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The Impact of Augmented Reality (AR) on Vocabulary Acquisition and Student Motivation

Jose Belda-Medina * and Victor Marrahi-Gomez

Department English Studies, University of Alicante, 03690 Alicante, Spain
* Correspondence: jr.belda@ua.es

Abstract: Although there is a growing body of literature about the use of Augmented Reality (AR) in language learning, research regarding its effectiveness for vocabulary development among secondary students is scarce. This study aims to measure the perception toward AR technology (H1), the effect of its use on vocabulary development (H2), and its impact on student motivation (H3). In this mixed method research based on convenient sampling, 130 students aged 14 to 15 (9th-graders) from two secondary education schools were assigned to an experimental (n = 64) and a control (n = 66) group. Both groups needed to learn 30 geographic terms in English over four weeks. The control group used a traditional method based on a handbook, while the experimental group was exposed to an AR-based lesson containing the same lexical terms. The instruments involved an English pre-post-test about the target vocabulary, a pre-post-survey, and a class discussion. Quantitative and qualitative data were analyzed through SPSS 20 statistical software and a thematic analysis, respectively. The results evidenced positive attitudes and a strong interest in AR integration in language learning. However, no significant differences were observed regarding vocabulary learning performance between both groups of secondary students.

Keywords: augmented reality (AR); language learning; vocabulary development; student motivation; secondary education

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1. Introduction

Since the development of the first head-mounted display system by Evan Sutherland in 1968 and the coinage of the term AR by Boeing researcher Tim Codell in 1990, Augmented Reality (AR) technology has rapidly evolved in the last decades. AR can be shortly described as a technology that combines the physical world with digital content, providing an immersive experience of a real-world environment. AR integrates digital elements with the user's environment in real time through the employment of different electronic devices, for example, head-up displays (HUD), holographic displays, and handheld devices such as smartphones and smart glasses. Conventionally, AR technology is described as part of the reality–virtuality continuum, as illustrated by Skarbez et al. [1] in Figure 1.

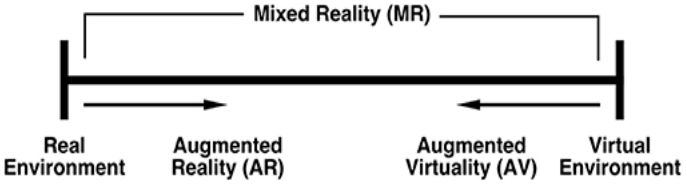

Figure 1. Reality–Virtuality Continuum.

Traditionally, two main types of AR technology are distinguished, marker-based and markerless, but some other types have recently emerged within the markerless type: location-based AR, projection-based AR, overlay AR, and contour AR. All these technologies have been integrated today into different programs and wearables such as AR glasses,

smart watches, headsets, and lenses. Additionally, there is currently a full array of software development kits (SDKs) or authoring tools available that can be used to develop AR projects such as ZapWorks, Vuforia, Roar, Augment, ARkit, Unity, and Wikitude. These SDKs are being employed in all educational grades across the curriculum to provide the students with a more immersive experience and to enhance their engagement and motivation [2,3].

The use of AR in education is on the rise as evidenced by the increasing number of publications [4–6]. There is a rich body of literature about the different educational areas and stages in which AR has been successfully implemented. Yuen et al. [7] summarized these areas into five: discovery-based learning, object modeling, skills training, AR books, and AR gaming. Several authors have delved into the benefits of AR integration in the classroom as perceived by different types of learners. The most often cited affordances are related to student enjoyment [8,9], engagement [10,11], increased motivation [12,13], and enhanced interaction [14].

According to different authors, some of the positive pedagogical effects of AR on the learning progress are a better representation of abstract concepts [15,16], reduced cognitive load [17,18], enhanced cognitive skills [19,20], and improved self-learning capabilities [21,22]. As an immersive multimodal technology, AR facilitates student interaction with the context, experiential learning, and building on understanding [23,24].

However, there are also some limitations to the effective integration of AR in education, which are related to technological and pedagogical problems [25,26]. Among the first ones, authors usually mention poor technological resources and connectivity, and lack of technical support in some educational settings [27]. Regarding pedagogical constraints, some studies have pointed out the lack of proper training and reluctance among current educators, and unawareness about the principles and practices of modern pedagogical models for AR integration in the classroom, such as those of Constructivism and Connectivism [28].

There is already a good number of reviews about the integration of mobile AR in language learning in different educational settings [29,30]. Most of these works focused on the adoption of AR among elementary and college students. However, research about the effectiveness of using mobile AR on vocabulary development and student motivation in secondary education is scant [31–33]. To bridge this gap, our study aims to examine the effect of integrating mobile AR for vocabulary learning and its impact on student motivation in secondary education.

2. Objectives and Hypotheses

This research has three objectives: first, to examine the perception toward technology integration in language learning among secondary students; second, to measure the effect of using AR technology on vocabulary performance; third, to assess the impact of AR technology on student motivation. The hypotheses are as follows:

Hypothesis 1 (H1): *Secondary education students have a positive attitude toward the use of technology in language learning.*

Hypothesis 2 (H2): *The use of AR technology has a positive effect on English vocabulary learning among secondary students.*

Hypothesis 3 (H3): *The use of AR technology in language learning has a positive impact on student motivation in secondary education.*

3. Augmented Reality (AR) in Language Learning

AR technology has been implemented in different domains of language learning, but one particular area of interest is vocabulary development, both at the receptive and productive levels. This section synthesizes research findings pertaining to the use of augmented reality in language learning. The selection was based on empirical studies

published over the last two decades about the impact of AR integration on vocabulary development and student motivation, particularly in pre-college education.

