frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 23 May 2024
DOI 10.3389/feduc.2024.1359692



OPEN ACCESS

EDITED BY
Helmi Norman,
National University of Malaysia, Malaysia

REVIEWED BY
Wahyu Widada,
University of Bengkulu, Indonesia
Haida Umiera Hashim,
MARA University of Technology, Malaysia

*CORRESPONDENCE
Jose Belda-Medina
jr.belda@ua.es

RECEIVED 21 December 2023
ACCEPTED 25 April 2024
PUBLISHED 23 May 2024

CITATION
Marrahi-Gomez V and Belda-Medina J (2024) Assessing the effect of Augmented Reality on English language learning and student motivation in secondary education. *Front. Educ.* 9:1359692. doi: 10.3389/feduc.2024.1359692



# Assessing the effect of Augmented Reality on English language learning and student motivation in secondary education

Victor Marrahi-Gomez[1] and Jose Belda-Medina[2]*

[1]Digital Language Learning, Facultad de Educación, Universidad Francisco de Vitoria, Madrid, Spain, [2]Department of English Studies, Digital Language Learning (DL2), University of Alicante, Alicante, Spain

The integration of Augmented Reality (AR) in language learning has garnered attention in the field of education, yet its effectiveness in enhancing grammar proficiency among secondary school students remains relatively unexplored, especially given that previous research has predominantly focused on vocabulary acquisition at the primary and college levels. This study, based on a mixed-methods approach and convenience sampling, is aimed at assessing students' attitudes toward the integration of technology (H1) in language learning and examining the impact of using AR on grammar learning (H2) and motivation (H3) among secondary education students. Employing a mixed-method approach and convenience sampling, the research involved 130 students aged 14 to 15 from two secondary schools, divided into an experimental group ($n = 64$) and a control group ($n = 66$). Both groups received instruction on English comparative and superlative forms and completed a variety of exercises. The control group followed a traditional approach using a printed handbook, while the experimental group engaged with an AR-based lesson containing equivalent grammar activities and vocabulary in a multimedia format. Pre and post-tests were administered to evaluate grammar proficiency, accompanied by pre and post-surveys. Semi-structured discussion was used for the qualitative data. The findings revealed a strong interest in integrating AR technology into grammar learning, underscored by a positive attitude toward its implementation in secondary education. However, no statistically significant differences were detected in grammar learning performance between the two student groups. These findings emphasize the importance of providing proper teacher training in secondary education to effectively utilize AR technology and highlight the need for further research to explore its effectiveness and long-term impact.

KEYWORDS

**Augmented Reality, language learning, grammar, motivation, secondary education**

## 1 Introduction

Augmented Reality (AR) has emerged as a promising technology in education, offering an innovative learning experience, particularly in the field of language learning, as highlighted by Akçayır and Akçayır (2017), Min and Yu (2023), and Schorr et al. (2024). AR refers to a digital technology that superimposes computer-generated sensory information, such as images, sounds, or text, onto the real-world environment to enhance the user's perception of reality. The prevalence of Software Development Kits (SDKs) such as ZapWorks, Roar,

Augment, and ARkit Unity is steadily rising within various educational settings. These SDKs are employed to provide students with immersive experiences and enhance their performance, engagement, and motivation (Antonioli et al., 2014; Buchner et al., 2022; Damopoli et al., 2022; Belda-Medina and Marrahi-Gomez, 2023).

According to different research works (Saltan and Arslan, 2016; Akçayır and Akçayır, 2017; Lau and Wen, 2021; Demirdag et al., 2024), the use of AR in education is on the rise, as seen in the number of related publications. AR technology presents various advantages and challenges in language learning. It can transform traditional language learning into an engaging experience, increasing student satisfaction and engagement (Dirin and Laine, 2018; Nami, 2020). Moreover, recent studies have shown that AR can enhance skills development in students, allowing for more interaction with the environment while promoting creative thinking and problem-solving abilities (Nizam et al., 2018; Belda-Medina and Calvo-Ferrer, 2022; Lin and Wang, 2023).

However, the lack of knowledge and proper training among in-service and pre-service teachers, along with the absence of technical equipment and support, presents significant challenges in using AR for language learning, hindering its adoption (Wu et al., 2013; Jamrus and Razali, 2019; Osuna et al., 2019). Most research to date has primarily concentrated on vocabulary acquisition in elementary education (Solak and Cakir, 2015; Taskiran, 2019; Lau and Wen, 2021). Consequently, there is a research gap in understanding how mobile Augmented Reality (AR) influences grammar skills across different educational levels. Therefore, this study is dedicated to examining the impact of mobile AR on student motivation and grammar learning among secondary education students.

# 2 Article literature review

## 2.1 The effect of AR technology on student motivation

AR technology has evolved rapidly since Ivan Sutherland created the first head-mounted screen system in 1968 and Tim Codell coined the term 'AR' in the early 1990s (Belda-Medina, 2021). AR can be described as a technology that merges the real world with digital content, offering an immersive experience within a real-world environment. Electronic components are integrated into AR through various devices, including head-up displays (HUD), holographic displays, and handheld devices such as smartphones and smart glasses. AR technologies are often categorized and placed on a continuum known as the "reality-virtuality continuum, as llustrated in Figure 1 by Skarbez et al. (2021).

The positive impact of Augmented Reality (AR) technology on student motivation, particularly in the field of language learning, has been widely examined (Yuen et al., 2011; Martin-Gutierrez et al., 2012; Nincarean et al., 2013; Savela et al. 2020). Recent studies conducted by Sun and Gao (2020), Belda-Medina (2022), Belda-Medina and Marrahi-Gomez (2023) have highlighted the motivational benefits of integrating AR into education. Similarly, Taskiran's (2019) research focused on the significant improvements in English language learning motivation, attributing these enhancements to various factors such as improved learning facilities, peer influence, and creative thinking. Tsai (2020) reported positive attitudes and a strong interest in adopting AR for language learning, resulting in enhanced student performance across different subject areas. Additionally, recent research indicated that AR technology captures students' attention, and increases their engagement, leading to positive attitudes in the classroom (Gamlo, 2019; Kaur et al., 2020). Students tend to enjoy using AR technology in their learning, finding it easy and convenient to use, and reporting high satisfaction, which can reduce their learning anxiety compared to traditional methods (Khan et al., 2019).

