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RESEARCH ARTICLE

The effectiveness of immersive learning technologies in K–12 English as second language learning: A systematic review

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Abstract

Immersive learning technologies offer K–12 English learners simulated contexts for language acquisition through virtual interactions, influencing learner attitudes and enhancing cross-curricular skills. While past literature reviews have explored learners' English skills and emotions, few have delved into the learning effectiveness of immersive technologies for K–12 students. This systematic review analyzed 33 studies from 2012 to 2021, focusing on research designs, the role of immersive technologies in English learning, and the theoretical underpinnings of these studies. Results highlight the methods used to gauge learning effectiveness, the ways immersive technologies bolster learners' attitudes and skills, and a noticeable gap in theoretical grounding. Recommendations for future research are provided.

Keywords: immersive technology; K–12; English as second language education (ESL); augmented reality; virtual reality; mixed reality

1. Introduction

Immersive learning technologies, including virtual reality (VR), augmented reality (AR), mixed reality (MR), and 360-degree videos, are revolutionizing English language education by providing authentic linguistic contexts (Bendeck Soto *et al.*, 2020) and facilitating practical application of English skills (Huang, He & Wang, 2020). VR offers an interactive, computer-generated world where users actively participate (Kim, Park, Lee, Yuk & Lee, 2001; Schmidt *et al.*, 2023), enhancing learners' involvement and English practice through avatar interactions (Liaw, 2019; Lin & Wang, 2021). AR, blending virtual elements into real-life settings, enriches learning experiences by bridging background knowledge gaps (Pribeanu, Balog & Iordache, 2017; Santos *et al.,* 2016). MR

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fuses these elements, presenting a real-world view with 3D avatars and objects for immersive cultural and linguistic interactions (Parveau & Adda, 2018). Lastly, 360-degree videos offer a real-world spherical view, elevating authenticity in language learning (Ozkeskin & Tunc, 2010). Collectively, these technologies underscore their significance in enhancing English language learning.

While these technologies offer innovative ways to engage learners, empirical studies have delved deeper into their specific impacts on various aspects of English language acquisition. Researchers have explored the impact of immersive technologies on English language learning (ELL), focusing on skill development such as writing (Koç, Altun & Yüksel, 2021), listening (Lan, Fang, Hsiao & Chen, 2018), vocabulary (Alfadil, 2020; Chen *et al.*, 2020; Tsai, 2020), and pronunciation (Alemi & Khatoony, 2020). Additionally, studies have assessed students' affective variables (Wu & Hung, 2022), collaboration, communication, critical thinking, and engagement in these technology-enhanced settings (Hsu, 2017; Kruk, 2014).

Clearly, immersive learning technologies have gained the attention of researchers and practitioners as a potential tool for language learning, as underscored by numerous literature reviews that analyze its educational use, which we enumerate here. First, Parmaxi (2020) conducted a content analysis of 26 scholarly manuscripts published from 2015 to 2018 and found that VR can serve as a useful tool in language classrooms, but that learning effectiveness can be challenged due to technical configuration demands and insufficient pedagogical grounding. Second, in another study, Lin and Lan (2015) analyzed 29 articles published from 2004 to 2013 and found that the most popular research topics were interactive communication, behaviors, affect, beliefs, and task-based instruction. Their research highlighted the need for more studies to focus on how teachers can influence the impact of immersive learning interventions. Third, Parmaxi and Demetriou (2020) conducted a systematic review of 54 publications from 2014 to 2019 on the use of AR in language learning and found that while mobile-based AR appears popular for supporting vocabulary, reading, speaking, writing, and other generic language skills, many of the included studies failed to sufficiently consider theory in their approaches. Fourth, Dhimolea, Kaplan-Rakowski and Lin (2022) conducted a systematic review of 32 peer-reviewed studies published between 2015 and 2020. They found some evidence of efficacy, for example, that VR is beneficial for contextual vocabulary learning and perceptions of language learning in VR tend to be positive, but that its effectiveness is inconclusive and that multiple exposures to VR are necessary for effective learning. Fifth, Hein, Wienrich and Latoschik (2021) conducted a review on immersive technology's role in foreign language learning, emphasizing how VR can influence student behavior and attitudes, enhancing language learning. They also noted high motivation and acceptance of immersive tools in language education. Sixth, Peixoto, Pinto, Melo, Cabral and Bessa (2021) found that VR allows learners to recreate authentic environments, enhancing participation and leading to optimal learning. Seventh, and finally, Raju and Joshith (2020) highlighted the benefits of AR in English learning, suggesting that AR interaction boosts enjoyment, motivation, and positive attitudes towards the language. In summation, while the potential of immersive technologies in language learning is evident, the nuances of their application and effectiveness remain subjects of rigorous academic exploration and debate.

Speaking now to the limited and inconclusive research on the effectiveness of immersive technologies for language learning, as highlighted by Govender and Arnedo-Moreno (2021), it is pertinent to note that merely learning a language for its utility can diminish motivation. This accentuates the importance of active learning mechanisms and underscores the pressing need for further research to discern the true impact of these technologies on language learning outcomes. One area where research on immersive technology for language learning is particularly limited is in K–12 environments. Therefore, K–12 ESL learners were selected as the target group for this study because age has long been recognized as a critical factor influencing second language acquisition (Oyama, 1976). Younger children have been found to consistently perform better than adolescents and adult learners (Sang, 2017). Additionally, the characteristics of immersive

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technologies appeal to and benefit young learners whose "understanding comes through hands and eyes and ears" (Scott & Ytreberg, 1990: 13). Because VR involves real-time simulations and interactions experienced through multiple sensorial channels, immersive technology-enhanced environments can stimulate learners' physical presence and enhance their real-life sensory experience (Burdea & Coiffet, 2003). These channels are primarily visual and auditory, but some VR systems also activate touch, smell, and taste, which could support young learners in learning through all senses in a way that is highly representative of the real world (Burdea & Coiffet, 2003). Bridging these insights, it becomes evident that the unique attributes of immersive technologies align well with the inherent learning tendencies of younger K–12 students, thus emphasizing the need for more focused research in this domain. This need is highlighted by the limited research on immersive technology's impact on language learning in K–12 settings. Given immersive technologies' potential, exploring their impact on K–12 ESL learners is essential. Therefore, the following research questions guided the current systematic literature review:

1. How is the effectiveness of K–12 students' English learning in immersive technology contexts operationalized and evaluated in empirical studies?
2. How do the design elements of immersive technologies identified contribute to English learning effectiveness?
3. What role does theory play in guiding and explaining immersive interventions?