In preschool education, He et al. [34] analyzed the effectiveness of using AR-based pictures on receptive vocabulary acquisition among 40 children, who were organized into an experimental group using AR, and a control group employing traditional word cards and pictures. The authors concluded that mobile-based AR learning is more effective than traditional methods such as card instruction in the study of vocabulary among English language learners. The results showed that mobile-based AR learning software is helpful for non-native students to learn vocabulary.

However, Chen and Chan [35] examined the impact of using AR flashcards to learn vocabulary in early childhood education and reached very different conclusions. In their study, 98 children aged 5 to 6 were randomly assigned to a control and an experimental group, and they employed traditional and AR flashcards, respectively. Their results showed no significant difference between either method regarding the effectiveness of AR on vocabulary acquisition, but there was a higher interest among participants in the experimental group. More recently, Yilmaz et al. [36] studies children's vocabulary acquisition, retention levels, and perspectives on English language learning using AR technology. For this purpose, 39 preschool children aged 5 to 6 were exposed to AR for four weeks. The authors concluded that there was a significant increase in word/concept learning right after the implementation but that the gains decreased after two weeks following the post-test. All these studies have shown that the use of AR-supported methods and applications can enhance the effectiveness of vocabulary instruction in preschool foreign language education. It allows students to interact with virtual objects and simulations in real-world environments, providing a more engaging and immersive experience. Additionally, AR can help to improve students' motivation, attention, and retention of new vocabulary.

In elementary education, Chen et al. [37] developed a game-based learning system with AR technology, which was employed with 46 second-grade students of an elementary school, who were divided into a control group and an experimental group. The results indicated more significant vocabulary gains thanks to the interactive and immersive method provided by AR technology. Similarly, Hsu [38] compared two AR learning systems for third-grade students to learn English vocabulary in situated surroundings, one was based on a collective game-based (CGB) design while the other was based on a sequential-mission gaming (SMG) design. The results evidenced high learning effectiveness using both systems thanks to the benefits of AR gaming designs, which provided an immersive and interactive experience to the students. Similarly, Tsai [39] examined, in a mixed method research, the differences in vocabulary learning performance as well as the instructional materials motivation by comparing the traditional lecturing method and the AR method among 42 students in an elementary school. The findings also revealed higher scores and motivation among learners using AR technology. These studies are consistent in their findings that the implementation of AR technology in language instruction may enhance students' vocabulary comprehension and retention thanks to the interactive and contextual nature of the learning experience.

However, Binhomran and Altalhab [40] reached different conclusions in a mixed method study where they analyzed AR effectiveness on vocabulary learning among 73 students aged 11 to 12. In this case, the findings did not reveal statistically significant differences between learners using a traditional and an AR-based method; although, the motivation was higher in the experimental group. Therefore, there are contradicting results about the effectiveness of using AR for vocabulary development in elementary education. This could be due to a variety of factors, such as the specific AR technology used, the implementation of the technology in the classroom, and the context being studied.

Research on the effect of AR technology on vocabulary development in secondary education is scarce when compared to elementary and college education. In fact, in a systematic review of 54 publications about AR technology in language learning, Parmaxi and Demetriou found only 4 studies reporting results from secondary education. Similarly,

Majid and Salam [41] pointed out in another review that 41.4% of the publications had college students as participants, 37.9% focused on elementary school students, 17.2% involved kindergarteners (17.2%), and only 3.5% of the studies were related to high school students, while none of the research was conducted on middle school students. This scarcity of studies in secondary education may be due to different reasons such as lack of expertise and distrust among in-service teachers, limited access to technology, lack of technical support, and perceived pedagogical limitations, for example limited interaction and the distraction factor.

One example of the few studies involving secondary students is that of Küçük et al. [42], who examined the achievement, attitude, and cognitive load levels in learning English through AR technology. The learning benefits of this study with a sample of 122 participants from five different secondary schools were decreased cognitive load in the process of self-directed learning in an AR environment, and a strong interest in AR for language learning. In another study, Bursali and Yimaz [43] analyzed the effect of AR applications on reading comprehension among 89 students aged 10 to 11. The results indicated that students using AR showed higher levels of reading comprehension and learning permanency, when measured weekly, than the control group. The students also expressed their interest and willingness to take more lessons based on this emerging technology.

However, most of these studies focused on attitudes, perceptions, and satisfaction among secondary students, not on vocabulary learning achievement. Consequently, there is a need to investigate the impact of using mobile AR technology in language learning in secondary education since these students typically exhibit a higher frequency of smartphone usage and are widely considered to be early adopters of the new technologies.

Regarding student motivation, several authors have expressed there is little doubt about the effectiveness of AR-based lessons to enhance student interest in the learning process [39,44]. This benefit is often highlighted in studies combining AR and gamification. For example, Taskiran [45] delved into the learners' satisfaction with AR technology from a game-based approach and concluded that most of the participants found the lessons highly motivating and enjoyable; students highly valued the use of such immersive technology. Chang et al. [46] analyzed whether the learning performance of high school students could be enhanced using AR within a situational context, and found that the real-life AR scenarios used in the lessons strengthened student confidence in learning English and increased their satisfaction. More recently, Marrahi-Gomez and Belda-Medina [3] reviewed previous literature about the impact of AR on student motivation in language learning and stated that most studies confirmed its positive impact.

However, these studies about student motivation focused again on elementary or college students, while little research involved secondary students. To bridge this gap, this study aims to examine the effect of using AR technology on vocabulary learning and its impact on student motivation in secondary education.

4. Method and Participants

4.1. Sample and Context

The sample consisted of 130 students of English as a Foreign Language (EFL) from two secondary education schools. This research was based on convenience sampling as all participants were enrolled in both schools that offered different levels of education, from elementary to high school, and Career Technical Education (CTE) programs. Four groups, two from each school, were selected for this research. The groups were formed by 9th-graders aged 14–15 (n = 130). Regarding gender distribution, 46% were male while 54% were female students. According to the results obtained in the pre-survey, the participants perceived that their level of English was elementary (A2/CEFR) in all four skills as shown in Table 1.