However, despite the substantial body of research on AR technology and its impact on student motivation, a gap exists in studies specifically targeting secondary education students. This gap is particularly noteworthy, especially considering that secondary students start being more exposed to smartphones and AR-based applications at this educational level. In a systematic review of 21 studies conducted between 2012 and 2017 within primary and secondary education, Pellas et al. (2019) emphasized the potential of AR game-based learning to enhance students' motivation and promote positive attitudes towards learning, underscoring the limited research available in this particular domain. Similarly, Belda-Medina and Marrahi-Gomez (2023) indicated that although AR technology increased student motivation, it did not lead to a significant difference in vocabulary learning performance when compared to traditional methods, further underscoring the dearth of studies conducted among secondary education students. Therefore, there is a need for more research to investigate the impact of AR technology on student motivation in secondary education settings.

## 2.2 AR technology in language learning

The integration of AR in language learning has demonstrated significant benefits across various educational levels (Gudoniene and Rutkauskiene, 2019; Papanastasiou et al., 2019). AR's ability to enhance language learning experiences has been highlighted in various studies. For example, at the elementary level, AR can captivate young learners by providing them with more visual stimuli in their mastery of the English language (Nizam et al., 2018; Yeh and Tseng, 2020). Similarly, different works have explored AR's potential to bridge the gap between virtual and real worlds at the college level, particularly in language and STEM education. By utilizing AR's immersive qualities, this approach to language learning effectively captures student engagement and enjoyment (Belda-Medina, 2021; Shadiev and Liang, 2024).

Several studies to date have explored the impact of AR technology on vocabulary acquisition (Solak and Cakir, 2015; Santos et al., 2016). The findings indicate that the use of AR enhances vocabulary learning and retention among language learners (Ji and Shin, 2019). For example, one study concluded that mobile-based AR learning is more effective than traditional methods like flashcards in improving vocabulary among English learners (Chen and Chan, 2019). Moreover, the accessibility of mobile devices and the ease of use of AR have been identified as significant factors contributing to its widespread adoption. This accessibility allows students to engage in interactive learning experiences anytime and anywhere (Dirin and Laine, 2018). Furthermore, integrating authentic language through AR has been found to promote contextual learning and improve vocabulary proficiency, ultimately leading to enhanced language skills (Qiu et al., 2023).

However, the effective implementation of AR in education faces various challenges, both pedagogical and technological (Wu et al., 2013; Jamrus and Razali, 2019). Regarding technological challenges, the effective implementation of AR in education faces obstacle such

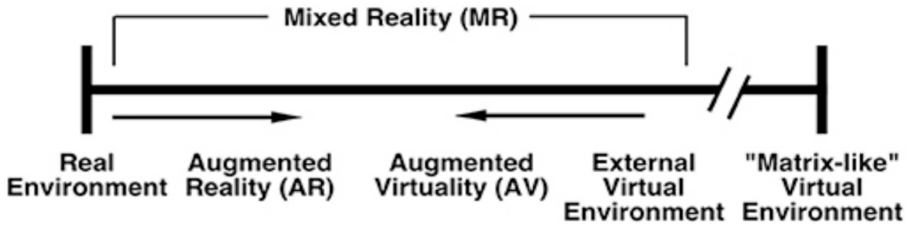


FIGURE 1
Reality–virtuality continuum.

as inadequate technology tools, connectivity issues, and a lack of technical support in specific educational settings (Osuna et al., 2019). As for pedagogical challenges, limitations arise from the absence of suitable training, resistance to change, and insufficient awareness among educators regarding contemporary pedagogical models for AR integration (Garzón et al., 2020).

While several studies have delved into the utilization of mobile AR for vocabulary acquisition, with a focus mainly on elementary and college levels (Parmaxi and Demetriou, 2020; Lau and Wen, 2021), there is a research gap in understanding how mobile AR affects grammar learning in language education (Solak and Cakir, 2015; Santos et al., 2016). To bridge this gap, our study aims to investigate the impact of mobile Augmented Reality (AR) on grammar development and student motivation in secondary education.

# 3 Objectives and hypotheses

This research has the three following objectives:

- (O1) To examine secondary students' attitudes towards the use of technology in language learning.
- (O2) To assess the effect of AR technology on grammar learning among secondary students.
- (O3) To evaluate students' motivation and self-perceptions regarding the use of AR technology in language learning.

These objectives align with the following hypotheses:

- *Hypothesis 1 (H1)*: Secondary education students hold a positive attitude towards the integration of technology in language learning.
- *Hypothesis 2 (H2):* The use of AR technology has a positive impact on grammar learning among secondary students.
- *Hypothesis 3 (H3)*: The integration of AR technology in language learning has a positive impact on students' perceptions and motivation in secondary education.

# 4 Context and method

## 4.1 Sample

A sample of 130 English as a Foreign Language (EFL) students across two public secondary schools in Spain, where smartphones were banned in one school and allowed in the other, participated in the study. Participants were selected through convenience sampling, resulting in four groups, two from each school, consisting of ninth-grade students aged 14 to 15 (9th graders or GCSE). In each school, there were two groups: an experimental group (EG) exposed to AR technology and a control group (CG) whose treatment was based on the printed materials conventionally used by their regular tutors. Thus, there were a total of two EGs and two CGs, one in each school. The gender distribution was 54% female and 46% male. Informed consent was obtained from tutors and parents for the experiment, and the study was carried out by the ethical procedures of the University of Alicante, where both researchers work as lecturers. The lecturers selected both public schools through the school administrators, and all data were analyzed anonymously and confidentially. Table 1 provides information about students' self-perceived English language proficiency levels in speaking, listening, reading, and writing skills, categorized according to the CEFR Framework.

## 4.2 Instruments

The study was based on a mixed-methods design as described by Pardede (2019). Each group participated in the one-hour intervention during the four-week period. Qualitative data were collected through a post-intervention survey and classroom discussions, while quantitative data on grammar performance were gathered through a pre-posttest. To analyze the quantitative data, researchers utilized IBM SPSS 20 software. Before the intervention, inquiries were made to the EFL tutors at both educational institutions to determine the grammar topic of study. They collectively proposed the development of a lesson centred around comparative forms in English using the topic of sea life.

