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Enhancing English as Foreign Language Education with Virtual Reality and Augmented Reality in K–12 Classrooms: A Systematic Review from 2019 to 2023

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Abstract

Educational applications of virtual reality (VR) and augmented reality (AR) for English language learning have become increasingly prevalent in K–12 classroom contexts. These tools have enormous potential to provide unique learning experiences and increase students' engagement; however, the benefits depend on appropriate implementation and use. Given the developmental breadth among K–12 students as a group, learners' perceptions while using AR/VR tools are likely to be highly relevant to learning outcomes. This paper presents a systematic review of recent research addressing VR and AR tools within K–12 education contexts for students learning English as a foreign language (EFL). The review was guided by the following research questions: (a) What are the most effective and commonly used VR/AR tools in K–12 EFL education? (b) What are students' perceptions of learning EFL with VR/AR tools? Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol, we identified 30 peer-reviewed papers published within the past five years that met our inclusion criteria. The findings revealed the specific types of AR and VR tools being used in the K–12

classrooms to assist students with language learning and their respective efficacies. Studies revealed learners' positive experiences and emotions related to various tools as well as potential limitations and detrimental impacts. On the basis of the findings, we present preliminary suggestions for using AR/VR for EFL among young learners, as well as suggestions for future research.

Keywords: Augmented reality, virtual reality, K–12 classrooms, language acquisition, EFL.

Introduction

Background

With recent developments in virtual reality (VR) and augmented reality (AR), such as Apple Vision Pro and Meta Quest 3, their integration into educational contexts is the current fascination for educators and students alike (Redondo, 2020). VR is a computer-generated digital environment where people can interact with virtual objects and receive feedback from them (Wohlgenannt et al., 2020). Unlike traditional media (TV, radio…), VR brings the users into another dimension that has the characteristics of immersion, interactivity, and presence (Mandal, 2013). Educational applications of VR offer numerous benefits, including increased engagement, personalized spatial memory, empathy training, and distance learning (Lege & Bonner, 2020). In the context of language learning, these components play a crucial role in allowing students hands-on and memorable experiences to foster growth and deeper knowledge retention.

On the other hand, AR allows users to view their environmental surroundings with overlaid computer-generated objects (Azuma, 1997). It blends virtual content like three-dimensional (3D) modeling, music, and sensing, with the real world (Chen et al., 2019). It has been widely applied in interactive books, educational games, and real-world simulations, offering dynamic learning opportunities (Iqbal et al., 2022). AR enhances educational experiences by enabling learners to interact with the physical world in novel ways, while gamified features further boost learners' motivation. Unlike VR, AR maintains the user's connection to their real-world context, making it particularly well suited for classroom applications.

Both VR and AR are supported by constructivist learning theories, which highlight active learner participation in meaningful contexts (Sommerauer & Müller, 2018). Situated cognition theory, as a subtheory of constructivism, provides further theoretical evidence for integrating VR and AR into education by emphasizing the interconnectedness of social and activity systems within authentic environments (Lave, 1991; Wilson & Myers, 2000). Thus, VR/AR facilitates efficient learning experiences through interactions with virtual elements and real-world surroundings that may be lacking in traditional educational contexts (Billinghurst & Duenser, 2012).

English is an influential language globally, serving as an official language in 53 countries, and is the most widely studied foreign language worldwide (Ilyosovna, 2020). It is not only important in business, travel, and communication with people from all around the world, but it is also the dominant language in many academic disciplines, such as engineering, medicine, and education (Rao, 2019). The influence of English is far-reaching, and because of this, it is a mandatory subject in most countries in the world.

Despite its importance, traditional English as a foreign language (EFL) instruction faces several pedagogical limitations. Traditional classroom-based EFL teaching often relies on teacher-centered methods, which can restrict flexibility and limit opportunities for learners' interaction and engagement

(Han & Shin, 2017). These environments may lack authentic language context, reducing students' exposure to meaningful and immersive communication experiences (Lee, Wang et al., 2024). Moreover, large class sizes and limited instructional resources frequently hinder personalized feedback, making it difficult to address diverse learners' needs effectively (Anis, 2023). These constraints became particularly evident during the COVID-19 pandemic, which disrupted conventional classroom practices and accelerated the need for innovative teaching approaches (Chandasiri, 2020). In response, the integration of educational technology has gained increasing attention as a means to enhance EFL instruction. Digital tools offer the potential to create more interactive, adaptable, and context-rich learning experiences while also supporting teachers in managing instructional challenges more efficiently (Ahmadi, 2018). These developments underscore the growing interest in leveraging emerging technologies, such as VR and AR, to address the limitations of traditional language classrooms (Mahyoob, 2020).

Among the emerging learning technologies, VR and AR have demonstrated significant potential across diverse educational fields, including the arts, social sciences, and STEM (science, technology, engineering, and mathematics) (Krüger et al., 2019). In the domain of EFL instruction, scholarly interest in integrating VR/AR has grown substantially, reflecting a broader trend toward EFL learning within immersive and interactive learning environments (Belda-Medina & Marrahí-Gómez, 2023). Given the continuous expansion of research in this area, there is an increasing need to synthesize the existing findings to inform pedagogical practices. Therefore, this study aimed to provide a comprehensive overview of the VR/AR tools implemented in EFL classrooms and to examine learners' perceptions of these technologies within global educational settings.

Considering the strong global emphasis on EFL education and the expanding role of VR and AR in educational settings, it is essential to examine how these emerging technologies are being integrated into EFL instruction. Moreover, the K–12 stage is particularly significant, as it represents a critical period for language acquisition and cognitive development (Nickow et al., 2024). However, to date, there remains a notable gap in the literature, namely that no recent systematic review has comprehensively explored the use of both VR and AR in K–12 EFL contexts. Therefore, to address this issue, the present study aimed to synthesize the empirical findings to better understand how VR and AR are currently utilized in K–12 EFL classrooms, with a particular focus on the tools employed and students' perceptions. The findings identify implications for the sustainability of implementation for educators. This review focuses exclusively on EFL learners in countries where English is not an official language, so studies involving immigrant or second-generation students in English-speaking contexts were not considered. The two research questions (RQs) that guided this study are:

RQ1: What are the most effective and commonly used VR/AR tools in EFL education in K–12 classrooms?
RQ2: What are students' perceptions of learning EFL with VR/AR tools?

Literature Review

AR has been called the next frontier of technology-enhanced language learning due to the ubiquitous nature of smartphones and its mainstream acceptance in other areas (Zhang et al., 2020). Incorporating virtual content into the viewer's environment not only enhances their understanding of the real world (Azuma et al., 2001) but also creates new learning opportunities that integrate virtual and physical resources that have not been previously possible (Wu et al., 2013; Zhang et al., 2020). AR is particularly well suited for language learning in K–12 contexts, as it unites students and teachers in shared social experiences. AR instructional tools enhance materials with images, animations, and even virtual

characters. They facilitate this through communicative approaches, constructivism, and situated learning. This is a monumental benefit for learners who thrive on using differentiation, such as English learners and learners with learning disabilities, and complements the universal design for learning (Walker et al., 2017). With AR, diversity in learners is valued and supported through supplemental multimedia content, unmatched by the limitations of the real world.