2. Methods

This systematic review follows PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman & The PRISMA Group, 2009) for transparency, accuracy, and completeness (Shamseer *et al.*, 2015). This review outlines our search strategy, database selection, and initial findings. We set criteria to filter studies, ensured data screening reliability through interrater reliability, and summarized our results. The subsequent section details the process.

2.1 Search strategy and databases

Using search criteria and databases (Table 1), we conducted an initial comprehensive screening. We focused on immersive learning technologies like VR, AR, MR, and 360-degree videos from peer-reviewed publications in the last 10 years. Keywords included subject and learning field, targeting abstracts, titles, and topics. We used "AND" for keyword coordination, "OR" for synonyms, and "*" for morphological variations. Only journal articles were considered, excluding formats like posters and videos.

Electronic databases hosting journals focused on language learning, computer-assisted language learning, and educational technology were searched: ERIC, Web of Science, Linguistics and Language Behavior Abstracts, PsycINFO (EBO), JSTOR, ACM Digital Library, BEI, and ProQuest. All searches were performed separately. Search results were transferred to Zotero (Idri, 2015).

2.2 Selection criteria

After the literature search, the inclusion and exclusion criteria (Table 2) were set to assess articles. Considering the research questions, articles were filtered based on subject, age group, language use, immersive technology role, English learners, and research design.

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Table 1. Search strategy and search terms

Category	Search term
Immersive technologies	immersive learning technology OR AR OR VR OR MR OR augmented reality OR virtual reality OR mixed reality OR virtual world* OR virtual environment* OR 360-degree video*
Year of publication	2012–2021
Subject	English
Field of learning	second language OR ESL OR EAL OR EFL OR SLA OR foreign language OR additional language OR second language acquisition

Table 2. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Participants in K–12 contexts.	Participants in postsecondary education or other adult learning contexts.
Incorporates immersive technologies.	Similar abbreviation of immersive technology-related terms.
Article available in English.	Article unavailable in English.
Research focuses on English as a second/foreign language.	Research for native English speakers.
Study reports empirical research findings.	Study does not report empirical research findings.
Research investigates how immersive technologies promote learning effectiveness.	Research investigates learning effectiveness irrelevant to the use of immersive technologies.

2.3 Reliability assessment and data extraction

Two researchers independently searched the literature based on set criteria, analyzing 919 records and removing 72 duplicates. They then assessed the reliability of codes for 271 of the 809 articles using Cohen's kappa, achieving a substantial agreement score of 0.77 (Cohen, 1960). After this, they reviewed the full articles and reached a consensus on coding.

2.4 Search results and findings

Of the 919 articles, 809 were excluded by the researchers based on title, abstract, language, age group, study type, or technology relevance. After a full-text review of the remaining articles, 33 met the criteria. Figure 1 illustrates adherence to PRISMA guidelines.

Of the 33 included studies, 15 were identified as AR-related empirical research and 18 as VR-related. No mixed- or cross-reality studies were included. No studies focusing on 360-degree videos were included due to inappropriate target groups or lack of access.

3. Results

The 33 articles identified on the basis of selection criteria were coded by two researchers for further analysis. The results of the analysis are presented as follows. Each section focuses on one of the three research questions.

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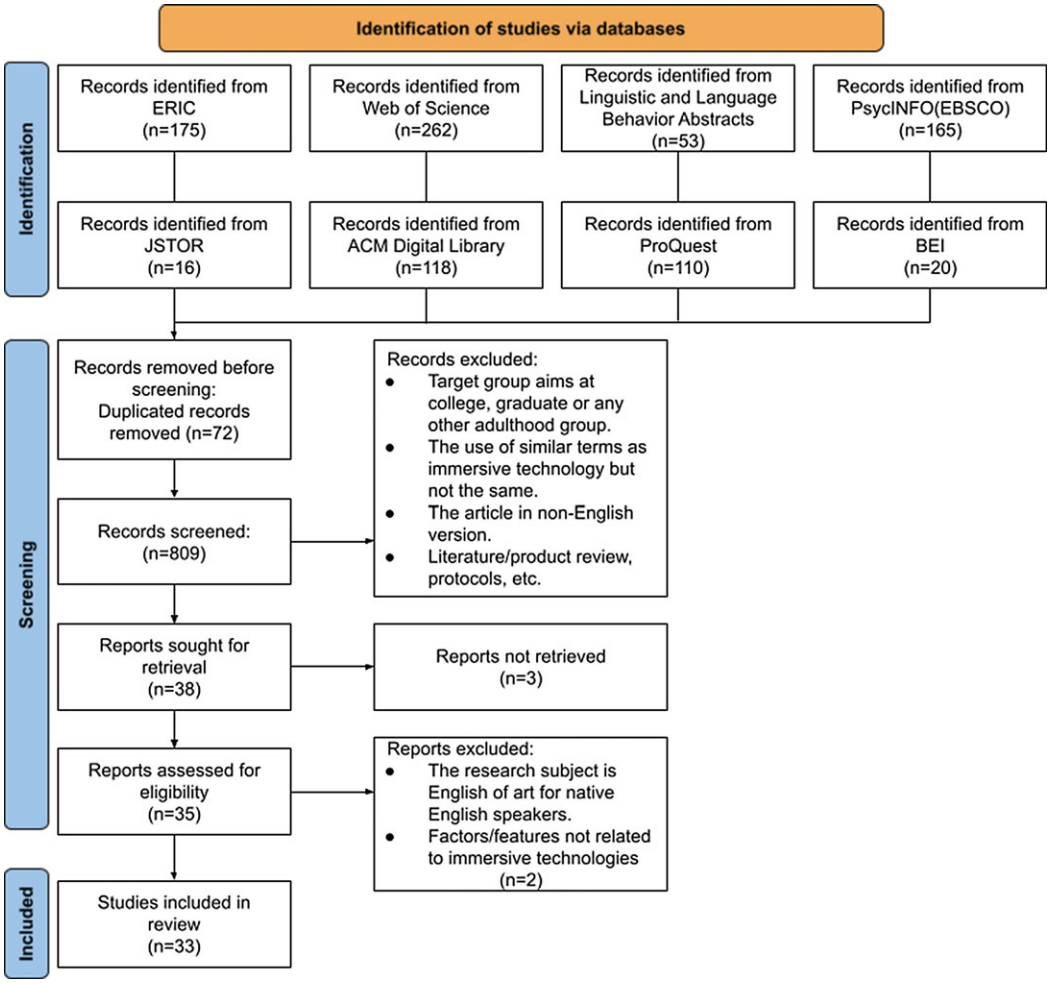