The pre-survey consisted of three sections and a total of 15 questions (Appendix). Section A, which focused on socio-demographics, included questions related to gender, birthplace, mother tongue, languages spoken at home, etc. Section B explored technology ownership and affinity, with questions about smartphone ownership and frequency of usage for various purposes. Section C assessed attitudes toward technology in education, using a Likert scale to measure agreement or disagreement with 15 statements related to the use of technology in language learning and its potential impact on motivation and learning outcomes. Administered on the first day before the intervention, the pre-survey was similar for both the control group (CG) and experimental group (EG). The post-survey comprised 10 questions, employing a Likert scale to assess participants' perceptions and attitudes regarding the AR-based language learning activity, covering their interest, engagement, perceived usefulness, ease of concentration, self-perceived grammar learning outcomes, and preferences for future learning methods.

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.

| Students | 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) |

The pre-posttest (Appendix) aimed to measure students' learning of comparative and superlative forms in English. It consisted of two sections. In the first section, students completed 10 gap-filling sentences, where they had to provide the correct comparative or superlative form of an adjective in the given context. The second section involved reading a short passage about sea life and filling in 10gaps with the appropriate comparative or superlative adjectives based on the context of the passage. This assessment allowed students to demonstrate their understanding of comparative and superlative forms in practical language use. The test was administered in a traditional paper-based format within the classroom setting, with participants given 30 minutes to complete the exercises. Test questions were sourced from the textbooks used in both schools.

## 4.3 Materials and procedure

Throughout the four-week period, participants were required to have access to a tablet or smartphone during class sessions. In cases where students did not have their own devices, the educational institutions provided tablets. The participants were already divided into different groups within each school, allowing for convenient assignment into a Control Group (CG) and an Experimental Group (EG). The CG used traditional materials, such as a handbook, to learn about comparative forms in English, while the EG engaged with an AR-based lesson. During the first session, all students completed a placement test to assess their English proficiency based on the Cambridge Unlimited placement test, available at https://bit.ly/3Rv9G3M, accessed on January 17, 2023. This test consisted of 60 multiple-choice questions with varying levels of difficulty (A1–C2). Following the placement test, students took a grammar test to evaluate their prior knowledge in comparison to what they could learn through the intervention.

The instructional stage took place in the second and third sessions. Each session consisted of two one-hour classes. EG students engaged with several multimedia components (videos, websites and games) related to English comparative forms through an AR-based pedagogical approach. In contrast, CG students received similar instruction on comparative forms using a more traditional method based on the class handbook. The handbook used for the CG included five pages, featuring visual aids and theoretical explanations relevant to the targeted grammatical concepts. It also included a pair of written activities:

For the Experimental Group (EG), an instructional module employing AR technology was previously designed. This module covered the same set of grammar activities and was created using the Software Development Kit (SDK) named Aumentaty, accessible via the website www.aumentaty.com, accessed on January 17, 2023. Aumentaty is a freely available educational software product developed by the Universitat Politècnica de València in Spain. It includes an SDK named "Creator" that serves as an authoring tool for constructing AR-based instructional content. The AR-based lesson included various multimedia elements and visual representations, facilitated through the integration of various triggers and overlays. To engage with this lesson, students were required to download the Scope application onto their tablet or smartphone. They then uploaded the AR lesson and used the application to scan the images distributed in the classroom and complete two multimedia activities. The multimedia components of the AR lesson were structured to include both discursive elements, featuring text-based explanations of grammar, and illustrative elements, including links to videos, web-based activities, and similar resources. This arrangement allowed students the freedom to move around the classroom space and interact with the AR content. The printed and AR-based materials are shown in Figure 2.

In the following session, all students completed the post-test, based on the same grammar questions from the pre-test. Then, participants filled out a post-survey to assess their motivation and perceptions of the instructional materials used in each case. In the last stage, a semi-structured discussion on the potential benefits and limitations associated with each instructional method was conducted, involving the students, tutors and researchers. A visual representation of the distinct research stages is shown in Figure 3.

# 5 Results

The data showed that all participants ($n = 130$) owned smartphones although their use was prohibited in the classroom in one of the participating schools. Analysis of the pre-survey results revealed similar purposes of smartphone use among all students, as outlined in Table 2. Communication activities, including instant messaging and social networking, emerged as the primary motivations, followed by information retrieval and entertainment activities, such as video consumption and music listening. Gaming was in the third position, with some participants indicating their familiarity with AR-based games like Pokémon Go, The Walking Dead, and Harry Potter. In contrast, educational purposes such as language learning scored significantly lower. Some participants pointed out that their tutors did not promote the educational use of smartphones in and outside the classroom.

## 5.1 Attitudes towards the use of technology in education and language learning (H1)

Regarding H1 about attitudes toward technology integration in education, the results were positive, as illustrated in Table 3. The scores were based on a five-point Likert scale, including 15 items, with 5 negatively worded statements to prevent the acquiescence bias present in self-reporting scales. The reliability, measured using Cronbach's

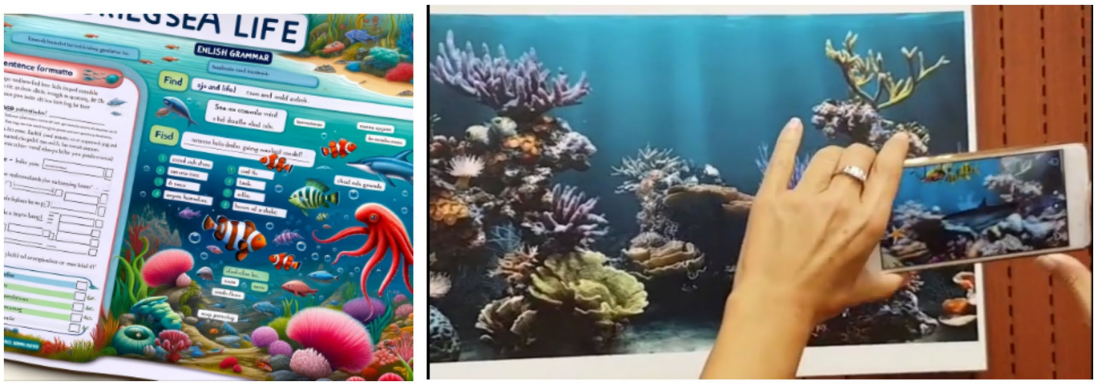


FIGURE 2
Paper-based (CG) and AR-based (EG) lessons on comparative forms in English.