Table 1. Self-perceived language level according to the CEFR Framework: 1 = A0, 2 = A1, 3 = A2, 4 = B1, 5 = B2, 6 = C1, 7 = C2.

	English Level	Speaking	Listening	Reading	Writing
CG (N = 66)	3.1 (A2)	3.0 (A2)	3.0 (A2)	3.1 (A2)	3.1 (A2)
EG (N = 64)	3.1 (A2)	3.0 (A2)	3.0 (A2)	3.2 (A2)	2.9 (A2)

This study is part of a larger research project, [The integration of AR in language learning], financed by the Instituto de Ciencias de la Educación at the Univesity of Alicante (Reference number: 4887). The study was conducted in accordance with the Declaration of Helsinki. The overall project adheres to the ethical principles outlined by both public schools (check the last section about consent) regarding the requirements related to information, consent, anonymity, and the right to withdraw from the project. The governing boards and tutors from both institutions granted permission to carry out this experiment involving the use of mobile AR in the classroom. All participants gave written consent to use the data obtained for scientific purposes and their names were omitted to ensure anonymity.

4.2. Method and Instruments

This study was based on a sequential mixed methods research as described by Pardede for EFL studies [47]. The intervention took place over four consecutive weeks in one-hour-long sessions with each of the four groups. Quantitative data were collected through an English vocabulary pre-post-test and analyzed through IBM SPSS 20, while qualitative data were gathered through a post-survey and class discussion.

Before the intervention, the English language tutors of both schools were consulted on the topics of study, and they all proposed to prepare a lesson about geographic terminology in English as it was part of the curriculum. Therefore, the pre-test contained 30 geographic terms distributed in two questions: the first question contained 20 sentences based on gap-filling, and the second included 10 examples of image–word association (Appendix A). The post-test completed after the intervention replicated the same questions for both groups as no correction feedback had been provided. The pre-post-test was administered in class in a paper-based format and the participants had twenty minutes to complete them. These terms were selected from the vocabulary list of Cambridge Assessment English (B1) which can be accessed at https://bit.ly/3cL6odU, accessed on 17 January 2023, and were approved by the regular teachers.

The pre-survey contained twelve questions arranged in two sections. The first section was aimed at gathering socio-demographic data (gender, mother tongue, languages spoken at home), and data related to the English language level and content subjects taken in English; the second section of the pre-survey contained two questions related to technological ownership and smartphone usage. The pre-survey was the same for both groups (CG and EG) and was administered the first day before the intervention.

The post-survey was designed to assess student motivation and interest in the paper-based vs. AR method, and it was partly based on the scales used by Tsai [39] and Taskiran [45], which were partially adapted for research needs. The survey consisted of 10 statements related to student enjoyment, engagement, and further interest. Seven items were common to all participants, while three were specifically worded for each group depending on the teaching method, handbook for the CG, and AR technology for the EG. The post-survey was administered on the last day of class after completing the post-test about geographic terms (week 4).

In the last session (week 4) after the intervention, the students discussed their perceptions of both the traditional and technological methods in class and expressed their insights. Following a thematic analysis (TA), these discussions were summarized and later codified to identify the main themes for the qualitative analysis.

4.3. Materials and Procedure

Research participants were required to bring a tablet or smartphone to the classroom during the four-week sessions. The schools provided a tablet to those students in need. As the use of smartphones was banned in the classroom and participants were underage, their parents or legal guardians were previously informed and requested to submit a signed document authorizing the student's participation and use of smartphones for the AR experiment in the classroom.

The four groups participating in this research were already separated in each school, so they were conveniently assigned into a Control Group (CG) and an Experimental Group (EG). Therefore there was a CG and an EG in each school. The CG employed traditional materials such as a handbook to learn the geographic terminology, while the EG used an AR-based lesson. During the first session, all students were asked to complete a placement test to determine their English knowledge based on the Cambridge Unlimited placement test available at https://bit.ly/3Rv9G3M, accessed on 17 January 2023. This test consists of 60 multiple-choice questions with different levels of difficulty (A1–C2). Then, students were required to complete a pre-test to measure their prior knowledge of geographic terms, and a pre-survey.

The second and third sessions (weeks 2 and 3) covered the instructional period and they consisted of two one-hour-long lessons. Students included in the CG were taught some lexical items related to geography using a traditional-based method (handbook), while students in the EG worked with the same lexical items through an AR-based lesson. The handbook used in the CG consisted of three colorful pages displaying several images and theoretical information about the geographic terms. It also included four activities (two gap-filling and two image-word associations) based on the thirty target terms. During the instructional period, the CG groups completed all the activities in class following a traditional approach.

Regarding the EG, an AR-based lesson with the same lexical items was designed using the SDK named Aumentaty, available on www.aumentaty.com, accessed on 17 January 2023. This is a free educational software created by the Universitat Politècnica de València (Spain). It includes an SDK called Creator that is used to develop the AR-based lesson. This lesson encompassed different multimedia and representational content using several triggers and overlays. Once the authors uploaded the AR lesson, students needed to download the Scope app onto their tablet or smartphones, and use it to scan the images and figures that had been previously distributed in the classroom. After a short explanation, the students could walk around in the classroom and interact with the multimedia content included in the AR-based lesson, which was organized as discursive (vocabulary text-based explanations) and illustrative (video links, web-based activities, etc.) representations, as shown in Figure 2. The AR lesson contained four activities (a link to a website with information, a YouTube video, and two online games) related to the geographic terms that the students needed to complete under the supervision of the instructors.