AR technology and instruction tools have been tested in hundreds of studies (Fan et al. 2020; Parmaxi & Demetriou, 2020). Garzón & Acevedo (2019) revealed that AR has a positive effect on students' learning gains through a meta-analysis of 64 quantitative studies (d = 0.68). Three decades of empirical research have demonstrated that AR increases learning gains, motivation, enjoyment, and learner autonomy (Garzón, 2021). In a review of over 60 studies, Fan et al. (2020) found that the acquisition of language knowledge in the form of words and skills is successful through AR usage in children as young as four years old. The review also revealed that learning gains increase when educators use 3D multimedia (presentation strategies). Children are enthralled by the use of animated AR characters, which results in higher motivation and comprehension (Moreno et al., 2001). Evidently, 3D multimedia produces higher learning gains for new language content (Fan et al., 2020). AR-enhanced language learning instruction bridges the gap for students with learning disabilities through visualizations of abstract concepts, presenting content in multiple modalities, and first language (L1) support (Smith et al., 2023).

The use of appropriately designed immersive content has been shown to help increase learning and comprehension of content within K–12 environments (Repetto et al., 2018). VR has been used in a range of areas and in schools, and the role that immersive technologies have played in reading comprehension is an area of growing interest and exploration (Osvath & Schneider, 2023). In a review of literature from 2010 to 2020, Villena-Taranilla et al. (2022) concluded that VR has a medium to large positive effect on students' learning gains, noting that immersive VR promotes larger gains than semi-immersive and nonimmersive systems. VR is increasingly recognized as a promising technology for K–12 and higher education due to its capacity to create immersive learning experiences through simulated realism, multimodal interaction, visualization of abstract concepts, and a sense of embodiment and empathy, which are all key affordances highlighted in current research (Ke et al., 2020; Makransky & Petersen, 2019; Tilhou et al., 2020). These features enable experiential and inquiry-based learning, benefiting students through enriched experiences, greater engagement, enhanced knowledge transfer, improved collaboration, increased empathy, agency, and a sense of embodied presence (Dalgarno & Lee, 2010).

VR-based instruction in K–12 education has generally increased over the past two decades (i.e., 2000–2020), following an S-shaped growth curve in three notable surges: 2002, 2008, and 2018 (Luo et al., 2021). Each of these surges aligned with major technological advancements. It was first noteworthy in 2002, with a heavy focus on desktop-based simulations for science subjects (Moreno & Mayer, 2002; Park et al., 2002; Shin, 2002). Interest renewed in 2008 with the rise of virtual worlds like Second Life, which educators used to teach abstract concepts through virtual interaction and presence (Hew & Cheung, 2010; Merchant et al., 2012). The most recent surge in 2018 likely resulted from the launch of commercial VR headsets, such as Oculus Rift and HTC Vive, spurring more research on immersive VR in education (Pedram et al., 2023). The benefits of using immersive technologies in K–12 education are promising, as evidenced by learning gains and increased motivation among learners (Luo et al., 2021).

Regarding the context of EFL education, VR offers second language (L2) learners' unique opportunities to practice English oral communication skills in simulated real-world environments. For example, students can engage in role-playing avatar scenarios, such as ordering food in a virtual restaurant, job

interviews, shopping in a grocery store, or asking for directions, which all provide rich contexts for vocabulary development and communicative opportunities (Chen & Kent, 2020). Research has shown that such immersive experiences support the development of both speaking and listening skills by lowering affective filters and reducing learners' foreign language speaking anxiety (Chen, 2024). Learners report increased confidence in using English after participating in VR-based interactions, often due to the safe and motivating nature of virtual environments (Yan et al., 2024). VR also supports vocabulary retention by exposing learners to new words in meaningful situations. This contextualized and multimodal approach enhances long-term memory encoding, making it more effective than traditional flashcards or textbooks (Tai et al., 2022). Furthermore, when learners feel emotionally engaged within a VR environment, they are more likely to connect with the language content on a deeper cognitive level, promoting better transfer to real-world use (Vats & Joshi, 2024).

Previous Studies

Sixteen previous systematic reviews were found that were partly related to our topic (See Appendix A for the summary of the previous reviews). Out of these sixteen, only one focused on both VR and AR in English education (Huang et al, 2021). Other reviews only focused solely on either VR (Bahari, 2022; Chen et al., 2022; de Paula Forero Pataquiva & Kilmova, 2022; Dhimolea et al., 2022; Hein et al., 2021; Ozgun & Sadik, 2023; Parmaxi, 2023; Peixoto et al., 2021; Tegoan et al., 2021) or AR (Alshumaimeri & Mazaher, 2023; Fan et al., 2020; Parmaxi & Demetriou, 2020). Three reviews examined the impacts of VR and AR in K–12 education overall but did not specifically focus on any subject (Li et al., 2021; Mass & Hughes, 2020; Penn & Ramnarain, 2023). Moreover, almost all of the 16 previous reviews focused on the benefits and limitations of VR/AR in language learning, the language skills being taught, the teaching strategies, and future research directions (Bahari, 2022; Parmaxi, 2023; Tegoan et al., 2021). Only a few explored the specific tools or software used and students' perception of application in learning English (Fan et al., 2020; Huang et al., 2021; Parmaxi & Demetriou, 2020). All of the reviews examined studies before 2019, which is a limitation, given the development of new tools and software in recent years. Another limitation is that higher education appears to be the main context for applying VR/AR technologies in language learning, providing a gap in knowledge on the potential for VR/AR impact on K–12 students' learning outcomes (Dhimolea et al., 2022; Peixoto et al., 2021). Please see Appendix A for more information about the previous studies.

Therefore, our study is distinct from previous reviews in three ways. First, as recommended by Huang et al. (2021), this systematic review focused on both technologies. This not only provides a broad overview of the software and applications used but also compares the affordances of both technologies. Second, this review does not limit itself to the effectiveness of VR/AR in EFL learning, teaching strategies, or language skills, but identifies specific VR/AR tools and students' perceptions. Last, unlike previous studies, which had no age limitations, this review only focuses on the K–12 context. This study had two main aims: (1) To identify which VR and AR tools were used in K–12 EFL education, and (2) discuss the students' current perceptions regarding the tools in studies limited to the past five years (2019–2023), in compliance with the increasing interest in this field (Hua & Wang, 2023; Kaplan-Rakowski et al., 2023; Parmaxi, 2023).