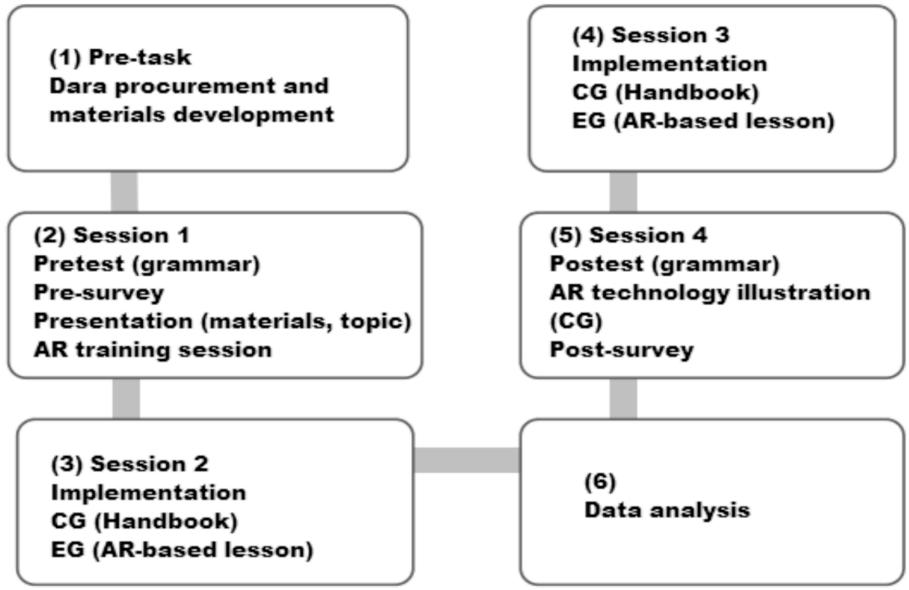


FIGURE 3
Research stages.

Alpha, yielded a value of 0.87. when analyzed separately, no significant differences were found between the students attending the school where smartphones were prohibited and those attending the school where these devices were allowed. As a result, the researchers did not include the school's smartphone usage policy as a determining factor in the study's results.

Consistent with previous studies (Gamlo, 2019; Taskiran, 2019), Table 4 participants displayed enthusiasm for learning English through technology, as evidenced by the scores for items #1 (M = 3.6) and #4 (M = 4.1). They also believed that their learning progress would be enhanced through the use of technology, as indicated by items #2 (M = 3.8), #3 (M = 4.0), and #8 (M = 3.7). Additionally, they supported the use of smartphones both in the classroom (#6 M = 3.6) and outside (#8 M = 3.7). In line with prior findings (Kacetl and Klímová, 2019; Sun and Gao, 2020). The data revealed that students supported the use of technology in general (#10 M = 3.7) and believed in the benefits of combining traditional methods with new technology-oriented approaches (#11 M = 3.9). Results concerning the potential distraction factor of technology were moderate, both at the individual level (#9 M = 2.7) and as a group (#7 M = 3.0). Consistent with previous studies (Gamlo, 2019; Sun and Gao, 2020) on the use of smartphones in language learning, items 13 (M = 2.2) and 14 (M = 4.0) confirmed the enjoyment and engagement experienced by participants who were exposed to technology.

The Wilcoxon signed-rank test used to determine any significant difference between the two groups, EG and CG, revealed no statistically significant difference as shown in Table 4. These results align with prior research on the impact of technology integration on students' motivation in both structured and unstructured learning contexts (Chen and Chan, 2019; Taskiran, 2019). This supports the idea that secondary school students hold positive perceptions toward the incorporation of technology in the classroom.

TABLE 2 Purposes of smartphone usage.

| Group | Communication | Information search | Play games | Educational purposes | Learn English |
|---|---|---|---|---|---|
| CG ($N = 66$) | 4.2 (M) | 3.8 (M) | 2.8 (M) | 2.5 (M) | 1.3 (M) |
| | 1.3 (SD) | 1.1 (SD) | 1.3 (SD) | 0.9 (SD) | 0.8 (SD) |
| EG ($N = 64$) | 4.3 (M) | 3.9 (M) | 3.2 (M) | 2.6 (M) | 1.4 (M) |
| | 1.3 (SD) | 1.1 (SD) | 1.4 (SD) | 1.0 (SD) | 0.7 (SD) |

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).

| $n = 130$ $\alpha = 0.86$ | CG ($n = 66$) | | EG ($n = 64$) | |
|---|---|---|---|---|
| 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 | 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 in the classroom to learn more effectively | 3.6 | 1.2 | 3.7 | 0.9 |
| 7. I believe the use of smartphones can be distracting | 3.1 | 1.1 | 2.9 | 1.2 |
| 8. Using technology and smartphones would improve the effectiveness of learning English outside 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 would be higher by combining traditional teaching with new technologies | 3.8 | 1.0 | 3.7 | 1.1 |
| 11. My learning progress in English would be higher if we used technology more often in the classroom | 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 |

TABLE 4 Wilcoxon signed-rank test.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Z | −0.356b | −0.020b | −1.277b | −0.529c | −0.261b | −1.433b | −0.590c | −1.181b |
| Asymp. Sig. (2-tailed) | | | | | | | | 0.238 |

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|
| Z | −0.025b | −0.347 c | −1.324b | −1.944c | −0.268b | −1.465c | −1.297c |
| Asymp. Sig. (2-tailed) | | | | | | | |

(a) Wilcoxon signed-ranked test, (b) based on negative ranks, and (c) Based on positive ranks.