Figure 1. PRISMA flowchart of the screening process of eligible records

3.1 Operationalization and evaluation of learning effectiveness in included studies

The first research question considers the operationalization and evaluation of the effectiveness of immersive technology on K–12 students' English learning.

3.1.1 The operationalization of learning effectiveness in identified empirical studies

Learning effectiveness can be defined as "the degree to which the learning outcomes are achieved" (Blicker, 2005: 102), in which "learning outcomes are statements of what a learner is expected to know, understand and/or be able to demonstrate after completion of a process of learning" (European Communities, 2009: 47). To explore the operationalization and evaluation of learning effectiveness, we mapped the evaluated variables and resources, English skills, and corresponding data collection methods (Table 3).

Two components of the Kirkpatrick and Kirkpatrick (2006) model were used to characterize the learning effectiveness of training and educational programs. This model contains four levels of assessment: (1) reaction, (2) learning, (3) behavior, and (4) result. Specifically, levels 1 and 2 were used to map how researchers evaluated learning effectiveness based on reaction, learning, and

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Table 3. Operational definitions of learning effectiveness: Design elements and outcomes in VR and AR intervention studies

Empirical studies	Modality	Reaction variables/ Reaction	Learning variables/ Learning	Other evaluated variables and methods	Design elements	Learning outcomes
Alemi & Khatoony, 2020	VR	N/A	Pronunciation (a)	N/A	1, 3, 6	Motivation, engagement, attention, confidence, enjoyment, curiosity
Alfadil, 2020	VR	N/A	Vocabulary (a)	N/A	1, 2, 3, 6	Motivation, engagement, attention, confidence
Chang, Chen & Liao, 2020	AR	Motivation (b)	General English learning (a)	N/A	4, 9,7	Attention, confidence, satisfaction, interest
Chen, 2020	AR	Motivation, satisfaction (b)	General English learning (a)	N/A	1, 2, 9	Motivation, satisfaction
Chen & Wang, 2015	AR	Motivation (b, c)	Vocabulary (a), attitude (c)	Individual learning differences (a, c)	2, 4	Motivation, collaboration, enjoyment
Chen, 2018	AR	N/A	Phonics (a), attitudes (b)	Learners' perceptions of technology (c)	2, 9	Engagement, satisfaction, enjoyment, motivation, novelty
Chen *et al.*, 2020	AR	Motivation (b)	Vocabulary (a), attitude (b)	N/A	1, 2, 9	Less anxiety, motivation, confidence
Dalim, Sunar, Dey & Billinghurst, 2020	AR	Enjoyment, engagement (c, d, e), motivation (b)	Vocabulary (a, b)	Ease of use (b), teacher's perceptions of technology (c)	1, 2, 8, 5, 7	Enjoyment, motivation, interest, cognition
Dooly & Sadler, 2016	VR	N/A	General English learning (a, c)	N/A	1, 2	Motivation, engagement, awareness, collaboration, enthusiasm
Fan & Antle, 2020	AR	Motivation (b, c, d, e)	Alphabetic (i)	N/A	2, 4, 9	Attention, confidence, satisfaction, interest
Fokides & Zampouli, 2017	VR	N/A	General English learning (a, b)	Learner's background (a)	1, 2	Motivation, cognition, attention, enjoyment
Hsu, 2017	AR	Flow state, anxiety (b)	Vocabulary (a)	N/A	2, 4, 9, 7	Less anxiety, motivation
Huang, Han, He, Du & Liang, 2018	VR	N/A	General English learning (a), attitudes (b)	N/A	1, 2, 3, 6	Engagement, motivation

(*Continued*)

Table 3. (*Continued*)