Understanding K–12 EFL students' perspectives on immersive technologies holds both theoretical and pedagogical significance. Motivation is widely regarded as one of the most critical factors in L2 acquisition, with a substantial body of literature supporting its role in learners' achievement from both theoretical and empirical perspectives (Alamer & Al Khateeb, 2023; Panagiotidis et al., 2023; Pranawengtias, 2022). Among the various theoretical models, Dörnyei's (2009) L2 motivational self system is the most widely applied, and one of its core components is the L2 learning experience, which refers to the learning environment. This construction encompasses classroom-based experiences and

instructional approaches. Accordingly, the integration of VR and AR technologies into classroom instruction can be viewed as a key element of the L2 learning experience. Therefore, investigating learners' perceptions of these immersive technologies is essential not only for understanding how motivational factors influence EFL learning outcomes but also for informing pedagogical strategies aimed at enhancing learners' engagement and achievement.

Methodology

To address the research questions with the most pertinent and up-to-date studies, this systematic review examined peer-reviewed articles published between 2019 and 2023 that focus on the application of VR and AR in K–12 EFL education. This five-year span was selected to reflect the most recent technological developments and pedagogical applications, particularly following the release of more accessible immersive devices such as Oculus Quest and Microsoft HoloLens 2, and the shift toward digital and remote learning during the COVID-19 pandemic. By focusing on studies from this period, the review captures the current state of practice and innovation in the integration of VR/AR in EFL instruction. The review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009).

Search Strategy

An initial search was conducted using four electronic databases: Academic Search Premier, Education Source, Scopus, and Web of Science. The search employed the following terms: "augmented reality" OR "virtual reality" OR "AR" OR "VR" AND "English language learning" OR "English language education" OR "English learning" OR "EFL" OR "ESL" OR "English as a second language" OR "English as a foreign language" OR "ELL" OR "ELI" OR "English language instruction" OR "English" AND "K-12" OR "K-12 education" OR "elementary school" OR "middle school" OR "high school" OR "secondary education" OR "primary education" OR "early childhood education" OR "kindergarten." We also conducted a hand search through all of the references of the aforementioned 16 systematic reviews pertaining to this topic to ensure that studies relevant to this review were not missed. After the hand search was conducted, no additional studies were yielded that met the inclusion criteria. The inclusion criteria for this review are listed in Table 1.

Table 1 *Inclusion/Exclusion Criteria for this Review*

Inclusion	Exclusion
The study must be conducted with a specific VR/AR tool	Any study that used other tools
The study must be conducted in a K–12 context	The study was conducted in a higher education context
The study must be an empirical study	Any study that was not an empirical study
The study must be related to EFL learning	Any study that was not related to language learning
The study must include students' perceptions of the teaching methods and VR/AR tool	Any study that did not include students' perceptions on the teaching methods and VR/AR tool
The study must be published in English	Studies published in other languages
The articles must be peer-reviewed	Any study that was not peer-reviewed
The full text of the articles must be available online	Any study that was inaccessible

Article Selection

The initial search identified 660 studies. After removal of 190 duplicates and screening of the titles and abstracts, 361 articles were excluded on the grounds of relevance, leaving 109 articles for the full-text review. Following the application of the inclusion and exclusion criteria, 30 articles were selected for this study (See Appendix B for details of the 30 articles). The PRISMA process is summarized in Figure 1.

Coding Process

To analyze the 30 selected studies, this review employed a structured content analysis approach (Kleinheksel et al., 2020). The authors developed a coding scheme that aligned with the study's two research questions. First, the first and second authors collaboratively developed a coding framework in a shared Google spreadsheet to extract the basic study characteristics, including the learners' age groups, L1, target languages, language skills, and the VR/AR tools used. To ensure the inter-rater reliability, Cohen's *k* was calculated, and it reached 0.91, which indicated almost perfect agreement (McHugh, 2012). This categorization provided a descriptive foundation for addressing RQ1 and offered a synthesized overview of the selected studies.

For RQ2, which examined student perceptions of the tools and instructional strategies, the same two authors independently identified and labeled themes from the articles, including motivation, engagement, enjoyment, perceived usefulness, and technological or instructional challenges, using a predefined coding scheme to guide the identification of recurrent themes (see Appendix C for examples of coding). Cohen's *k* reached 0.84, demonstrating strong agreement (McHugh, 2012). The two authors then compared their results line by line to identify discrepancies. Differences primarily occurred in

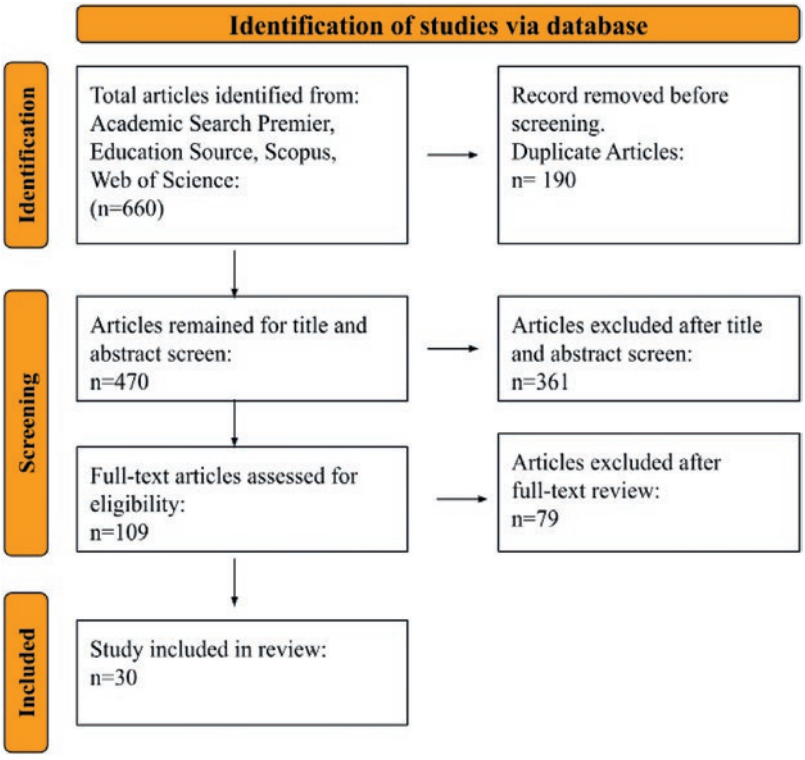

Figure 1 *PRISMA Chart for the Screening Process.*

how certain perception-related statements were categorized (e.g., whether a comment reflected "motivation" or "usability"). These cases were reviewed in joint discussions, and decisions were made through mutual agreement according to the definitions established in the coding scheme. This iterative process ensured that the themes were accurately and consistently applied across the dataset.

The final coded data were then summarized to reflect how frequently and in what context each theme appeared across the studies. This structure formed the basis for synthesizing the findings in the results section.

Results

Demographics of the Articles Included

Year of Publication

Among the 30 articles published between 2019 and 2023, a significant majority were published in 2023, accounting for 16 articles. Only one article appeared in each of the years 2019 and 2021, while seven articles were published in 2022. The distribution of publication years and trends is illustrated in Table 2.

Students' L1

Regarding the L1 of the students, Chinese accounts for 13 of the 30 studies, thus encompassing almost half at 43.3%. Spanish is the second most common L1 for the students, with five studies included. For other students' L1, Turkish (n = 4), Arabic (n = 3), Korean (n = 2), Persian (n = 1), Greek (n = 1), and Bahasa Indonesia (n = 1) are also included. Students' L1 in the studies are summarized in Table 2.