## 5.2 The effect of using AR technology on grammar learning (H2)

The data shown in Table 5 related to H2 revealed no significant difference in the results of the pre-post-test between the EG and the CG. The results of the independent samples t-test indicate that both materials, the paper-based and the AR-based activities, helped the students improve their grammar skills. In the initial assessment, CG participants (M = 35.9, SD = 20.0) showed slightly lower performance compared to the EG students (M = 32.0, SD = 19.2) in terms of grammar performance. This pattern persisted in the subsequent post-test, where the EG students (M = 88.0, SD = 13.2) obtained higher scores compared to the CG (M = 74.2, SD = 16.0). Therefore, no significant difference between both groups can be attributed to the learning materials, paper- and AR-based.

## 5.3 The effect of using AR technology on student motivation and self-perceptions (H3)

As indicated in Table 6 concerning H3, EG participants achieved higher scores in terms of student satisfaction (M = 4.2), interest

(M = 4.3), and perceived usefulness (M = 4.1) compared to the CG. Additionally, the EG displayed an enhanced perception of their learning progress (M = 3.4) in contrast to the CG group, despite this disparity not aligning with the previously discussed results. Although CG participants did not interact with AR technology during the intervention, their responses to the three items related to technology (#6–8), demonstrated an underlying interest. The EG and CG both expressed an interest in deepening their comprehension of the potential uses of AR (#9 and #10).

In relation to H3, an independent samples t-test was conducted to examine students' motivation and interest. As the results in Table 7 indicate, the instructional methods had a significant impact on student motivation (t (130) = 4.2, $p < 0.001$, 95% CI [1.14, 0.04]). The results indicated that participants who were exposed to AR technology expressed higher levels of motivation. This finding is consistent with previous research, emphasizing the positive effects associated with the integration of AR technology in the classroom (Santos et al., 2016; Sun and Gao, 2020).

## 5.4 Qualitative analysis

During the final session, all enrolled students actively engaged in a semi-structured discourse centred on the advantages and limitations associated with the integration of AR technology in language learning. The discussion was led by one of the researchers while the other recorded and annotated key observations. Subsequently, both researchers collaborated in the systematic categorization of the articulated concepts into distinct thematic patterns. This thematic analysis yielded five significant themes, as illustrated in Table 8. Particularly noteworthy was the students' recognition of novelty and relevance as prominent benefits of this technological application (P 51). Consequently, these students exhibited a positive disposition towards embracing AR technology within an educational context (P 93).

These findings harmonize with earlier research (Garzón et al., 2020; Lau and Wen, 2021) emphasizing the advantages of incorporating AR into gaming scenarios by integrating real-world

TABLE 5 T-test results about grammar performance.

| | | t | df | Sig. | Mean Diff | Std. Error Diff. | 95% CI of the Diff | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower | Upper |
| Grammar | Equal variance assumed | −1.205 | 61.2 | 0.18 | 6.531 | 5.123 | −16.94 | 3.491 |
| Pre-Test | Equal variance not assumed | −1.134 | 57.4 | 0.19 | 6.531 | 5.151 | −16.723 | 3.52 |
| Grammar | Equal variance assumed | −1.299 | 62 | 0.16 | 7.302 | 5.127 | −18.014 | 3.116 |
| Post-Test | Equal variance not assumed | −1.299 | 61.9 | 0.16 | 7.302 | 5.126 | −18.012 | 3.119 |

TABLE 6 Interest, motivation and self-perception of learning.

| $n = 130$ $\alpha = 0.86$ | 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 grammar | 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 English grammar (comparative forms) | 3.4 | 0.82 | 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 grammar through this method (handbook) | 2.7 | 1.3 | – | – |
| 6. (EG). My interest would be higher using 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 grammar 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 |

TABLE 7 T-test results about student motivation and learning method.

| | | t | df | Sig. | Mean Diff | Std. Error Diff. | 95% CI of the Diff | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower | Upper |
| Motivation and interest | Equal variance assumed | −4.206 | 63 | 0.00 | −0.733 | 0.184 | −1.14 | −0.406 |
| | Equal variance not assumed | −4.21 | 62.9 | 0.00 | −0.733 | 0.184 | −1.14 | −0.406 |

TABLE 8 Thematic analysis: benefits and limitations.

| | 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 videogames |
| | | | 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's a different and new way to learn grammar or vocabulary |
| | | | It was my first time using a smartphone to learn English using AR 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 lessons 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, songs and 3D images |
| | | | For me learning grammar or the word volcano through activities and images is not enough and 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 because they are not allowed in our school, and I believe that most teachers do not want to change their traditional methods |
| | | | I am not sure if teachers know about this technology and how to use it in our lessons |
| | Lack of resources | 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 |

locations and objects, thereby facilitating the enhancement of language skills in a natural setting. Furthermore, the students accentuated the value and user-friendliness of digital tools such as the AR-based lesson. The Scope app, in particular, garnered praise for its intuitive usability, with students swiftly mastering the download and utilization of the AR application named Scope (P42). Additionally, they expressed enjoyment in exploring the classroom to scan various components (triggers) and actively participating in multimedia activities and online games that enriched their comprehension of sea life terminology (P76). These outcomes substantiate previous research affirming the advantages of AR technology in the classroom, including its capacity to boost student motivation and engagement, foster multimedia interaction, and cultivate collaborative learning experiences (Lara-Prieto et al., 2015; Qiu et al., 2023).

Nevertheless, participants predominantly underscored the primary constraints linked to their educators' reluctance in adopting these emerging technologies in the classroom (P84). According to the students' accounts, this reluctance stemmed from their instructors' limited familiarity with the potential benefits and their insufficient training in utilizing such tools, consistent with prior research (Solak and Cakir, 2015; Chen and Chan, 2019). Participants also voiced concerns about the shortage of digital resources and unreliable connectivity in certain locations. Consequently, these technical limitations resulted in complications during online activities (P 32). Existing research (Chen and Chan, 2019; Jamrus and Razali, 2019; Belda-Medina and Calvo-Ferrer, 2022) has extensively discussed these limitations associated with reluctance and distrust regarding the integration of emerging technologies among in-service teachers.

## 6 Discussion

The primary aim of this study was to investigate the impact of AR technology integration on student motivation and grammar performance in secondary education. The results confirmed H1, which posited that students hold positive attitudes toward technology use in language learning. Despite classroom restrictions on smartphone usage in one of the schools, students collectively supported the use of technological tools and electronic devices, aligning with prior research (Küçük et al., 2014; Küçük et al., 2016; Green, 2019; Taskiran, 2019). Participants believed that incorporating tablets and smartphones could enhance their language learning progress. While most students embraced these tools positively, some expressed concerns about potential classroom distractions, emphasizing the need for effective technology integration strategies in educational institutions.