Empirical studies	Modality	Reaction variables/ Reaction	Learning variables/ Learning	Other evaluated variables and methods	Design elements	Learning outcomes
Khatoony, 2019	VR	Motivation, satisfaction (a)	Pronunciation (i)	Learners' performance (d)	1, 2, 6	Enjoyment, motivation, engagement
Koç *et al*., 2021	AR	N/A	Writing (a), attitudes (b)	Learners' perceptions of technology (b)	1, 2, 5, 9	Motivation, enjoyment, interest
Kruk, 2014	VR	N/A	Grammar (a)	Learners' background (b), learners' perceptions of the class (h)	1, 2, 3, 4	Motivation, engagement, attention
Kruk, 2015	VR	N/A	Grammar (a)	Learner's background and perception of technology (a)	1	Engagement
Lai & Chen, 2021	VR	Affective perception (b)	Vocabulary (a)	N/A	1,3, 6	Motivation, engagement, awareness, cognition
Lan, 2015	VR	N/A	General English learning (a)	Students' reaction and behavior with technology (d)	1, 3, 4, 5	Awareness, enjoyment
Lan *et al*., 2018	VR	N/A	Listening (a)	N/A	1, 2, 4	Cognition, attention
Limsukhawat, Kaewyoun, Wongwatkit & Wongta, 2016	AR	Satisfaction (b)	Phonics (a), attitudes (b)	N/A	1, 2, 4, 6	Enjoyment, novelty, satisfaction
Liu, Liu, Yang, Guo & Cai, 2018	AR	N/A	Attitudes (c), general English learning (i)	N/A	1, 2	Enjoyment, communication, collaboration, interest
Morton, Gunson & Jack, 2012	VR	N/A	Speaking (d, i), attitudes (b)	N/A	1, 2, 3, 6	Engagement, enjoyment, motivation
Ou Yang, Lo, Hsieh & Wu, 2020	VR	N/A	Speaking (a)	Learners' technology experience (b), learners' perceptions of technology (c)	1, 2, 3, 4, 5	Attention, motivation
Redondo, Cozar-Gutierrez, Gonzalez-Calero & Ruiz, 2020	AR	Motivation, enjoyment, socio-affective relationships (b)	Vocabulary (a)	N/A	4, 9	Motivation, enjoyment
Shrestha & Harrison, 2019	VR	N/A	Writing (g)	Learners' perception of technology (c, g), learners' behavior (d)	1, 2, 3	Attention, motivation

(*Continued*)

Table 3. (*Continued*)

Empirical studies	Modality	Reaction variables/ Reaction	Learning variables/ Learning	Other evaluated variables and methods	Design elements	Learning outcomes
Tai & Chen, 2021	VR	N/A	Listening (a)	Technology experience (b), learners' perceptions of technology (c)	1, 2, 3, 5	Motivation, engagement, attention, enjoyment
Tai, Chen & Todd, 2020	VR	Motivation (b)	Vocabulary (a)	Learners' perception of technology (b, c)	1, 2, 3, 4, 5	Attention, motivation, engagement, imagination
Tsai, 2020	AR	Motivation (b)	Vocabulary (a)	Learners' comments of technology (c)	4, 9	Motivation, attention, confidence, satisfaction, interest
Urueta & Ogi, 2020	VR	N/A	Vocabulary (a)	Ease of use (f)	3	Interest, motivation, confidence
Vedadi, Adbullah & Cheok, 2019	AR	Motivation, satisfaction (b)	Vocabulary (a, c, d)	N/A	2, 4	Attention, confidence, satisfaction, interest
Vedadi, Abdullah, Kolivand, Cheok & Aris, 2018,	AR	N/A	Vocabulary (a)	Gender differences in knowledge acquisition (a)	1, 8	Interest, confidence, motivation, problem-solving
Zheng, Schmidt, Hu & Liu, 2017	VR	N/A	General English learning (d)	Learners' performance (d)	1, 3, 6	Engagement, cognition

Note. VR = virtual reality; AR = augmented reality; a = test; b = questionnaire; c = interviews; d = observation recordings; e = observation notes; f = survey; g = reflective notes; h = evaluation sheets; i = feedback; 1 = 3D modeling; 2 = 2D graphics; 3 = VR simulation; 4 = digital sound; 5 = input function; 6 = game elements; 7 = camera function; 8 = sensor displays; 9 = AR-generated video.

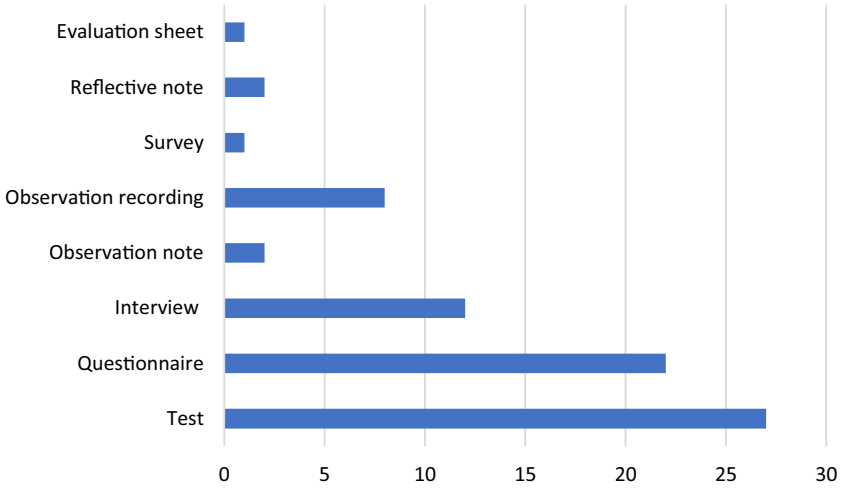

Figure 2. Data collection methods in the identified studies

evaluated variables. Reaction variables show how learners respond to immersive technology interventions; learning variables refer to students' increased knowledge and change of attitude (Kirkpatrick & Kirkpatrick, 2006). Table 3 shows that 19 studies evaluated changes in students' reactions in response to immersive technology intervention. Eight studies measured and analyzed students' behavior during the learning experience. To analyze learning outcomes, test and questionnaire scores, feedback (including students' performance and response in class), recordings, and interview transcripts were used. Further, multiple data collection methods were used to measure effectiveness of immersive technologies (Figure 2), including testing ($n = 27$), questionnaires ($n = 22$), interviews ($n = 12$), observation recordings ($n = 8$), observation notes ($n = 2$), surveys ($n = 1$), reflective notes ($n = 2$), and evaluation sheets ($n = 1$).