The last stage included a session in which students had to complete the post-test that replicated the same vocabulary questions as the pre-test. Then, the students filled out a post-survey about their motivation and level of satisfaction with the method employed in each case. Finally, there was a semi-structured discussion in class about the benefits and limitations of each method among the participants. Figure 3 shows the different stages and research procedure.

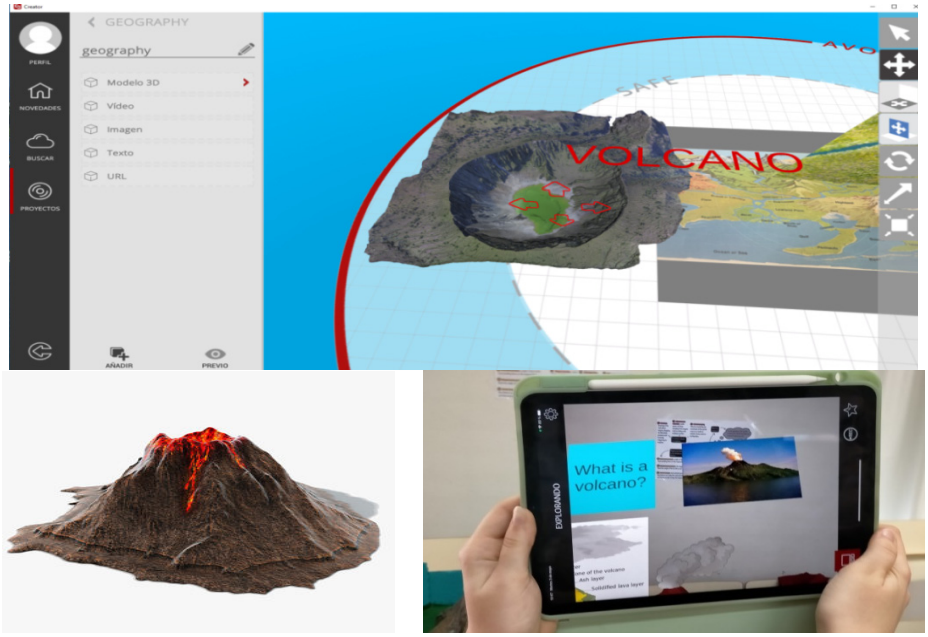

Figure 2. AR project (from top to bottom: Aumentaty Creator software, 3d Model of a volcano used as a trigger, image scan of the volcano by participants).

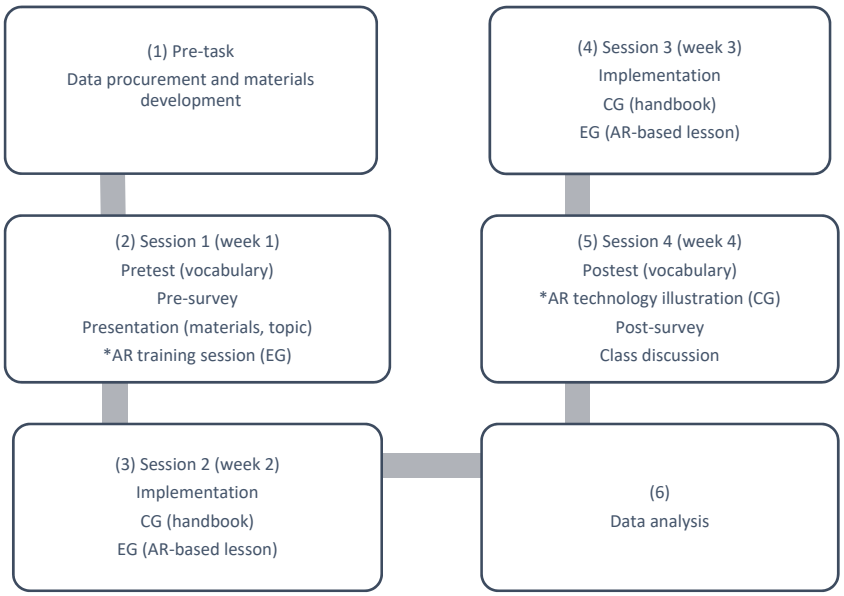

Figure 3. Research stages and procedure.

5. Data Results and Discussion

All participants (n = 130) in this study had a smartphone; although, its use was not allowed in class. Regarding the main purposes of smartphone usage, the pre-survey elicited similar results for all groups (EG and CG) as shown in Table 2. The main reason was communication, particularly instant messaging and social networking, as they later discussed in class. This was followed by general information retrieval and leisure, such as watching videos and listening to music. Game playing came in third place, as some participants mentioned their familiarity with some AR-based games such as Pokémon Go, The Walking Dead, and Harry Potter, so their prior knowledge of AR technology was related to such games. The scores for educational purposes and English learning were significantly lower. Some students pointed out that they sometimes checked different educational websites and apps for their homework, and a few had downloaded language

learning apps, such as Duolingo and Memrise, but they insisted on the fact that smartphone usage in and outside of the classroom was not particularly reinforced by their regular tutors.

Table 2. Purposes of smartphone usage.