Despite previous research (Garzón, 2021; Qiu et al., 2023) highlighting the advantages of utilizing AR in vocabulary acquisition across different educational levels, the outcomes did not support H2, which proposed a positive influence of AR technology on grammar learning. Earlier studies (Green, 2019) have previously advocated for the effectiveness of integrating AR-based materials, particularly among elementary-level students. However, our findings suggest that the effectiveness of AR on grammar learning may rely on various factors, such as the specific design of AR interventions, characteristics of the tools used, educational levels, contextual settings, and engagement frequency. Therefore, further research is required to determine whether AR technology significantly impacts grammar development.

In relation to H3, regarding the impact of AR technology on motivation, the findings demonstrate students' interest in this immersive technology. These results align with previous research that supports the positive influence of AR technology on student motivation (Lara-Prieto et al., 2015; Chen and Chan, 2019; Belda-Medina, 2022). The qualitative analysis highlighted young learners' willingness to integrate AR technology into education. However, challenges have emerged, including educators' lack of preparedness and reluctance to incorporate AR. This emphasizes the need for comprehensive awareness-building and training for secondary

education instructors, covering both the pedagogical potential of AR technology and its effective integration within the educational context, as emphasized in earlier works (Solak and Cakir, 2015; Taskiran, 2019).

## 7 Conclusion and implications

The results highlighted the positive attitude of secondary students towards technology integration (H1), despite existing restrictions on smartphone use in one of the participating schools. This finding offers teachers a unique opportunity to utilize students' readiness to accept technology in language education. However, it is crucial to address concerns regarding potential distractions caused by these devices by developing clear guidelines and policies for smartphone and tablet usage in educational settings, educating both students and teachers on responsible and purposeful technology use, as expressed in previous research (Shrivastava et al., 2014). It is also important to guide how to integrate technology effectively for educational purposes. This emphasizes the importance of considering the perspectives of secondary school teachers, who initially had reservations due to the ban on smartphones but actively participated in the implementation process. This underscores the significance of offering continuous professional development opportunities for educators, in line with prior research (Garzón, 2021; Belda-Medina, 2021; Belda-Medina and Calvo-Ferrer, 2022).

In relation to the impact of AR technology on grammar learning (H2), the findings provide a nuanced perspective. Several studies have pinpointed the positive effect of using AR on vocabulary acquisition (Santos et al., 2016; Chen and Chan, 2019), but there is a scarcity of studies on its impact on other language skills and components. Although students exposed to AR technology demonstrated increased motivation and interest in language learning (H3), there was no statistically significant difference in grammar performance compared to those using traditional materials. This suggests that while AR technology excels in enhancing student motivation, it may benefit from supplementary support or integration with traditional methods to enhance grammatical proficiency. Moreover, the heightened motivation could be attributed to the 'novelty factor' associated with AR technology, but its sustained effect needs further exploration. Educators should consider these mixed results when incorporating this technology into the language classroom, ensuring that it aligns with specific educational objectives.

A significant implication derived from the study concerns to the readiness and training of in-service teachers. The perceptions of students highlight the crucial role of instructors' familiarity with AR technology and pedagogical training in its successful implementation (Perifanou et al., 2022). Therefore, educational institutions and authorities have a responsibility to prioritize comprehensive initiatives aimed at raising awareness and providing training for educators. These programs should cover both technical skills and pedagogical strategies to ensure that educators are well-prepared and confident in utilizing AR technology in language learning (Belda-Medina, 2022).

This study has provided crucial insights into the implementation and effects of AR technology in secondary education English grammar learning. Despite the lack of statistically significant differences in grammar proficiency between the AR-enhanced and traditional teaching methods, the findings are instrumental for educators and technology integrators. The equal performance in grammar learning across both groups indicates that while AR does not necessarily surpass traditional methods in effectiveness, it introduces a valuable dimension of engagement and motivation without compromising educational outcomes. This aspect is crucial for educational stakeholders aiming to enhance student engagement without risking academic performance. The relevance of this research lies in its clear demonstration that AR can maintain, and potentially increase, student interest and satisfaction in learning environments. The data from the experimental group (EG), which showed heightened motivation and positive perceptions towards AR technology, underscore the potential of immersive technologies to enrich the educational experience. These findings suggest that when students are engaged and motivated, they are more likely to participate actively and benefit from the educational content provided, regardless of the medium.

For curriculum developers and educational policy makers, these results advocate for the integration of AR as a complementary tool rather than a replacement for traditional methods. Such integration should be carefully designed to harness the motivational benefits of AR while reinforcing the core educational objectives, especially in subjects as foundational as language learning. Additionally, this study highlights the importance of preparing teachers through targeted training that not only focuses on the operational aspects of AR but also on its pedagogical integration into the curriculum.

The implications for future research are significant. It is recommended that further studies investigate the long-term effects of AR integration on various aspects of language learning beyond grammar and motivation, such as comprehension and writing skills. Expanding the scope of research to include diverse educational settings and longer intervention periods can provide deeper insights into how AR can be most effectively employed in education.

This study has several limitations, particularly in relation to the sample size and context, as well as the AR tool used. The specific educational environment and characteristics of the AR software employed may have an impact on these constraints, highlighting the need for more comprehensive research on its influence on grammar learning. Additionally, the participant pool was limited to secondary students from two public schools with different smartphone usage policies, indicating the need for future research in more diverse settings. Extending the study beyond 4 weeks could provide valuable insights into the long-term effects of AR technology on language education.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

## Author contributions

VM-G: Formal analysis, Investigation, Software, Resources, Visualization, Writing – original draft, Writing – review & editing. JB-M: Investigation, Methodology, Formal analysis, Funding acquisition, Writing – original draft preparation.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study is part of a research project titled 'The integration of AR in language learning (EDUC-AR)', financed by the Generalitat Valenciana, Spain (Reference number: CIAICO/2022/079).