Tests were used most frequently in identified studies evaluating students' language knowledge and performance and offer insight into the effectiveness of different teaching methods (Fokides & Zampouli, 2017). Pre-test/post-tests were designed to compare English learners' increase in knowledge due to the immersive learning intervention, and differences in scores provided evidence for changes that might be attributed to use of immersive technologies.

Questionnaires were used for diverse purposes such as to analyze student enjoyment and interest levels when using immersive learning technologies (Dalim, Sunar, Dey & Billinghurst, 2020), provide background information about the research participants' learning history (Fokides & Zampouli, 2017; Kruk, 2014), collect data on learning motivation for further quantitative analysis (Chen & Wang, 2015; Tsai, 2020), explore attitudes towards immersive technologies (Chen *et al.*, 2020; Limsukhawat, Kaewyoun, Wongwatkit & Wongta, 2016; Morton, Gunson & Jack, 2012), and understand how immersive technologies promote specific English skills (Tai & Chen, 2021).

Interviews with students aimed to gather feedback on their experiences, attitudes, and learning outcomes in the VR- or AR-supported classroom. Interviews with teachers found that feedback tended to concentrate on the use of immersive technologies, benefits to English language learners, and usability of immersive learning systems (e.g. Vedadi, Abdullah & Cheok, 2019).

Researchers observed and analyzed learners' behavior by video recording and observational notes to know learners' feelings and experiences during interventions. Results from pre-test/post-tests and questionnaires revealed positive learning effectiveness. Qualitative data (e.g. reflective notes) examined learners' perceptions of immersive technology-based courses and assessed the usability of immersive technology.

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3.1.2 Research design and methodology

All eligible studies reported findings suggesting that immersive technologies can facilitate the target group's ESL despite the different methods used to measure learning effectiveness across a range of English language knowledge and skills. The total records ($N = 33$) consist of 10 articles using quantitative methods, 20 using mixed methods, and 3 using purely qualitative methods.

More than half of the studies ($n = 19$) adopted an experimental or quasi-experimental design with a control and experimental group to investigate learning effectiveness. Such studies include VR versus video material (Dooly & Sadler, 2016; Tai, Chen & Todd, 2020), VR versus personal computer (Lai & Chen, 2021), real and physical body versus the 3D avatar versus non-embodied learning (Lan *et al.*, 2018), VR versus traditional teaching methods (Chang, Chen & Liao, 2020; Khatoony, 2019; Kruk, 2014, 2015; Morton *et al.*, 2012), VR with different teaching methods versus traditional teaching methods (Fokides & Zampouli, 2017), English learners with high versus low proficiency in AR context (Chen & Wang, 2015), AR with different teaching methods (Hsu, 2017), AR versus traditional classroom teaching (Dalim *et al.*, 2020; Koç *et al.*, 2021; Redondo, Cozar-Gutierrez, Gonzalez-Calero & Ruiz, 2020; Tsai, 2020), AR contexts with different variables such as English proficiency and caption scaffolding (Chen *et al.*, 2020), AR versus video materials (Chen, 2020), and AR with different media conditions (Vedadi *et al.*, 2019).

3.2 Design elements of immersive technologies and improved learning outcomes

The second research question concerned how immersive technologies' design elements can facilitate K–12 ESL. Eighteen studies focused on VR-enhanced contexts and 15 on AR-enhanced contexts. Studies are categorized by design elements and learning outcomes in Table 3.

In VR-related studies, VR simulated contexts, game elements, 3D models such as avatars, and models with digital sound and 2D, 3D graphics scaffolding such as videos, and images were mainly used. Almost all identified studies used VR design elements in virtual learning contexts, contributing to the main learning outcomes of increased motivation, engagement, and attention.

AR-related studies ($n = 15$) are summarized in Table 3. Design elements of AR incorporated in the K–12 context mainly included 3D interactive models, images, videos, and text accompanied by audio. Learners interacted with 3D models and text/audio to increase contextualization of learning, which influenced learning effectiveness and attitudes. For example, 360-degree photos can bring learners to virtual yet authentic situations to practice language (Koç *et al.*, 2021). AR-based learning systems also boast the camera function for scanning target images or AR markers ($n = 4$) to access supplementary materials such as tutorial videos and capturing images (Hsu, 2017). For example, individual students scanned insect specimens with mobile devices. Video clips of specimens appeared on their devices in AR that they could watch and zoom in on (Chen, 2020).

Table 3 shows the design elements used in AR and VR interventions. In addition, the studies report learning outcomes enhanced by immersive technologies that contribute to ELL effectiveness. All learning outcomes were extracted based on learners' answers from interviews and questionnaires. Figure 3 shows the distribution of learning outcomes.

Learners' attitudes and emotions were investigated in 33 studies. Because of the different types of AR and VR studies, it is meaningful to compare and analyze the more divergent learning outcomes. The AR-focused studies suggested that AR more effectively builds learners' problem-solving and communicative skills and increases satisfaction, a sense of novelty, and interest in their learning experience. VR appeared to be more productive in enhancing learners' curiosity, imagination, cognition, awareness, attention, and enthusiasm. Both AR and VR interventions increased motivation, enjoyment, and engagement in learning English.