Group	1. Communication	2. Information Search	3. Leisure	4. Play Games	5. Educational Purposes	6. Learn English
CG	4.2 (M)	3.8 (M)	3.8 (M)	2.8 (M)	2.5 (M)	1.3 (M)
(n = 66)	1.3 (SD)	1.2 (SD)	1.1 (SD)	1.3 (SD)	0.9 (SD)	0.8 (SD)
EG	4.3 (M)	3.9 (M)	3.9 (M)	3.2 (M)	2.6 (M)	1.4 (M)
(n = 64)	1.3 (SD)	1.1 (SD)	1.2 (SD)	1.4 (SD)	1.0 (SD)	0.7 (SD)

5.1. Attitudes toward the Use of Technology in Education and Language Learning (H1)

Concerning the first hypothesis (H1) about attitudes toward technology integration in education, the results were quite positive as shown in Table 3. The scores were based on a five-point Likert scale that included 15 items, 5 with reverse coding to prevent certain statistical biases present in some self-reporting scales. The reliability coefficient measured in Cronbach's Alpha was 0.870. Consistent with previous findings [48,49], participants were keen on learning English through technology as the scores of items #1 (M = 3.6) and #4 (M = 4.1) demonstrated. They also believed that their learning progress would be higher thanks to the use of technology, as reflected in items #2 (M = 3.8), #3 (M = 4.0), and #8 (M = 3.7), and agreed with the use of smartphones in the classroom (#6 M = 3.6) and outside of the classroom (#8 = 3.7). The results are in line with previous research [50,51] that demonstrated that students were generally positive about the use of different types of technology for language learning. They also supported a higher frequency of use of technology in general (#10 M = 3.7) and believed in the benefits of combining traditional with new technology-oriented methods (#11 M = 3.9). The results about the potential distraction factor of technology were moderate, both personally (#9 M = 2.7) and as a group (#7 M = 3.0), which is consistent with previous results [52,53]. However, the enjoyment and engagement factors, thanks to the integration of technology, were illustrated in items 13 (M = 2.2) and 14 (M = 4.0), in line with prior research about the use of smartphones and social media for vocabulary learning [54].

Table 3. Perception toward the use of technology in language learning based on a 5-point Likert scale: (1) completely disagree to (5) completely agree, reverse coding (7, 9, 12, 13, 15).

n = 130 α = 0.870	GC (n = 66)		GE (n = 64)	
Items	**M**	**SD**	**M**	**SD**
1. I am interested in learning English through technology.	3.6	1.0	3.6	0.9
2. I believe using technology can have a positive impact on learning English.	3.8	0.8	3.9	0.9
3. Using technology can improve my learning progress in English.	4.0	0.8	4.1	0.8
4. Using technology would increase my interest in learning English.	4.1	0.9	4.2	0.9
5. I believe computers and tablets should be used in the classroom to learn more effectively.	3.9	1.0	4.1	0.8
6. I believe smartphones should be used to learn more effectively in the classroom.	3.6	1.2	3.7	0.9
7. I believe the use of smartphones can be a distracting factor among students.	3.1	1.1	2.9	1.2
8. Using technology and smartphones would improve the effectiveness of learning English outside of the classroom.	3.6	1.1	3.8	1.0
9. The use of technology could distract me in my English class.	2.8	1.2	2.6	1.1
10. My learning outcomes in English would be higher if we used technology more often in the classroom.	3.8	1.0	3.7	1.1
11. My learning progress in English would be higher by combining traditional teaching with new technologies.	3.8	1.1	4.0	1.0
12. I believe using technology might prevent us from covering all the lessons included in the curriculum.	2.2	1.0	2.5	1.4
13. I would get bored using technology in the classroom.	2.3	0.8	2.2	1.0
14. Using technology and smartphones in the classroom would make my lessons more engaging and enjoyable.	3.9	1.2	4.1	1.2
15. I think I would not learn as much using technology in the classroom.	2.3	1.0	2.1	1.3

The Wilcoxon signed-rank test used for non-parametric data did not elicit any significant difference between both groups (EC and CG) regarding H1 results as shown in Table 4. Therefore, the results demonstrated that secondary students hold positive views and attitudes toward technology integration in language learning, consistent with previous studies about the effect of its impact on the student's cognitive abilities, motivation for both formal and informal learning, and self-directed learning [48,50].

Table 4. Wilcoxon signed-rank test. ([a]) Wilcoxon signed-rank test, ([b]) based on negative ranks, ([c]) Based on positive ranks.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Z	−0.356 [b]	−0.020 [b]	−1.277 [b]	−0.529 [c]	−0.261 [b]	−1.433 [b]	−0.590 [c]	−1.181 [b]
Asymp. Sig. (2-tailed)	0.722	0.984	0.202	0.597	0.794	0.152	0.555	0.238
	9	**10**	**11**	**12**	**13**	**14**	**15**	
Z	−0.025 [b]	−0.347 [c]	−1.324 [b]	−1.944 [c]	−0.268 [b]	−1.465 [c]	−1.297 [c]	
Asymp. Sig. (2-tailed)	0.980	0.729	0.185	0.052	0.789	0.143	0.195	

5.2. The Effect of Using AR Technology on Vocabulary Learning (H2)

Regarding H2 about vocabulary performance, the pre-post-test did not elicit any statistically significant difference between both groups as shown in Table 5. The results of the independent samples t-test demonstrated that all participants improved their knowledge using both methods, the handbook and the AR-based activities. Initially, the CG students (M = 34.8, SD = 26.02) ranked lower than EG students (M = 48.6, SD = 30.88) in the vocabulary pre-test, and the same pattern was observed in the post-test, where EG students (M = 83.7, SD = 17.62) outperformed the CG (M = 70.3, SD = 24.91), although their English level was similar according to the Cambridge Unlimited Placement test results. To determine whether the EG participants learned more vocabulary than the CG, thanks to the AR-based lesson employed, an independent samples t-test was performed. The statistical data shown in Table 5 did not reveal any significant difference between both groups, so the method did not have a significant impact on vocabulary performance as both groups improved their knowledge, t (130) = −1.31, −1.39, $p > 0.001$, 95% CI (−17.1, 3.56), (−18.23, 3.21). This may contradict previous findings in different educational stages stating that AR technology improves the learning outcomes [32], but it is also in line with prior research indicating that this technology may have a positive effect on student motivation and interest but not on learning performance [31].

Table 5. Results of *t*-test about geographic terminology.