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## References

Akçayır, M., and Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: a systematic review of the literature. *Educ. Res. Rev.* 20, 1–11. doi: 10.1016/j.edurev.2016.11.002

Antonioli, M., Blake, C., and Sparks, K. (2014). Augmented reality applications in education. *J. Technol. Stud.* 40, 96–107. doi: 10.21061/jots.v40i2.a.4

Balog, A., and Pribeanu, C. (2010). The role of perceived enjoyment in the students' acceptance of an augmented reality teaching platform: a structural equation modelling approach. *Stud. Inform. Control.* 19, 319–330. doi: 10.24846/v19i3y201011

Belda-Medina, J. (2021). ICTs and Project-Based Learning (PBL) in EFL: Pre-service Teachers' Attitudes and Digital Skills. *International Journal of Applied Linguistics \ u0026amp; English Literature*. 10, 63–70.

Belda-Medina, J. (2022). Using augmented reality (AR) as an authoring tool in EFL through mobile computer-supported collaborative learning. *Teach. Engl. Technol.* 22, 115–135,

Belda-Medina, J., and Calvo-Ferrer, J. R. (2022). Integrating augmented reality in language learning: pre-service teachers' digital competence and attitudes through the TPACK framework. *Educ. Inf. Technol.* 27, 12123–12146. doi: 10.1007/s10639-022-11123-3

Belda-Medina, J., and Marrahi-Gomez, V. (2023). The impact of augmented reality (AR) on vocabulary acquisition and student motivation. *Electronics* 12:749. doi: 10.3390/electronics12030749

Buchner, J., Buntins, K., and Kerres, M. (2022). The impact of augmented reality on cognitive load and performance: a systematic review. *J. Comput. Assist. Learn.* 38, 285–303. doi: 10.1111/jcal.12617

Chen, R. W., and Chan, K. K. (2019). Using augmented reality flashcards to learn vocabulary in early childhood education. *J. Educ. Comput. Res.* 57, 1812–1831. doi: 10.1177/0735633119854028

Damopolii, I., Paiki, F. F., and Nunaki, J. H. (2022). The development of comic book as marker of augmented reality to raise students' critical thinking. *TEM J.* 11, 348–355. doi: 10.18421/TEM111-44

Demirdag, M. C., Kucuk, S., and Tasgin, A. (2024). An investigation of the effectiveness of augmented reality technology supported English language learning activities on preschool children. *Int. J. Hum. Comput.*, 1–14. doi: 10.1080/10447318.2024.2323278

Dirin, A., and Laine, T. H. (2018). User experience in mobile augmented reality: emotions, challenges, opportunities and best practices. *Computers* 7:33. doi: 10.3390/computers7020033

Gamlo, N. (2019). The impact of Mobile game-based language learning apps on EFL Learners' motivation. *Engl. Lang. Teach.* 12, 49–56. doi: 10.5539/elt.v12n4p49

Garzón, J. (2021). An overview of twenty-five years of augmented reality in education. *Multimodal Technol. Interact.* 5:37. doi: 10.3390/mti5070037

Garzón, J., Baldiris, S., Gutiérrez, J., and Pavón, J. (2020). How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. *Educ. Res. Rev.* 31:100334. doi: 10.1016/j.edurev.2020.100334

Green, M. (2019). Smartphones, distraction narratives, and flexible pedagogies: students' mobile technology practices in networked writing classrooms. *Comput. Compos.* 52, 91–106. doi: 10.1016/j.compcom.2019.01.009

Gudoniene, D., and Rutkauskiene, D. (2019). Virtual and augmented reality in education. *Balt. J. Mod. Comput.Balt. J. Mod. Comput.* 7, 293–300. doi: 10.22364/bjmc.2019.7.2.07

Jamrus, M. H. M., and Razali, A. B. (2019). Augmented reality in teaching and learning English reading: realities, possibilities, and limitations. *Int. J. Acad. Res. Progress. Educ.* 8, 724–737. doi: 10.6007/IJARPED/v8-i4/6696

Ji, H. E., and Shin, H. W. (2019). Young foreign language Learners' engagement and motivation in augmented reality-based vocabulary learning. *Multimed. Assist. Lang. Learn.* 22:9:31. doi: 10.15702/mall.2019.22.3.9

Kacetl, J., and Klímová, B. (2019). Use of smartphone applications in English language learning—a challenge for foreign language education. *Educ. Sci.* 9:179. doi: 10.3390/educsci9030179

Kaur, D. P., Mantri, A., and Horan, B. (2020). Enhancing student motivation with use of augmented reality for interactive learning in engineering education. *Proc. Comput. Sci.* 172, 881–885. doi: 10.1016/j.procs.2020.05.127

Khan, T., Johnston, K., and Ophoff, J. (2019). The impact of an augmented reality application on learning motivation of students. *Adv. Hum.-Comput. Interact.* 2019, 1–14. doi: 10.1155/2019/7208494

Küçük, S., Kapakin, S., and Göktaş, Y. (2016). Learning anatomy via mobile augmented reality: effects on achievement and cognitive load. *Anat. Sci. Educ.* 9, 411–421. doi: 10.1002/ase.1603

Küçük, S., Yilmaz, R., Baydas, Ö., and Göktas, Y. (2014). Augmented reality applications attitude scale in secondary schools: validity and reliability study. *Egit. Bilim.* 39, 383–392. doi: 10.15390/EB.2014.3590

Lara-Prieto, V., Bravo-Quirino, E., Rivera-Campa, M. Á., and Gutiérrez-Arredondo, J. E. (2015). An innovative self-learning approach to 3D printing using multimedia and augmented reality on mobile devices. *Proc. Comput. Sci.* 75, 59–65. doi: 10.1016/j.procs.2015.12.206

Lau, S. Y., and Wen, Y. (2021). "A systematic literature review of augmented reality used in language learning" in *Contextual Language Learning: Real Language Learning on the Continuum from Virtuality to Reality*. eds. L. Yu-Ju and S. Grant (Singapore: Springer), 171–186.

