive load and anxiety compared to those with global learning style

Table 10 (continued)

Level	Study	Participants	Research Design and Purpose	Variables	Results
	Limsukhawat et al. (2016)	36 students (1st grade)	Quantitative research English Phonics Learning Performance of ESL Learners	English Phonics Learning Performance before and after the application Attitude	The students using the AR application developed their English Phonics Learning performance and developed positive attitudes towards the application
	Chen & Wang (2015)	52 students (3rd grade)	Quasi-experimental research Comparing vocabulary learning performance and levels of students participating in AR-supported learning	Vocabulary learning Learning style Prior English proficiency Motivation Learning experience	Learners with field dependent learning styles and prior English proficiency had higher vocabulary learning levels. However, these variables did not affect their learning motivation
	Mahadzir and Phung (2013)	5 students (1st grade)	Qualitative research Examining motivational states of students using AR pop-up book according to ARCS model	Motivation (via Observation Interviews)	The students were motivated to learn animal names in English
	Barreira et al. (2012)	26 students (3rd grade)	Quasi-experimental research Comparing vocabulary learning with MOW AR application and traditional ways	Vocabulary learning	There was significant improvement in English vocabulary learning of the students in the experimental group compared to those in the control group
Pre-school	Pan et al. (2021)	76 students (pre-kindergarten)	Quasi-experimental research Comparing AR-supported 3D materials and traditional 2D materials in learning English alphabet	Learning English alphabet Motivation Teacher perception	AR-group students named the English alphabet faster, but motivational levels in both groups were similar
	Dalim et al. (2020)	120 students (4–6 years old)	Quasi-experimental research Comparing student groups using and not using TeachAR application in learning colors and shapes in English	Achievement Task completion time Motivation Enjoyment/Interest	The experimental group students were more successful in vocabulary learning, more motivated, had more fun and completed the tasks faster

Table 10 (continued)

Level	Study	Participants	Research Design and Purpose	Variables	Results
	Redondo et al. (2020)	102 students (3–5 years old)	Quasi-experimental research Comparing vocabulary learning through AR application vs. traditional ways	Achievement Motivation Enjoyment Positive emotional and social relationships	Motivation, learning and socio-affective states of the experimental group were higher
	Chen and Chan (2019)	98 students (5–6 years old)	Quasi-experimental research Comparing vocabulary learning with flashcards through AR application vs. traditional ways	Vocabulary learning Teacher perception	There was a significant difference between the pre-test and post-test results of both groups. Flashcards were effective in both groups. Though the students enjoyed using the AR application, there was not a significant difference between both groups
	Lee et al. (2019)	30 Kindergarten Parents and a teacher	Quantitative research Examining usability of the AR application to teach vocabulary in English and teacher and parent experiences	Usability of AR application Teacher and parent experience	Most of the participants considered AR application as user-friendly and effective in learning English. However, teachers had concerns about classroom management, and parents had concerns about excessive use of electronic devices
	Chen et al. (2017)	20 students (3–5 years old)	Quasi-experimental research Comparing vocabulary teaching through AR-supported multimedia materials and traditional teaching ways	Vocabulary learning Usability of AR application Interest and participation	The students in the AR group had higher levels of retention, learning interest and participation
	Çevik et al. (2017)	31 students (5–6 years old)	Quasi-experimental research Comparing vocabulary teaching through AR-supported pictures and plastic toys	Vocabulary learning Teacher perception	The students using the AR pictures learned vocabulary items better
	Martínez et al. (2017)	150 students (5 years old)	Quantitative research Examining student experiences in learning vocabulary and grammar through AR-supported materials	Learning vocabulary and grammar Motivation	AR application increased the students' motivation and promoted their vocabulary and grammar knowledge

Table 10 (continued)

Level	Study	Participants	Research Design and Purpose	Variables	Results
	Safar et al. (2017)	42 students	Quasi-experimental research Comparing vocabulary learning through AR application vs. traditional ways	Vocabulary learning Student-material interaction	The students in the experimental group were more successful in learning the alphabet and had more interaction with the materials. There is a positive correlation between interaction and achievement
	He et al. (2014)	40 students (4–6 years old)	Quantitative research Comparing vocabulary learning through AR application vs. traditional ways and examining teacher attitudes towards the application	Vocabulary learning Teacher attitude	Vocabulary learning was higher in the experimental group. Teachers had positive attitudes towards the AR application. Teachers added such materials can distract students' attention; therefore, they are more practical in individual learning
	Hsieh and Lee (2008)	Kindergarten students	Qualitative research Examining the usability of the ARELS application	Student experience in relation to the usability of ARELS application	ARELS application supported traditional learning through human–computer interaction. The students had fun through interaction

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Data availability The data that support the findings of this study are available but restrictions apply to the availability of these data, which were used under licence for the current study and so are not publicly available. The data are, however, available from the authors upon reasonable request.

Declarations

Ethical approval All procedures performed in studies involving human participants were in accordance with 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.

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare that they have no conflict of interest.

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