However, immersive technologies did not work for all learners. Four studies reported negative feedback on immersive tools due to technical issues such as failure to show the images (Dalim *et al.*, 2020), inability of immersive tools to be manipulated simultaneously (Tai & Chen, 2021), unsatisfactory display speed (Fokides & Zampouli, 2017), and unavailability of technology because

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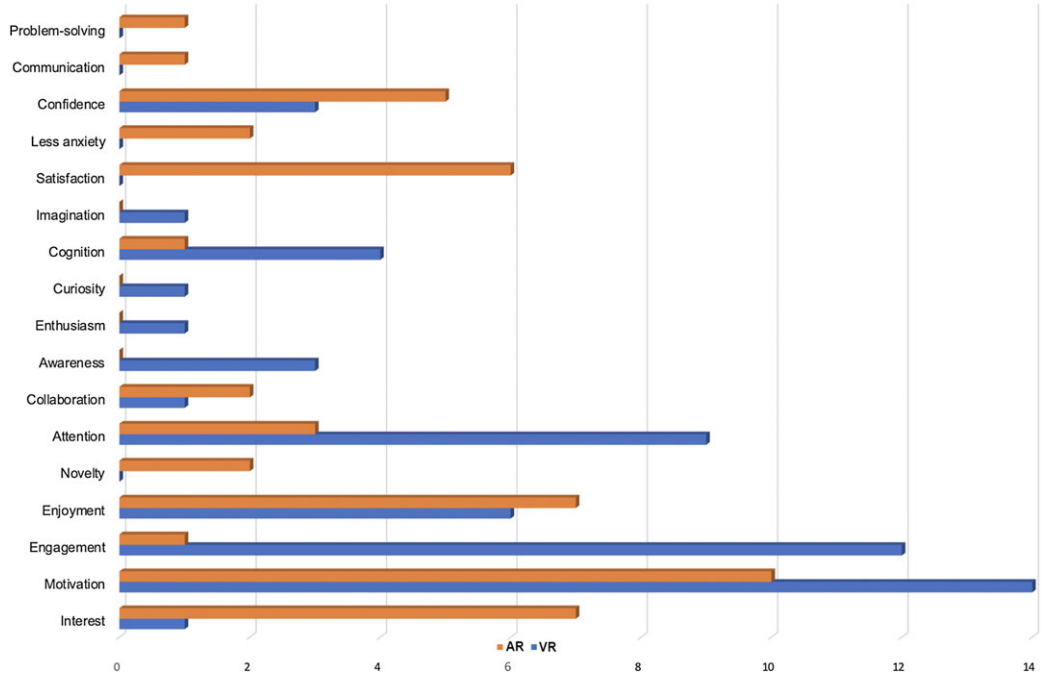

Figure 3. Learning outcomes enhanced by augmented reality (AR) and virtual reality (VR) interventions

of high cost and lack of professional training (Liu, Liu, Yang, Guo & Cai, 2018). In addition, negative immersive learning experiences were found in eight studies, including mental overload and learning anxiety (Hsu, 2017), eye strain (Alemi & Khatoony, 2020; Tsai, 2020), distraction (Tai & Chen, 2021; Tsai, 2020; Urueta & Ogi, 2020), poor adaptation to the immersive tools (Fan & Antle, 2020), and longer course design preparation and class time (Chen, 2018). Consideration of learner issues is critical in the design of learning interventions (Schmidt *et al.*, 2022); hence, further research in this area is warranted.

3.3 Role of theories in the included articles

This section is divided into the theories that informed the design of immersive tools and theories that explained the experimental results. Approximately 43% of the identified studies ($n = 15$) used relevant theories to support design and explain the results of empirical studies. As shown in Table 4, theories were identified as either (1) informing design, such as design of evaluation, design of data collection method, design of immersive interventions, and class design, or (2) explaining and corroborating empirical findings.

3.3.1 Theories informing design

The Attention, Relevance, Confidence, and Satisfaction (ARCS) model (Keller, 1983) is an approach to instructional design using multimedia technology based on a synthesis of motivational concepts. It was used to examine whether the AR-enhanced learning environment could improve students' attitudes, interests, behavior, and satisfaction (Chang *et al.*, 2020). Fan and Antle (2020) used it to design items in the questionnaire on students' motivation to learn with an AR app. One study mentioned the ARCS model in the abstract but actually applied it in empirical research (Vedadi *et al.*, 2019).

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Table 4. Use of theories in the identified studies

Theories that inform design	Reference	Theory focus
Attention, Relevance, Confidence, and Satisfaction (ARCS) model (Keller, 1983)	Chang *et al*., 2020; Fan & Antle, 2020	Design of data collection method
Interaction hypothesis (Long, 1996)	Morton *et al*., 2012	Design of immersive interventions
Eco-dialogical model (Zheng, 2012)	Zheng *et al*., 2017	Design of immersive interventions
Assessment, Pedagogy, Technology method (APT) (Osborne, 2014)	Huang *et al*., 2018	Design of immersive interventions
Content and Language Integrated Learning (CLIL) (Coyle, 2008)	Fokides & Zampouli, 2017	Class design
Constructivism (Bruner, 1966)	Fokides & Zampouli, 2017; Liu *et al*., 2018	Class design
Total physical response (TPR) (Asher, 1969)	Lan *et al*., 2018	Class design
Jolly Phonics learning (Lloyd, 1998)	Limsukhawat *et al*., 2016	Class design
Incidental vocabulary learning (Webb, 2019)	Lai & Chen, 2021	Design of immersive interventions
Social constructivism (Vygotsky, 1968)	Dooly & Sadler, 2016	Design of immersive interventions
Dual coding theory (DCT) (Clark & Paivio, 1991)	Dalim *et al*., 2020	Explain results
Hypothetical Model of Immersive Cognition (HMIC) (Ladendorf, Schneider & Xie, 2019)	Tai & Chen, 2021	Corroborate results

The interaction hypothesis (Long, 1996) claims that conversational interaction between a learner and, for example, a native speaker can facilitate the learner's development since it affords negotiated interaction providing comprehensible input in the target language. The interaction hypothesis was used to simulate interactive scenarios where English learners negotiated with the computer rather than with a real speaker (Morton *et al*., 2012).