Lin, Y. J., and Wang, H. C. (2023). Applying augmented reality in a university English class: learners' perceptions of creativity and learning motivation. *Innov. Lang. Learn. Teach.* 17, 291–305. doi: 10.1080/17501229.2022.2040513

Marrahí-Gómez, V., and Belda-Medina, J. (2022). The application of augmented reality (AR) to language learning and its impact on student motivation. *Int. J. Engl. Linguist.* 2, 07–14. doi: 10.32996/ijls.2022.2.2.2

Martin-Gutierrez, J., Guinters, E., and Perez-Lopez, D. (2012). Improving strategy of self-learning in engineering: laboratories with augmented reality. *Procedia Soc. Behav. Sci.* 51, 832–839. doi: 10.1016/j.sbspro.2012.08.249

Min, W., and Yu, Z. (2023). A bibliometric analysis of augmented reality in language learning. *Sustain. For.* 15:7235. doi: 10.3390/su15097235

Nami, F. (2020). Educational smartphone apps for language learning in higher education: students' choices and perceptions. *Australas. J. Educ. Technol.* 36, 82–95. doi: 10.14742/ajet.5350

Nincarean, D., Alia, M. B., Halim, N. D. A., and Rahman, M. H. A. (2013). Mobile augmented reality: the potential for education. *Procedia Soc. Behav. Sci.* 103, 657–664. doi: 10.1016/j.sbspro.2013.10.385

Nizam, S. M., Abidin, R. Z., Hashim, N. C., Lam, M. C., Arshad, H., and Majid, N. A. A. (2018). A review of multimodal interaction technique in augmented reality environment. *Int. J. Adv. Sci. Eng. Inf. Technol* 8, 1460–1469. doi: 10.18517/ijaseit.8.4-2.6824

Osuna, J. B., Gutiérrez-Castillo, J., Llorente-Cejudo, M., and Ortiz, R. V. (2019). Difficulties in the incorporation of augmented reality in university education: visions from the experts. *J. New Approac. Educ. Res.* 8, 126–141. doi: 10.7821/naer.2019.7.409

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., and Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality* 23, 425–436. doi: 10.1007/s10055-018-0363-2

Pardede, P.. (2019). Mixed methods research designs in EFL. EFL theory and practice: Voice of EED UKI (proceeding of EED collegiate forum 2015–2018).

Parmaxi, A., and Demetriou, A. A. (2020). Augmented reality in language learning: a state-of-the-art review of 2014–2019. *J. Comput. Assist. Learn.* 36, 861–875. doi: 10.1111/jcal.12486

Pellas, N., Fotaris, P., Kazanidis, I., and Wells, D. (2019). Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning. *Virtual Reality* 23, 329–346. doi: 10.1007/s10055-018-0347-2

Perifanou, M., Economides, A. A., and Nikou, S. A. (2022). Teachers' views on integrating augmented reality in education: needs, opportunities, challenges and recommendations. *Future Int.* 15:20. doi: 10.3390/fi15010020

Qiu, X. Y., Chiu, C. K., Zhao, L. L., Sun, C. F., and Chen, S. J. (2023). Trends in VR/AR technology-supporting language learning from 2008 to 2019: a research perspective. *Interact. Learn. Environ.* 31, 2090–2113. doi: 10.1080/10494820.2021.1874999

Saltan, F., and Arslan, Ö. (2016). The use of augmented reality in formal education: a scoping review. *Eurasia J. Math., Sci Tech. Ed.* 13, 503–520. doi: 10.12973/eurasia.2017.00628a

Santos, M. E. C., Lübke, A. I. W., Taketomi, T., Yamamoto, G., Rodrigo, M. M. T., Sandor, C., et al. (2016). Augmented reality as multimedia: the case for situated vocabulary learning. *Res. Pract. Technol. Enhanc. Learn.* 11, 4–23. doi: 10.1186/s41039-016-0028-2

Savela, N., Oksanen, A., Kaakinen, M., Noreikis, M., and Xiao, Y. (2020). Does augmented reality affect sociability, entertainment, and learning? A field experiment. *App. Sci.* 10:1392. doi: 10.3390/app10041392

Schorr, I., Plecher, D. A., Eichhorn, C., and Klinker, G. (2024). Foreign language learning using augmented reality environments: a systematic review. *Front. Virtual Real.* 5:1288824. doi: 10.3389/frvir.2024.1288824

Shadiev, R., and Liang, Q. (2024). A review of research on AR-supported language learning. *Innov. Lang. Learn. Teach.* 18, 78–100. doi: 10.1080/17501229.2023.2229804

Shrivastava, A., Shrivastava, M., and Muscat, O. (2014). Classroom distraction due to mobile phones usage by students: college teachers' perceptions. *Int. J. Comput. Eng. Inf. Technol.* 3, 638–642.

Skarbez, R., Smith, M., and Whitton, M. C. (2021). Revisiting Milgram and Kishino's reality-virtuality continuum. *Front. Virtual Real.* 2:647997. doi: 10.3389/frvir.2021.647997

Solak, E., and Cakir, R. (2015). Exploring the effect of materials designed with augmented reality on language Learners' vocabulary learning. *J. Educ.* 12, 50–72. doi: 10.9743/JEO.2015.2.5

Sun, Y., and Gao, F. (2020). An investigation of the influence of intrinsic motivation on students' intention to use mobile devices in language learning. *Educ. Technol. Res. Dev.* 68, 1181–1198. doi: 10.1007/s11423-019-09733-9

Taskiran, A. (2019). The effect of augmented reality games on English as foreign language motivation. *E-learning and digital. Media* 16, 122–135. doi: 10.1177/2042753018817541

Tsai, C. C. (2020). The effects of augmented reality to motivation and performance in EFL vocabulary learning. *Int. J. Instr.* 13, 987–1000. doi: 10.29333/iji.2020.13460a

Wu, H. K., Lee, S. W. Y., Chang, H. Y., and Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Comput. Educ.* 62, 41–49. doi: 10.1016/j.compedu.2012.10.024

Yeh, H. C., and Tseng, S. S. (2020). Enhancing multimodal literacy using augmented reality. *Lang. Learn. Technol.* 2020, 27–37.

Yuen, S. C. Y., Yaoyuneyong, G., and Johnson, E. (2011). Augmented reality: an overview and five directions for AR in education. *J. Educ. Tech. Dev. Exch.* 4:11. doi: 10.18785/jetde.0401.10