Educational Context

Among the studies included, half were conducted in elementary schools, comprising 15 studies. Six studies were conducted in middle schools, six studies in high schools, and only three studies were set in a kindergarten context. Table 3 displays how the studies were divided into different contexts.

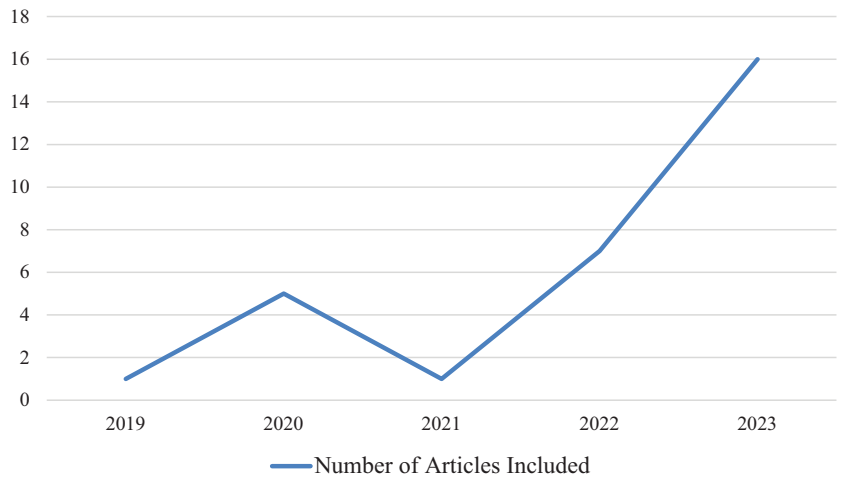

Figure 2 *Year of Publication of The 30 Articles Included in the Study.*

Table 2 *Students' L1 in the Studies*

Students' L1	Number of Studies
Chinese	13
Spanish	5
Turkish	4
Arabic	3
Korean	2
Persian	1
Greek	1
Bahasa Indonesia	1

Table 3 *Educational Context*

Context	Number of Studies
Kindergarten	3
Elementary school	15
Middle school	6
High school	6

Language Skills

In the 30 articles, most language skills were investigated. Two-thirds of the studies focused on vocabulary learning ($n = 20$), three were related to language speaking skills, and two explored reading skills. The other five articles each focus on a specific language skill, including expository writing, pronunciation, grammar, listening, and sentence structure. The results on language skills are shown in Table 4.

Table 4 *Main Language Skills Explored in the Studies*

Language Skill	Number of Studies
Vocabulary	20
Speaking	3
Reading	2
Pronunciation	1
Expository writing	1
Listening	1
Sentence structure	1
Grammar	1

RQ1: What are the most effective and commonly used VR/AR tools in EFL education in K–12 classrooms?

By analyzing the 30 articles, the VR/AR tools applied in the studies were identified. Only one study used both VR and AR tools. Among the other studies, 10 studies applied VR tools only, with 19 studies applying AR tools. The distribution of VR and AR tools is displayed in Table 5.

Table 5 *Distribution of VR/AR Tools*

VR/AR Tools	Number of Studies
VR	10
AR	19
Both VR and AR	1

VR Tools Applied in the Studies

Regarding the VR tools applied, no single one was identified as commonly adopted in the existing studies. Google Earth VR (n = 2) and self-designed VR tools (n = 4) appear to be relatively popular in EFL education. There were discrepancies in which development platforms were used. Some studies identified using development software like Unity and 3Ds Max, CoSpaces, and Immerse, whereas one did not specify the platform. Other tools used in the studies included YouTube VR (n = 1), Panoramic Image VR (n = 1), Mondly VR (n = 1), and Angels and Demigods (n = 1). The VR tools applied in the studies are concluded in Table 6, and the development platforms for self-designed VR tools are concluded in Table 7.

Table 6 *VR Tools Applied in the Studies*

VR Tools	Number of Studies
Self-designed VR tools	4
Google Earth VR	2
YouTube VR	1
Panoramic Image VR	1
Mondly VR	1
Angels and Demigods	1

Table 7 *Development Platforms for Self-designed VR Tools*

Development Platforms for Self-designed VR Tools	Number of Studies
Unity combined with 3Ds Max	1
CoSpaces	1
Immerse	1
Not mentioned	1

AR Tools Applied in the Studies

Of the 19 studies that applied an AR software/tool in EFL education, 12 applied a self-designed AR software/tool, accounting for 63.2%. Three studies used AR flashcards as teaching materials. Other AR tools applied in the studies include the You Only Look Once (YOLO) algorithm (n = 1), Storybook

Alive (*n* = 1), VocabGo (*n* = 1), and StemUp (*n* = 1). For self-designed AR tools, HP Reveal (*n* = 3), formerly known as Aurasma, was the most commonly adopted development platform, with Vuforia (*n* = 2) as the second favorite development tool. Other development tools applied in the studies are MywebAR (*n* = 1), Assemblr AR (*n* = 1), Aumentaty (*n* = 1), 3Ds Max (*n* = 1), and JavaScript (*n* = 1). Yet again, two studies applied self-designed AR tools but did not disclose their development platform. The details of the development platform for customized AR tools are depicted in Table 8, and the development platforms used for self-designed AR tools is described in Table 9.

Table 8 *AR Tools Applied in the Studies*

AR Tools	Number of Studies
Self-designed AR tools	12
AR flashcards	3
YOLO algorithm	1
Storybook Alive	1
VocabGo	1
StemUp	1

Table 9 *Development Platforms used for Self-designed VR Tools*

Development Platforms for Self-designed AR Tools	Number of Studies
HP Reveal (Aurasma)	3
Vuforia	2
MywebAR	1
Assemblr AR	1
Aumentaty	1
3Ds Max	1
JavaScript	1
Not mentioned	2

RQ2: What are students' perceptions of learning EFL with VR/AR tools?

Quantitative Likert scales and qualitative interviews with the participants are the two most commonly used assessments of students' perceptions. Throughout the 30 studies, it was found that students consistently expressed positive attitudes toward employing VR/AR tools or software for language learning. The primary drivers behind these positive perceptions were the engaging and enjoyable nature of the activities (e.g., Chen & Liao, 2022; Shaaban & Mohamed, 2024; Smith et al., 2023; Topu et al., 2023), heightened feelings of involvement and motivation (e.g., Hussein et al., 2023; Mamani-Calapuja et al., 2023; Raman et al., 2023), as well as ease of access and adaptability (Belda-Medina & Marrahi-Gomez, 2023; Chen et al., 2020; Hu et al., 2022; Naji et al., 2024; Rapti et al., 2023; Tai et al., 2022). Additionally, a reduction in language anxiety and an increase in confidence (Chang et al., 2020; Hung et al., 2023; Lee et al., 2024; Tsai, 2020; Ustun et al., 2022) were

cited as significant factors contributing to positive student perceptions. Specific features like animations, pop-up pictures, and sounds were highlighted as highly favorable among students (Naji et al., 2024 Tsai, 2020; Yilmaz et al., 2022). They also enjoyed immersive environments, interacting with virtual objects in real environments (Chang et al., 2020; Restall et al., 2023; Tai et al., 2022; Wu & Hung, 2022), and gamification (Liao et al., 2024). Some learners also emphasized personalized learning experiences (Naji et al., 2024. Conversely, learners also voiced concerns and negative attitudes. For instance, students reported that the activities consumed excessive time, and they struggled to incorporate the findings from the activities into their writing tasks (Chen et al., 2020). Several participants expressed concerns regarding potential detrimental effects, including dizziness and the distractions of moving images within headsets (Binhomran & Altalhab, 2021; Tai et al., 2022; Tsai, 2020; Wu & Hung, 2022). Moreover, technical issues, such as poor internet connectivity, were also identified (Belda-Medina & Marrahi-Gomez, 2023; Song et al., 2023).