In the eco-dialogical model (Zheng, 2012), the linguistic perspective of communication as a negotiation of meaning between two actors is extended systematically to consider how objects in the environment and sociocultural factors can influence meaning-making and the realization of values. Zheng, Schmidt, Hu and Liu (2017) used this model to explore whether eco-dialogical learning can facilitate the development of translanguaging abilities of ELL secondary school students in a virtual world.

The Assessment, Pedagogy, Technology (APT) method developed by Osborne (2014) adapts principles of ecological psychology to align the needs of teachers and learners through the affordances of digital technologies. Huang, Han, He, Du and Liang (2018) used it to design and develop VR educational games to improve English learners' learning performance and engagement.

Content and Language Integrated Learning (CLIL) focuses on appropriate and effective language usage, particularly the interrelationship between content, communication, cognition, and culture (awareness of self and others) to build on the synergies of integrated learning (content and cognition) and language learning (communication and cultures) (Coyle, 2008). Constructivist learning theory argues that people construct their comprehension and knowledge of the world by going through things and reflecting on those experiences (Bereiter, 1994). CLIL, together with constructivism, was used in the empirical study by Fokides and Zampouli (2017) to develop a multi-user virtual learning environment. In addition, constructivism combined with inquiry-based learning strategies was incorporated in Liu *et al*.'s (2018) AR intervention study to make the classroom more engaging and motivating and to develop learners' ability to collaborate and self-regulate. It emphasizes active participation and learner responsibility for discovering new knowledge (De Jong & Van Joolingen, 1998).

Total physical response (TPR) (Asher, 1969) is applied to concentrate language learners' attention on listening and reacting to oral commands. In short, TPR is built around the coordination of speech and action and attempts to teach language through physical (motor) activity (Widodo, 2005). TPR was used by Lan *et al.* (2018) to investigate how VR learning influences young students' listening performance.

Jolly Phonics focuses on letter-sound associations and the importance of training children to better comprehend letter-sound correspondence (Lloyd, 1998). Limsukhawat *et al.* (2016) developed an AR-supported mobile game application to provide learners with phonics practice based on this approach to encourage learners to practice blending, decoding, and encoding words for reading and writing, and found positive improvement in students' learning efficiency and attitudes.

In Webb's (2019) study, incidental vocabulary learning indicated that the essential research direction of incidental learning is the extent to which words can be learned through different input types. Lai and Chen (2021) used it to design a VR-enhanced learning environment to improve students' vocabulary acquisition.

The socio-constructivist principle proposed by Vygotsky (1968), suggests that learning and culture are the frameworks through which humans experience, communicate, and understand reality (Akpan, Igwe, Mpamah & Okoro, 2020). It informed the project-based language learning of the VR intervention system in the study by Dooly and Sadler (2016).

3.3.2 Theories explaining the results

Only two studies were found to explain research findings from theoretical perspectives. Dual coding theory (DCT) (Clark & Paivio, 1991), a cognitive theory, claims that a learner's memory consists of two separate but interrelated verbal and visual codes for processing information.

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Dalim *et al.* (2020) used DCT to explain that the AR-supported learning environment makes words visualized and auditory so that learners' memory of vocabulary can be enhanced and other information processing skills such as association of features with previous knowledge can be stimulated. Hypothetical Model of Immersive Cognition (HMIC) (Ladendorf *et al.*, 2019) was used by Tai and Chen (2021) to corroborate the finding that sense of presence in VR interventions can enhance learning effectiveness.

Beyond the explicit use of theories to inform design and explain results in empirical studies, two studies implicitly indicated the use of theories. Ou Yang, Lo, Hsieh and Wu (2020) indicated that the benefits of using VR in facilitating ELL's communicative ability are supported by the theories of constructivist learning, contextualized learning, and immersive learning. In Chen's (2018) study, constructivism, situated learning theory, self-determination theory, and flow theory were mentioned to elaborate on how the affordances of AR could enhance learning. However, neither study explicitly referenced theories to inform design or explain results.

4. Discussion and implications

For RQ1, we described how current research operationally defines learning effectiveness in immersive technology intervention contexts. We also analyzed the research designs used in the selected empirical studies and the different English knowledge and skills found to be influenced by immersive technologies. Our findings show that mixed methods were most frequently used, with a particular focus on vocabulary teaching and learning practice over other methodologies. This is possibly due to the large number of vocabulary-teaching cases. Few studies adopted only qualitative methods and those that did mainly focused on general English learning, including comprehensive skills with science (Liu *et al.*, 2018) and socio-pragmatic competencies in communication (Dooly & Sadler, 2016). Besides methodologies, we also analyzed evaluation methods used in empirical research, with findings suggesting that tests and questionnaires were used most frequently. Building on these observations, it becomes evident that, given the predominant focus on vocabulary teaching and learning practice, future designs should examine the effectiveness of immersive technology interventions in different ELL skills beyond vocabulary. This would provide a more comprehensive understanding of the potential benefits of immersive technology in ELL contexts.