		***t*-Test for Equality of Means**						
		t	**df**	**Sig. (Two Tailed)**	**Mean Diff.**	**Std. Error Diff.**	**95% CI of the Diff**	
							Lower	**Upper**
Vocabulary Pre-test	Equal variances assumed	−1.316	63	0.193	6.782	5.154	−17.084	3.516
	Equal variances not assumed	−1.312	59.637	0.195	6.782	5.171	−17.129	3.56
Vocabulary Post-test	Equal variances assumed	−1.399	63	0.167	7.509	5.367	−18.234	3.215
	Equal variances not assumed	−1.399	62.973	0.167	7.509	5.366	−18.232	3.213

5.3. The Effect of Using AR Technology on Student Interest and Motivation (H3)

The results about student interest and motivation (H3) were higher among the students in the EG group as illustrated in Table 6. The scores of the EG group were significantly higher in satisfaction (#1 M = 4.2), interest (#2 M = 4.3), and perceived usefulness (#3 M = 4.1). The perceived learning gains were also higher (#5 M = 4.5) among the EG group as opposed to the CG (#5 M = 3.4), although this perception did not match the learning outcomes as explained in the previous subsection. The scores of the three items

(#6–8), partly adapted to each group, also evidenced that all participants were interested in AR technology, even though the GC students did not employ it during the intervention. Moreover, both groups manifested an interest in learning more about the adoption of AR in the near future (#9 and #10).

Table 6. Student interest and motivation.

n = 130 α = 0.863	**CG (n = 66)**		**EG (n = 64)**	
Items	**M**	**SD**	**M**	**SD**
1. I liked the activity	2.8	1.1	4.2	0.8
2. I found this activity very interesting	3.0	1.2	4.3	0.8
3. I believe the activity was useful to learn English vocabulary	2.7	1.3	4.1	0.9
4. It was easy for me to concentrate on the English content through this method	3.6	0.9	3.8	1.1
5. I have learned the English vocabulary	3.4	.82	4.5	0.7
6. (GC) My interest would be higher in AR-based classes	3.9	0.9	-	-
7 (GC) I would learn more with AR technology	3.6	0.7	-	-
8. (GC) I enjoyed learning new vocabulary through this method (handbook)	2.7	1.3	-	-
6. (EG). My interest would be higher with the traditional method (handbook)	-	-	2.2	1.1
7. (EG). I would learn more with the traditional method (handbook)	-	-	2.1	0.7
8. (EG) I enjoyed learning new vocabulary through this method (AR technology)	-	-	4.3	0.9
9. I would like to use AR in my English lessons in the future	3.8	1.1	3.9	0.8
10. I would like to learn more about AR in education	3.9	1.2	4.1	1.1

To examine the student interest and motivation (H3), an independent samples *t*-test was performed. The t-test results evidenced a statistically significant difference, as shown in Table 7, so the methodology employed had an impact on student motivation: t (130) = −4.2, $p < 0.001$, 95% CI (−1.14, −0.04). The results indicated that the motivation was higher among those participants exposed to AR technology. This finding is consistent with previous works, highlighting the positive impact of using AR technology [33,39].

Table 7. Results of the *t*-test about student motivation and learning method.

		***t*-Test for Equality of Means**						
		t	**df**	**Sig. (Two Tailed)**	**Mean Diff.**	**Std. Error Diff.**	**95% CI of the Diff Lower**	**Upper**
Motivation	Equal variances assumed	−4.206	63	0.000	−0.733	0.184	−1.14	−0.406
	Equal variances not assumed	−4.210	62.955	0.000	−0.773	0.184	−1.140	−0.406

5.4. Qualitative Analysis

In the last session (week 4), all students participated in a semi-structured discussion about the benefits and limitations of AR integration in language learning. As the CG had not been exposed to AR technology during the intervention, there was a short demonstration just for these participants. While the first researcher led the discussion, the second transcribed the most important comments. Then, both researchers codified the ideas into different themes. Five main themes emerged in the thematic analysis, as illustrated in Table 8. Among the benefits, students pinpointed the novelty factor and relevance of this technology because they are young learners who are already familiar with some of these emerging technologies in other areas, particularly video games (P51), so they enjoyed (P93) using AR in education. These results are in line with previous findings [28,54] that highlighted the benefits of AR by incorporating real-world objects and locations into the game, allowing players to practice their language skills in a realistic context. The students also highlighted the usefulness and easiness of such digital tools as the AR-based lesson designed with Aumentaty. The students were very intuitive about the system (Scope app) and learned how to download and use with ease the AR application named Scope (P42).

Moreover, they enjoyed moving around the classroom to scan the different elements (triggers) and learn more about the geographic terms in context through different multimedia activities and online games (P76). This supports previous research about the advantages of using AR technology in the classroom, such as enhanced student engagement and motivation, multimedia interaction, and collaborative learning [22,46].

Table 8. Thematic analysis: comments about AR technology.

	Theme	P	Comments (Selection)
Benefits	Relevance	51	I believe AR and VR are really important as some of us are already familiar with them thanks to video games. It is important to integrate them into our education system and combine them with other more traditional methods.
	Novelty	93	Using AR technology is good because it is a different and new way to learn vocabulary. It was my first time using a smartphone to learn vocabulary through an AR-based lesson and I enjoyed it.
	Easiness	42	It's easier to understand the terms when you can watch different videos and play online games.
	Usefulness	18	I found the AR-based lesson very useful because I could apply the terms I learned to different online activities.
	Multimedia interaction	76	What I liked the most about AR technology is that it combines different types of activities, such as links to websites, videos, songs, and 3D images. For me learning the word volcano through an image or a sentence is not enough, I want to watch different examples of it and learn about the real world.
Limitations	Teacher's preparation and willingness	84	I liked the fact that we could use our smartphones to learn English vocabulary in class because they are not allowed in our school and I think most teachers don't want to change their traditional methods. I am not sure if they know about this technology and how to use it in our lessons.
	Lack of resources and poor connectivity	32	I had some problems when I scanned some of the images, so I had to check it with a classmate who used a different smartphone and it worked well. I also know some other classmates who had problems with the Internet connection when they were doing the AR activities.