Discussion

Characteristics of the Studies

The integration of VR and AR into language education has garnered significant scholarly interest within the domain of technology-enhanced language learning. The volume of research has surged over the past five years, with a notable increase in 2023. This trend is possibly influenced by the burgeoning popularity and technological advancements of VR/AR, exemplified by the release of devices such as the Apple Vision Pro and Meta Quest 3. The reviewed studies predominantly involve students whose L1 is Chinese, reflecting China's substantial demographic of English language learners. Although the current review is that of K–12 educational settings, elementary schools are the primary focus. This emphasis in the current research may be due to the critical period of language acquisition in young children. Additionally, elementary students are generally more adept with technology compared with preschoolers. As highlighted by Peixoto et al. (2021), VR/AR holds considerable potential for enhancing a multitude of language skills, as corroborated by this review, showcasing the diverse range of skills, with vocabulary acquisition being the most prominent. Vocabulary is emphasized, which may be due to the substantial concrete evidence supporting technology's positive impact on vocabulary learning and its pivotal role in language acquisition. Speaking skills are also explored, likely because the immersive environments provided by VR/AR offer students increased opportunities for conversational communication. However, there is a lack of substantial references regarding listening and writing skills, as Fan et al. (2020) mentioned. This gap highlights areas in need of future research and exploration.

The VR/AR Tools Applied in the Studies

The VR/AR software and tools reviewed in the present systematic review are classified into two primary categories: VR tools and AR tools. Of the studies analyzed, 1 integrates both types of tools, while 10 studies utilized VR tools, and 19 studies employed AR tools. This difference identifies the greater adoption of AR among EFL educators, potentially due to AR's user-friendly characteristics. Notably, among the 19 studies utilizing AR tools, 63.2% employed self-designed tools, with the remainder incorporating five distinct existing AR tools. Likewise, 2 of the 10 studies utilizing VR tools involved self-designed tools, with the remaining studies using seven different pre-existing VR tools. Research in both domains highlights the absence of a universally accepted software package or tool for the creation of VR/AR applications in K–12 EFL education. The findings also imply that creating custom AR tools may be more feasible for language educators compared with VR tools, as AR development platforms often require less coding expertise. Customized AR tools can be tailored to specific educational needs, such as the students' ages and language proficiency levels, and the teaching objectives. It appears that

the development of VR content appears to pose greater challenges for EFL educators. This review aims to elucidate the characteristics of both VR and AR tools to offer language educators a more thorough understanding of these technologies in the context of EFL education.

VR Tools Included

Among the 10 studies that applied VR tools, Google Earth VR appears to be relatively popular VR software for EFL educators. It allows users opportunities to see the world without leaving their classrooms. Google Earth not only provides students with personal experiences so that students can potentially have more inspirational ideas for their papers (Chen et al., 2020) but also develops students' speaking abilities (Raman et al., 2023). Students reported feeling confident when speaking English with their peers in the fictitious environment. Moreover, Google Earth VR provides information such as geographic knowledge and cultural knowledge, which can be important if EFL educators plan to teach content-based English. As free software that can be easily downloaded, it is accessible for language educators to apply in the classroom.

Another popular VR software applied in the studies was Mondly VR, a specific language learning application. It provides different real-life examples of vocabulary learning through environments such as hotels and restaurants. Therefore, interaction with the contextual application within virtual environments would be an effective method for developing English learners' skills of daily communication and vocabulary. According to Tai et al. (2022), Mondly VR promotes students' English learning by providing them with multimodal support, interactivity, and immediate feedback. It appears to enable students to have a higher retention level after learning new vocabulary compared with students who learned vocabulary with normal videos. Moreover, Mondly VR is not limited to English and provides resources that other language teachers can apply in their classrooms as well.

Several other tools were also applied in the studies, such as YouTube VR, Panoramic Images VR, and *Angels and Demigods*. YouTube VR and Panoramic Images VR were both applied to teach students English by immersing them in a VR picture or video. Students' learning outcomes were significantly better than those who learned English with traditional images or videos, which may be thanks to the feature of interactivity compared with still pictures or videos. *Angels and Demigods* is a VR game applied by Lai and Chen (2023) to teach elementary students vocabulary. Like other virtual environments where students can interact with the virtual characters in the game, this game also brought students more interesting learning experiences. Even though both groups of students expressed positive perceptions, compared with learning English vocabulary with a PC game, students who learned English vocabulary with VR games tended to display better retention levels in the delayed test. Furthermore, VR games, like other VR tools, appear to significantly enhance students' language learning experiences, considering that they combine language learning with both emerging learning technologies and game-based teaching strategies. *Angels and Demigods* is just one example of a VR game that can be applied in EFL educational contexts. There are abundant other free VR games available that may have the potential to be integrated into language classrooms, so it is highly recommended that future research should focus on VR games or gamified VR tools in language learning.

Four studies utilized self-designed VR software or tools. Except for Acar and Cavas (2020), who did not specify the development platform used, each of the remaining studies employed a different VR development platform. Yang et al. (2020) utilized Unity in conjunction with 3Ds Max to create a VR Life English learning system aimed at enhancing students' English communication skills across various contexts. Likewise, Wu and Hung (2022) and Lee, Yang et al. (2024) employed CoSpaces and Immerse, respectively, to develop immersive virtual environments for improving students' English-speaking

skills. Similar to existing VR tools, these custom ones also emphasize the significance of immersion and an interactive virtual environment, which have the potential to foster greater student confidence and willingness to engage in English conversation. Crucially, self-designed VR software packages/tools offer language educators the advantage of tailoring settings and contexts to align with specific teaching objectives and course requirements. Given the capabilities of VR development platforms, including interactive and immersive environments, 3D modeling, and support for various headsets and systems, these platforms could also be adapted to create AR teaching materials. Notably, among the three platforms mentioned, Unity requires the users to have prior coding knowledge, whereas CoSpaces and Immerse require minimal or no coding experience. Consequently, in the absence of widely adopted VR software tools for EFL education, it is recommended that EFL educators should consider developing custom VR tools if their specific needs warrant such an approach.