Regarding RQ2, the target groups' attitudes and emotions enhanced by immersive technologies were found to be crucial for ELL effectiveness, which echoes Krashen's (1986) affective filter hypothesis. Affective variables included motivation, self-confidence, anxiety, and personality traits as crucial factors facilitating second language acquisition (Schütz, 2007). Cross-curricular skills, including collaboration, communication, awareness, and attention facilitated by immersive learning helped to create a learner-centered climate, which also aligns with Krashen's Acquisition Learning Hypothesis regarding acquired (unconscious acquisition of knowledge) and learned (formal instruction) language performance systems. Immersive technology interventions afford a virtual environment with real-life contexts and flexible interactions with 3D models and characters, stimulating students to use their own pace of learning input and output and achieving spontaneous learning behaviors, such as communication, heightened awareness, attention, etc. The identified studies used immersive technology interventions in class design and instructions to make the learning process novel and interactive, further contributing to optimal learning achievement. Building on this, the studies underscored the potency of immersive technology interventions in class design and instructions, enhancing the learning experience's novelty and interactivity, leading to optimal learning outcomes. Consequently, these findings underscore the implication that, from a pedagogical vantage point, future endeavors should prioritize a learner-centered approach, ensuring students can navigate their learning journey, emphasizing spontaneous behaviors like communication and heightened awareness.

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In terms of RQ3, half of the studies cited relevant theories to support the design framework and results explanation. This indicates a general lack of theoretical grounding in the design of immersive tools and interpretation of results in empirical studies of immersive technology interventions in the K–12 ESL context, a finding that echoes Huang and Schmidt's (2023) systematic review of theory-informed digital game-based language learning. Given the general lack of theoretical grounding in the design of immersive tools and interpretation of results in empirical studies of immersive technology interventions in K–12 ELL contexts, designers should consider placing greater emphasis on integrating learning theories into their designs.

Moving beyond the research questions that guided this research, the current study also summarized studies that used treatment and control group methodology to compare the effectiveness of immersive technology in language learning. This methodology bears similarities with the media comparison study. Media comparison may be popular because researchers can easily run studies and explain the comparative achievements of different media. However, this methodology has a long history of intense critique, in part because media alone cannot influence learning outcomes (Clark, 1994; Jonassen, Campbell & Davidson, 1994). Indeed, many scholars agree that media is most appropriate as a vehicle for delivering learning experiences rather than as a conduit for improving learning. Furthermore, design and methodological problems frequently occur in empirical studies in line with the arguments of Reeves's (1995) pseudoscience; thus, interpreting learning outcomes as being influenced by media interventions is challenging (Bryant & Hunton, 2000). Given these insights, the implication is clear: researchers must exercise caution when employing media comparison studies, ensuring rigorous design and methodology while being wary of overattributing learning outcomes solely to the media used. Researchers might also consider alternative study designs, such as case studies, design-based research, and mixed-methods designs, or more contemporaneous approaches, such as learning experience design (Schmidt & Huang, 2022; Schmidt, Tawfik, Jahnke & Earnshaw, 2020).

4.1 Limitations

Our findings should be interpreted in light of the following limitations. First, our approach concentrated more on the affordances and features of immersive technologies in English learners' learning outcomes but did not consider how learning theories might have influenced their design. Synthesizing why researchers used certain design theories and how their designs will improve ESL effectiveness also warrants future research, as does the exploration of how learning theories are implemented in the design and development of emerging technology learning affordances and how they influence ESL as a whole. Additionally, we only looked at papers in English – the "Tower of Babel" bias – which could have potentially excluded important studies. Including so-called gray literature may have uncovered additional studies. Likewise, concentrating on adverse effects resulting from immersive technology would be meaningful.

The findings presented here suggest that immersive technologies hold great promise for ESL; however, further research is warranted. In addition, while our research sheds light on some of the gaps and challenges associated with the empirical research in this area as well as the influence of immersive learning designs on learning outcomes, the focus of the current paper was not concerned with pedagogical implications. Given the broad range of empirical research in K–12 contexts that we identified in our systematic review, it is clear that ELL instructors see value in the use of immersive learning for promoting language learning outcomes. However, what is not clear is how K–12 instructors might effectively integrate immersive learning interventions into their own teaching practices so as to promote highly effective learning outcomes. We see this as an area of critical need for future research. Finally, another limitation of our study is the potential for positive publication bias. It is possible that studies with positive results were more likely to be published, while studies with negative results were less likely to be published. This bias could have influenced our findings and may have resulted in overestimating the effectiveness of immersive

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technology interventions in K–12 ELL contexts. Future studies should consider the potential for publication bias and take steps to mitigate its effects, such as conducting a comprehensive search of gray literature and including unpublished studies.

4.2 Conclusion

This systematic literature review delves into immersive technology's role in K–12 ELL settings, emphasizing the evaluation of learning effectiveness and the need for theory-driven research designs. While the study recognizes the potential of technologies like VR in enhancing motivation and cross-curricular skills, it also advocates for exploring other immersive tools, such as 360-degree videos. Despite limitations like potential bias and unexplored adverse effects, the review underscores the significance of further research in this domain to benefit English learners.

This paper addressed three research questions, mapping out evaluations from identified literature. Tests predominantly assessed English skills, while questionnaires and interviews gauged learners' attitudes and perceptions of immersive technology. Table 3 indicates that immersive technology's design elements, backed by second language acquisition theories, enhance affective variables and cross-curricular skills. However, while theories informed design and results interpretation, their application in the research was found lacking.

This paper enriches scholarly discourse by precisely defining learning effectiveness, moving beyond ambiguous "good learning" definitions. It maps evaluation methods to a learning effectiveness framework, offering insights for future research. The study underscores the need for a robust theoretical foundation in design and interpretation, suggesting frameworks like self-determination theory for VR-supported individual learning or social constructivism for multi-user VR designs. The research also identifies trends in immersive technology for ESL, noting an underutilization of 360-degree videos and mixed reality, possibly due to cost and technical challenges, but encourages researchers to diversify their technological tools for richer educational outcomes.

Supplementary material. To view supplementary material referred to in this article, please visit https://doi.org/10.1017/S0958344024000041

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