However, most of the constraints mentioned by participants were related to their in-service teachers' unwillingness to adopt these emerging technologies in the classroom (P84) because the teachers were not aware of the potential benefits and had a lack of preparation according to students, which is consistent with previous research [31,55]. Participants also complained about the scarcity of digital resources and poor connectivity in some rooms, which caused some technical problems when they were completing the online activities (P32). These limitations have already been investigated and described in previous studies [3,26,55].

6. Conclusions and Implications

This study analyzed the effect of using AR technology on vocabulary development and motivation among secondary students. The results confirmed H1 about the positive attitudes toward technology integration in language learning. The students were in favor of adopting different types of technology and electronic devices, even though smartphone usage was not allowed in the classroom. This is consistent with previous studies about students' attitudes toward technology integration in language learning [42,43,55]. Participants believed that the use of computers, tablets, and smartphones could enhance their learning progress and increase their interest in language learning. However, they also showed a moderate concern about the distraction factor that smartphones could have in the classroom. The first implication is that secondary schools should implement different measures to ensure technology integration, since young learners are ready to embrace all types of electronic devices. As digital natives, they are already familiar with tablets and smartphones, and reluctance to adopt them will not prevent these tools from being fully integrated into the future education system. Early resistance to computer adoption is

nowadays mirrored in the opposition to smartphone usage in the classroom. Current trends in Communicative CALL (Computer-Assisted Language Learning) and MALL (Mobile Assisted Language Learning) have set new principles and practices for the meaningful integration of all digital devices, including emerging technologies such as VR and AR, as illustrated in different studies [6,56].

Data obtained did not confirm the second hypothesis (H2) stating that the use of AR technology may have a positive impact on vocabulary performance among secondary students. This conclusion was also reached by Chen et al. [35], who found no significant differences between the vocabulary acquired by preschool students using AR tools and those who performed the activity with a traditional method. However, other researchers such as Tsai [39] claimed that AR-based lessons were more effective than other traditional methods for vocabulary acquisition among elementary students. The implication is that these results need to be examined with caution, as AR effectiveness for vocabulary development may depend on different factors such as AR-based design and type of tools employed, educational stage and setting, previous experience, and frequency of use. Therefore, further longitudinal research is needed to determine whether AR technology can have a significant impact on vocabulary acquisition. The problem here lies in keeping pace with changing times as AR and other emerging technologies are rapidly evolving and expanding, and the number of AR types (markerless, marker-based, location-based), digital tools, and wearables (head-worn, smart glasses, lenses) is constantly increasing. As pointed out by Jamrus et al. [26], "Augmented Reality is a technology rapidly rising and it will be a waste if we do not take the opportunity to use this technological advancement to improve our education sector especially in learning English" (p. 734).

Concerning the third hypothesis about student interest and motivation in AR technology (H3), the results are self-evident as all participants indicated a strong interest in this technology. In fact, there seems to be a wide consensus on the positive impact of AR integration on student motivation in language learning [2,22,46]. Secondary students showed a keen interest in learning more about the educational use of this technology and its implementation in other classes. Qualitative data analysis reinforced the idea that young learners show clear support for the adoption of AR technology in the classroom. However, some constraints mentioned were in-service teachers' lack of preparation and willingness to adopt AR, and technology-related problems observed in the classroom. The implication is that secondary education teachers should be properly informed and trained, both in the learning potential and the meaningful integration of AR technology in education, as already stressed in previous works [31,57].

Despite the growing interest in the use of AR technology in language learning, there is limited research on its effectiveness for vocabulary learning in the context of secondary education. Compared to previous research, in this study, AR had a positive impact on student motivation and engagement, which is consistent with previous works [42,43], but there was no significant difference in vocabulary performance between the groups who used AR and a traditional method. This lack of significant difference in vocabulary learning between AR and traditional methods may be due to a combination of several factors such as sample size and limited time to use AR, lack of previous experience, and type of AR technology used in the classroom. Therefore, further research is needed to clarify this issue among secondary students. The limitations of this study are related to the context and digital tools, as some results, particularly those related to H2, may be determined by the research participants and the educational setting as well as the type of AR technology and SDK employed.

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Data Availability Statement: Data supporting the research findings are available from the authors upon request.

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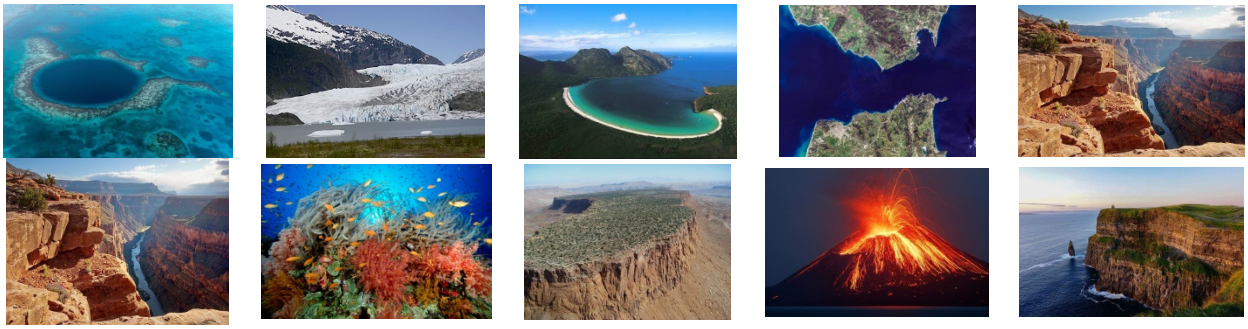
Appendix A