AR Tools Included

The most frequently utilized AR-enhanced educational materials are AR flashcards. These tools allow learners to scan a marker with smartphones or tablets, which then display a 3D model and animation of the target word on the screen while simultaneously providing its pronunciation. The adaptability and user-friendliness of AR flashcards facilitate their use by young children in language classrooms with minimal difficulty. Consequently, AR flashcards are predominantly applied in early language learning contexts, particularly for vocabulary acquisition. Their dual-channel approach, which integrates both visual and auditory stimuli, has significant potential to enhance students' engagement and motivation by rendering the learning experience more interactive and enjoyable. Yilmaz et al. (2022) have demonstrated that AR flashcards can improve educational outcomes and increase retention rates, with learners maintaining newly acquired vocabulary over extended periods.

Other existing AR tools applied in the studies, such as StemUp, Storybook Alive, and the YOLO algorithm, generally applied game-based or location-based strategy to teach English vocabulary (Binhomran & Altalhab, 2021; Liao et al., 2024; Naji et al., 2024). The feature of these existing AR mobile applications is mobility which allows students to learn English on a mobile device. Students can simply connect and interact with virtual objects in the real world. It is advised that future studies could further explore mobile applications that employ a location-based or game-based learning strategy.

Development Software for Self-designed AR Tools

Among the 12 studies that utilized custom-designed AR tools, HP Reveal (formerly known as Aurasma) and Vuforia emerged as the most frequently employed development platforms. This echoes the findings from previous reviews (Fan et al., 2020; Huang et al., 2021; Parmaxi & Demetriou, 2020). Unfortunately, HP Reveal has not been available since 2019. Vuforia's advanced tracking and image recognition functionalities and user-friendly features enable developers to create AR applications that enhance environmental interactivity and offer a more engaging learning experience. Unity is also a platform applied in the studies which have been introduced above. Additionally, two relatively recent AR development platforms, MywebAR and Assemblr AR, were featured in the studies (Hussein et al., 2023; Ustun et al., 2022). Both platforms were launched in 2021 and are still being frequently updated. Moreover, both platforms do not require any coding knowledge and also have a mode specifically for designing educational materials, which has drawn the attention of educators in recent years. Other platforms like Aumentaty and JavaScript are also included. However, both platforms are either not widely adopted or require rich coding skills, so they are not recommended for language educators with little coding experience. Notably, in the context of self-designed AR games, key game elements that are frequently utilized include quizzes, scavenger hunts, and team challenges. It is advisable for language educators to not only focus on designing 3D models and animations but also to carefully consider the

integration of these game mechanics into their game designs. Incorporating such interactive elements can enhance the educational value and engagement of AR applications, thereby fostering a more effective and stimulating learning environment.

Learners' Perceptions of using AR and VR in Language Learning

The use of VR and AR has had notable positive impacts on students' perceptions. Students appear to be more engaged, interested, and satisfied (Endahati & Wardani, 2023; Raman et al., 2023). Many learners gave positive feedback (Khazali et al., 2023). Another notable finding was that students perceived VR applications, like Google Earth, to be more flexible (Chen et al., 2020). Flexibility is an important aspect to draw attention to, as it means that learners believe the applications to have the ability to be personalized according to their specific needs. In this study, these positive perceptions are further aligned with the situated learning theory (Lave, 1991; Wilson & Myers, 2000). The constructivist theory of learning principles aligns with the use of AR and VR and further supports positive student interactions.

While there were many positive perceptions, learners also had negative views of the technologies. With the use of AR, some students had issues integrating what they learned into their assignments (Chen et al., 2020). This could have been due to poor implementation by the educators. However, some students had negative perceptions due to technical issues that created implementation issues (Belda-Medina & Marriahi-Gomez, 2023; Song et al., 2023). These issues are more aligned with the way that the tools operated and were created.

Learners' perceptions are vital for future implementations of VR and AR to be successful. If student perceptions are not taken into consideration, then negative experiences may become more frequent. This could lead to students being more resistant to interacting with these technologies in the future. If this were to occur, then the benefits of the technologies would be forgone. This systematic review has a few suggestions regarding learners' positive perceptions of the implementation of VR and AR. It is vital that any implementation is tested ahead of time and is relevant to the assignments that students are being asked to complete. Additionally, it is important that the technologies are able to be controlled by students and cater to their learning needs.

Implications

In the majority of the studies, the tools were self-designed. Currently, there are no specific standards for technologies to be implemented within classrooms. This lack of pre-created resources causes the responsibility to fall on the educator's shoulders. Combined with the educators' limited previous experience, the difficulty of collaboration and sharing, and time constraints, the path leads to equity issues within education. With no iterative improvements, there can be no created standards for technology that will be easily applied in the K–12 context.

VR and AR tools for EFL also have many pedagogical implications. The use of technology allows for enhanced learning experiences, which reduces the cognitive load on learners and enables them to scaffold information to reduce extraneous load (Sweller, 1988). Thus, using these technologies in language learning would allow previous pedagogy to apply to current learning processes. This can also have positive implications for research in the future. There could be comparisons between traditional and VR/AR-based learning in longer studies. Additionally, accessibility may increase through the use of these technologies, which could be evaluated.

While there are many positive aspects, there are also some limitations. There are difficulties in creating of resources that have implications for integration in the K–12 setting. It is not sustainable to integrate

technology without support and expect educators to continuously create their own tools. Negative experiences of integration can hinder educators' future opportunities and outlooks. Perceptions of these technologies are directly connected to their potential implications.

Research Gaps

In the realm of contemporary research on language education using VR and AR, there is a noticeable predominance of studies focusing on English as the target language. This observation underscores a significant gap in the literature regarding the application of VR/AR technologies to the acquisition of languages other than English (Peixoto et al., 2021). Additionally, numerous studies advocate for further investigation into the long-term effects of AR on language learning and the retention rates of students following the conclusion of such interventions (Chen et al., 2022; Wu & Hung, 2022; Yilmaz et al., 2022). Research to date has predominantly concentrated on vocabulary acquisition, with a marked deficiency in studies addressing other critical language skills, particularly reading and writing.

Although a considerable body of work has examined learners' perceptions of VR/AR technologies, there is a scarcity of research exploring the perspectives of instructors and school administrators. These stakeholders play a crucial role in adapting teaching methodologies, and their insights are essential for the effective integration of VR/AR tools into educational practices. Future research should therefore incorporate the viewpoints of these key participants. Regarding the technological tools employed, while there are numerous VR applications in EFL education, there remains a notable underutilization of AR software and tools within language classrooms. It is recommended that future studies explore the potential integration of existing AR tools, such as StemUp and VocabGo, into language instruction. Moreover, the current literature lacks sufficient exploration of how various contextual variables—such as socioeconomic status, gender, type of school, and geographic location—affect students' learning outcomes with VR/AR. Future research could benefit from investigating how these factors might influence the efficacy of VR/AR technologies in language learning, for example, by comparing the impacts on students from public versus private schools.

Study Limitations

A primary limitation of this review is its exclusive focus on articles published in academic journals, which constrains the breadth of sources examined. Future research should expand to include conference papers, book chapters, and doctoral dissertations to provide a more comprehensive overview of the subject. Additionally, this review only offers a general analysis of EFL education within the K–12 context, so future systematic reviews should consider investigating the impacts of VR and AR on specific language skills within particular age groups, such as the application of VR/AR tools in middle school English speaking classrooms. Moreover, this review predominantly addresses students' perceptions of VR/AR technologies but does not cover the viewpoints of teachers and administrators regarding the integration of such tools in K–12 EFL settings. Given that these stakeholders' perspectives significantly influence educational policies, understanding teachers' and administrators' attitudes toward the integration of VR/AR technologies could be crucial in shaping classroom practices. Research into these perspectives would provide valuable insights for educators aiming to adapt their teaching strategies and offer targeted recommendations for developers to enhance their products.

Conclusion

This systematic review analyzed 30 empirical studies on VR and AR-based tools for K–12 EFL education to explore the current state and future potential of immersive technologies in EFL classrooms.

Overall, the findings demonstrate that VR and AR tools offer multiple pedagogical benefits such as enhancing students' engagement, personalization, and interaction. AR tools were more widely used than VR, with a predominance of self-designed applications, which highlighted the lack of standardized resources in the field. This reliance on custom immersive tools raises concerns about educational equity, particularly in under-resourced areas. Learners generally show positive perceptions of their learning experiences using AR/VR; however, some also encountered technical or implementation challenges. These issues underscore the importance of infrastructure, teacher readiness, and institutional support in ensuring the successful integration of VR and AR tools in K–12 EFL classrooms. Furthermore, the review identified significant research gaps, including underexplored language skills (e.g., reading and writing), long-term learning outcomes, and the perspectives of educators and administrators.

In conclusion, AR and VR hold considerable promise for supporting K–12 EFL instruction, especially when integrated with suitable pedagogical frameworks. However, to fully realize their potential, future research must adopt a broader and more inclusive lens, like examining various educational contexts, expanding the focus beyond vocabulary, and incorporating administrators' perspectives. With continuous technological innovation and pedagogical support, VR and AR tools can evolve from experimental tools to impactful components of everyday K–12 EFL education.

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Appendix A
Recent systematic reviews on VR or AR in language learning or K–12 education

Authors	Topic	Studies reviewed	Year range
Alshumaimeri & Mazaher (2023)	Describing AR and the use thereof on the basis of examples derived from various contexts in the development of learners' language skills in learning EFL.	7	N/A
Bahari (2022)	Exploring and bringing together the reported affordances and challenges of VR to teach receptive and productive L2 skills.	75	2010–2020
Chen et al. (2022)	Examining the effects of VR on students' academic performance in language learning, including linguistic gains and affective gains.	21	2010–2021
Dhimolea et al. (2022)	Reviewing existing articles on VR-based language learning; describing the trends, VR content, and learners' perceptions.	32	2015–2020
de Paula Forero Pataquiva & Kilmova (2022)	Analyzing what language skills and what students' language proficiency level benefited most from the use of VR.	7	N/A
Fan et al. (2020)	Exploring AR applications' design, instructional strategies, and evaluation of learning outcomes in early language learning.	53	2010–2019
Hein et al. (2021)	Providing information at where immersive interventions are taking place and identifies potential gaps in research related to foreign language learning.	54	2001–2020
Huang et al. (2021)	Exploring AR and VR-enhanced language learning.	88	2003–2013
Li et al. (2021)	Providing an overview of the recent immersive technologies in education settings.	36	2016–2020
Mass & Hughes (2020)	Explore how VR, AR, and mixed reality (MR) are used in K–12 education.	29	2006–2017
Ozgun & Sadik (2023)	Helping researchers, educators, and teachers identify the benefits of using iVR systems for foreign language learning.	32	2018–2022
Parmaxi & Demetriou (2020)	Capturing the state of the art in using AR in language learning	54	2014–2019
Parmaxi (2023)	Reviewing the practice of using VR in language learning, and providing implications for future research and practice	26	2015–2018
Peixoto et al. (2021)	Evaluating of VR's impact on language learning environments.	30	2020–2021
Penn & Ramnarain (2023)	Exploring what pedagogies related to MR could be applied in K–12 education.	18	2011–2021
Tegoan et al. (2021)	Providing a basis for adopting XR technology for teaching languages in schools.	21	2011–2021

Appendix B
Details about the 30 articles included in the study

	Author(s)	Context	Students' L1	Language skills	VR/AR tool	Learners' perceptions
1	Acar & Cavas (2020)	Middle school	Turkish	Reading	Self-designed VR tool (development tool not mentioned)	Students' cognitive skills improved and they were responsible for their own reading skills.
2	Belda-Medina & Marrahi-Gomez (2023)	High school	Spanish	Vocabulary	Self-designed AR tool (developed with Aumentaty)	Positive: AR tools are easy to use; students felt more enjoyment and engagement, and they liked the interaction with multimodality. Negative: Lack of resources; poor internet connection.
3	Binhomran & Altalhab (2021)	Elementary school	Arabic	Vocabulary	Storybook Alive (AR)	Positive: The activity is entertaining and students especially like group learning. Negative: AR objects are distracting, and students need more help from the teachers.
4	Chang et al. (2020)	Middle school	Chinese	Listening	Self-designed AR tool (developed with HP Reveal)	Students feel more concentrated and confident in learning English and show satisfaction with this teaching strategy.
5	Chen & Liao (2022)	High school	Chinese	Vocabulary	Panoramic Image VR	Students show significant improvement in learning motivation and satisfaction.
6	Chen et al. (2020)	Middle school	Spanish	Expository writing	Google Earth VR	Positive: Students believe they gain increased writing effectiveness and productivity. Students think the VR tool is easy to use and flexible. Most of the participants want to use Google Earth in the future, as this tool gives them more details to write about. Students mentioned that Google Earth VR allowed them to their favorite places without going there in person. Negative: The activity took too much time; It is difficult to integrate the findings into students' writing.