1. (GAP-FILLING) Complete the sentences with the missing word: lake-coast–glacier–stream–archipelago-swamp-lagoon-tundra–pond–North–range–estuary–delta–desert–waterfall–isthmus–geyser–peninsula–cave
    a. A _____ is a flat, treeless area where the soil is permanently frozen, for example in Greenland.
    b. A _____ is a large mass of ice that moves slowly.
    c. The landscape is more mountainous in the _____.
    d. A _____ refers to a series of mountains, for example the Alps and the Appalachian.
    e. Rimini has beautiful beaches on the east _____ of Italy.
    f. A _____ refers to a body of water that is not very deep with a sandbank or strip of land separating it from the ocean.
    g. With one leap he crossed the _____ of the river.
    h. A _____ is a small body of water surrounded by land.
    i. A _____ is an area of land permanently saturated, or filled, with water. Shrek lives in one of them.
    j. The ____ refers to the area where the fresh water from a river meets the salt water from an ocean
    k. A _____ is The area at the mouth of a river formed with deposits brought down the river
    l. An _____ is a narrow strip of land that connects two larger land masses
    m. Water falling from a height, usually off a cliff or side of a mountain, is called _____
    n. A large body of water totally surrounded by land is called a _____, such as the Titicaca
    o. Spain is a _____, this is an area of land surrounded on three sides with water
    p. A _____ refers to an area with little rainfall and sparse vegetation, such as the Sahara in Africa
    q. A large open area in the ground on in the side of a mountain or hill is called a _____
    r. A _____ is a hot spring that occasionally sends up a column of water and steam
    s. The Philippines are a/an _____ , this is a group or chain of islands
2. (WORD-IMAGE MATCHING) Match the image with the correct word: harbor–canyon–cliff–coral reef–volcano–strait-atoll–glacier–plateau–bay:



Appendix B

Pre-survey

Section A (Socio-demographic)

1. Gender: Male ( ) Female ( ) Other ( )
2. Birthplace: ( ) Spain ( ) Abroad
3. Mother tongue (you may tick more than one): Spanish ( ), Catalan ( ), English ( ), French ( ), German ( ), Chinese ( ), Arabic ( ), Russian ( ), Other ( )
4. Languages spoken at home (you may tick more than one): Spanish ( ), Catalan ( ), English ( ), French ( ), German ( ), Chinese ( ), Arabic ( ), Russian ( ), Other ( )
5. When did you start learning English? ( ) pre-school ( ) elementary ( ) secondary ( ) native speaker
6. How many classes of English as a Foreign Language are you currently taking at school? ( ) 1, ( ) 2, ( )3
7. How many content classes in English are you taking this year at school? ( ) None ( ) 1, ( ) 2, ( ) 3, ( ) 4+
8. Are you attending or have you attended over the last two years private English lessons? ( ) Yes ( ) No
9. What do you think is your level of English? A1 (Beginners) A2 (elementary) B1 (Low intermediate) B2 (Upper intermediate) C1 (advanced) C2 (native or near-native)
10. What is your perceived level of English in the following areas:
    a. Speaking: A1/A2/B1/B2/C21/C2
    b. Listening: A1/A2/B1/B2/C21/C2
    c. Reading: A1/A2/B1/B2/C21/C2
    d. Writing: A1/A2/B1/B2/C21/C2

Section B (Technology ownership and affinity)

1. Do you have a smartphone? ( ) Yes ( ) No
2. How often do you use your smartphone for the following purposes? 1 (never) 2 (rarely), 3 (sometimes), 4 (quite often), 5 (very often)
    a. Communication (IM, Social Networking): 1/2/3/4/5
    b. Information retrieval: 1/2/3/4/5
    c. Leisure (music, videos, etc.): 1/2/3/4/5
    d. Playing games: 1/2/3/4/5
    e. Education (in & out of class): 1/2/3/4/5

Section C. Attitudes toward the use of technology in education.

Rate on a five-point Likert scale the following statements: (1) completely disagree (2) disagree (3) neither agree nor disagree), 4 (agree), 5 (completely agree)

1. I am interested in learning English through technology.
2. I believe using technology can have a positive impact on learning English.
3. Using technology can improve my learning progress in English.
4. Using technology would increase my interest in learning English.

5. I believe computers and tablets should be used in the classroom to learn more effectively.
6. I believe smartphones should be used to learn more effectively in the classroom.
7. I believe the use of smartphones can be a distracting factor among students.
8. Using technology would improve the effectiveness of learning English outside of the classroom.
9. The use of technology could distract me in my English class.
10. My learning outcomes in English would be higher if we used technology more often in the classroom.
11. My learning progress in English would be higher by combining traditional teaching with the new technologies.
12. I believe using technology might prevent us from covering all the lessons within the academic year.
13. I would get bored using technology in the classroom.
14. Traditional teaching should be replaced by more technologies in the classroom.
15. I think I would not learn as much using technology in the classroom.

Post-survey

Rate on a five-point Likert scale the following statements: (1) completely disagree (2) disagree (3) neither agree nor disagree), 4 (agree), 5 (completely agree)

1. I liked the activity
2. I found this activity very interesting
3. I believe the activity was useful to learn English vocabulary
4. It was easy for me to concentrate on the English content through this method
5. I have learnt the English vocabulary
6. (GC) My interest would be higher with AR-based classes
7. (GC) I would learn more with AR technology
8. (GC) I enjoyed learning new vocabulary through this method (handbook).
6. (EG). My interest would be higher with a traditional method (handbook)
7. (EG). I would learn more with a traditional method (handbook)
8. (EG) I enjoyed learning new vocabulary through this method (AR technology)
9. I would like to use AR in my English lessons in the future
10. I would like to learn more about AR in education

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