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	Author(s)	Context	Students' L1	Language skills	VR/AR tool	Learners' perceptions
7	Endahati & Wardani (2023)	Middle school	Bahasa Indonesian	Vocabulary	Self-designed AR tool (development platform not mentioned)	Students are more enthusiastic than those using nonmedia applications.
8	Hu et al. (2022)	Elementary school	Chinese	Pronunciation	Self-designed AR tool (developed with Unity 3D combined with 3Ds Max)	Students have improved learning interest and high satisfaction with the teaching strategy. Students believe the AR/VR tools are easy to use.
9	Hung et al. (2023)	Elementary school	Chinese	Vocabulary	AR/VR glasses (no specific software mentioned)	Students have higher confidence after using AR/VR wearables during learning activities.
10	Hussein et al. (2023)	Elementary school	Persian	Vocabulary	MywebAR	Students are more involved and motivated; their enthusiasm for this class is also higher.
11	Khazali et al. (2023)	Elementary school	Chinese	Vocabulary	Self-designed AR tool (developed with Vuforia)	Positive: Most of the students express positive thoughts on the teaching strategy and believe the AR application achieved their learning goals. Negative: Some students report that it is difficult to maintain attention during this learning process.
12	Lai & Chen (2023)	High school	Chinese	Vocabulary	*Angels and Demigods* (VR game)	Students believe that this game is fun and the immersive, and the interactive environment is effective for vocabulary learning. Students feel motivated when learning with VR games.
13	Lee, Yang et al. (2024)	Elementary school	Korean	Speaking	Self-designed VR tool (developed with Immerse)	Students feel more engaged and think the virtual environment is interesting and interactive. Students are more willing to speak English in an immersive virtual environment. Students believe that role-play activities are easier to conduct in an immersive virtual environment.
14	Liao et al. (2024)	Elementary school	Chinese	Vocabulary	StemUp (AR)	Learners feel enjoyment and engagement while learning with gamification.

	Author(s)	Context	Students' L1	Language skills	VR/AR tool	Learners' perceptions
15	Mamani-Calapuja et al. (2023)	Elementary school	Spanish	Vocabulary	Self-designed AR tool (Wordtastic Kids, development platform not mentioned)	Students had positive experiences as they had not had prior experiences with AR.
16	Naji et al. (2024)	Elementary school	Arabic	Vocabulary	YOLO algorithm (AR)	Students are highly engaging and motivated during the activity and have a high level of satisfaction with the VR tool's usability, as it is user-friendly and easy to navigate. Students believe that the content is clear and addresses learning needs. Students think this teaching strategy provides them with a personalized learning opportunity. Students express their preferences for of sound effects and integration, as well as the real-world relevance of VR.
17	Raman et al. (2023)	High school	Chinese	Speaking	Google Earth VR	Students generally have engaging learning experiences.
18	Rapti et al. (2023)	Elementary school	Greek	Vocabulary	Self-designed AR tool (developed with JavaScript and CSS HTML)	Students think that AR is fun and user-friendly, so they want to use it again. Students believe they can work at their own pace and like to work independently with AR.
19	Redondo et al. (2020)	Elementary school	Spanish	Vocabulary	Self-designed AR tool (developed with HP Reveal)	Students feel high levels of motivation and interaction during the learning activity.
20	Restall et al. (2023)	High school	Korean	Grammar	YouTube VR	Students feel the improvements were due to higher involvement in the VR materials. Students want different structures for module content and more interactions within the immersion. Students also feel that immersive VR is enjoyable.

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	Author(s)	Context	Students' L1	Language skills	VR/AR tool	Learners' perceptions
21	Shaaban & Mohamed (2024)	Elementary school	Arabic	Vocabulary	Self-designed AR tool (designed with Vuforia)	Students think that the activity is enjoyable.
22	Smith et al. (2023)	Kindergarten	Spanish	Vocabulary	Self-designed AR tool (designed with HP Reveal)	Positive: Students enjoy using the AR app and learning with a tablet, and they would love to use it again. Students believe they are more willing to speak with this teaching strategy. Negative: Some students report that they do not like pedagogical agents, and the tablet is too large for them.
23	Song et al. (2023)	Elementary school	Chinese	Vocabulary	VocabGo (AR)	Positive: Students feel enhanced engagement regarding curiosity, internal interest, and concentration. Negative: Technical issues; students' lack of a sense of control.
24	Tai et al. (2022)	Middle school	Chinese	Vocabulary	Mondly VR	Positive: Students describe the VR app and teaching strategy as motivating, engaging, immersive, interactive, and contextualized. Students also like the mobility and flexibility of VR and think that it is easy to use. Negative: A small portion of students think that the VR app lacks diversity, has too much function, and is distracting.
25	Topu et al. (2022)	Kindergarten	Turkish	Vocabulary	AR flashcards	Students feel more engaged and confident. Students are interested in the AR flashcards and have high satisfaction with the teaching strategy. Students believe that 3D models and pictures, integration of sound, and the movement of AR objects are their favorite parts. Students also express that learning with the AR app on a tablet makes it easier.

	Author(s)	Context	Students' L1	Language skills	VR/AR tool	Learners' perceptions
26	Tsai (2020)	Elementary school	Chinese	Vocabulary	AR flashcards	Positive: Students feel more focused, confident, motivated, and satisfied. Popup pictures are the students' favorite parts of the AR flashcards. Negative: A few students think the AR flashcards are harmful to their eyes. Some students mentioned that they felt distracted by the moving pictures.
27	Ustun et al. (2022)	High school	Turkish	Reading	Self-designed AR tool (Assemblr edu, development platform not mentioned)	Students felt their anxiety level decreased when using the AR tool.
28	Wu & Hung (2022)	Elementary school	Chinese	Speaking	Self-designed VR tool (developed with CoSpaces)	Positive: Students feel more engaged, since the VR tool can visualize unrealistic objects in the classroom. Students believe that they have an active learning experience because learning with VR fits learners' learning styles. Improvements proposed by the students: Students hope that VR can also be used in other subjects; there needs to be more and different scenes, types of games, and apps. Negative: A few students reported discomfort with VR (headache and dizziness).
29	Yang et al. (2020)	Middle school	Chinese	Sentence structure	Self-designed VR tool (Virtual Reality Life English, developed with Unity 3D combined with 3Ds Max)	Positive: Students enjoy the real feeling in the virtual environment, and they feel more engaged. Negative: Some students are afraid of tripping over wires. Some students think that they need more assistance in using the VR tool.
30	Yilmaz et al. (2022)	Kindergarten	Turkish	Vocabulary	AR flashcards	Students like the moving animation and sounds. Students believe that the AR flashcards are easy to use, and there was no difficulty in using them with the tablet.

Appendix C
Examples of the coding scheme for the students' perceptions

Theme	Definition	Example of a statement from an article
Motivation	References to increased interest or willingness to learn due to the VR/AR tool	*"The involved pupils show their interest and enthusiasm to learn the presented material."* (Hussein et al., 2023)
Engagement	Mentions of active participation or focus during learning with the VR/AR tool	*"The focus group interviews indicate that the Virtual Go Mode in the VocabGo app improved students' learning engagement in relation to curiosity."* (Song et al., 2023)
Ease of accessibility and adaptivity	Mentions of students using VR/AR tools with minimal difficulty	*"They reported that they had no difficulty in using it and that they would gladly use it again to learn EFL or other subjects."* (Rapti et al., 2023)
VR/AR tools' features contributing to the positive perceptions	The functions or interface of VR/AR tools make students perceive them as beneficial or engaging	*"I like real-time interaction in the virtual world."* (Tai et al., 2022)
Potential detrimental effects	Potential harm to health that students perceived	*"I felt that learning vocabulary with AR was harmful to our eyes."* (Tsai, 2020)
Technical issues	Challenges related to the functionality or usability of VR/AR tools that make learners have negative perceptions	*"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."* (Belda-Medina & Marrahi-Gomez, 2023)