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A systematic review of the use of virtual reality in teaching Chinese as a foreign language

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Abstract: The purpose of this review is to provide a thorough analysis of existing research on the implementation of virtual reality (VR) in teaching Chinese as a foreign language (TCFL). In recent years, there has been a growing interest in the potential benefits of VR for language learning, and multiple studies have explored its application in TCFL. However, to date, no systematic reviews on the specific uses of VR in TCFL have been conducted. This study aims to bridge this gap by conducting a comprehensive review of empirical articles on the topic, identified from the Scopus and Web of Science databases. The search terms include "VR", "virtual reality", and "Chinese language". The findings of this review shed light on the current trends in VR-related publications in the field of TCFL, the research settings where VR is used to support learning, and the potential benefits and effectiveness of VR in enhancing Chinese language learning, such as linguistic growth, communication skills, motivation, and immersive and authentic learning contexts. The review also highlights the challenges and limitations of using this technology in TCFL. The significance of this review lies in its potential to inform educators, researchers, and practitioners interested in using VR in TCFL about the current state of research and its implications for language learning. It can also contribute to the development of best practices for the effective use of VR in TCFL, ultimately leading to improved language learning outcomes for students.

Keywords: authentic learning context; Chinese language; immersion; motivation; virtual reality

1 Introduction

In our current digital age, technology in education has merged with and is indistinguishable from the learning experience (Kukulska-Hulme et al., 2022). New

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technological innovations and applications are introduced to provide learners with more learning opportunities and broaden their scope in terms of flexible ways of learning. "The digital environment provides an unprecedented means for people to express themselves, to assemble and participate, and opens new opportunities to improve access and inclusion" (Council of Europe, 2019). In the field of language education, numerous studies have summarised current trends and suggested future directions for the application of augmented reality (Carmigniani et al., 2011; Parmaxi & Demetriou, 2020; Zhang, 2018), virtual reality (Chen et al., 2022; Lin & Lan, 2015; Zheng et al., 2022), and both augmented and virtual reality (Huang et al., 2021; Qiu et al., 2023). The current review project focuses on virtual reality (VR), which is a computer-generated environment that simulates users' physical presence in a virtual world. A virtual world is an immersive, three-dimensional (3D), multimedia, multi-person simulation environment where each participant adopts an alter ego and interacts with the world in real time (Wagner & Ip, 2009).

By reforming how people interact with digital content, VR has become an effective tool for language learning that greatly enhances learners' linguistic competence and communication skills (Wang et al., 2020). In recent years, there has been growing interest in the use of VR for the purpose of enhancing language learning (Chen, 2016; Lan, 2015), with various aspects of language learning being explored. One area of focus is vocabulary acquisition, with Tai et al. (2020) reporting improvements in vocabulary acquisition and Lai and Chen (2023) finding that the VR group in a vocabulary translation delayed post-test scored significantly higher than the personal computer group. Writing skills have also been studied by Lan et al. (2019), who investigated how a 3D immersive experience enhanced Mandarin writing. VR provides highly immersive and interactive learning environments (Lan, 2020b) and flexible platforms to simulate real-life immersive learning situations (Legault et al., 2019). It can also improve communicative ability, as demonstrated by Ou Yang et al. (2020), who found that high-immersion VR can provide an immersive and interactive environment for communication practice for learners of English. According to Hu (2021), VR has the potential to increase engagement and motivation among learners, as evidenced by the high levels of motivation observed among students using VR to learn Chinese. Lan (2020a) found that students expressing enjoyment in virtual environments exhibited greater motivation and autonomy in their learning and a more positive attitude towards the learning content or activities.

Recent review studies have provided evidence supporting the positive impact of VR-assisted language learning on language learning. According to these studies, the positive effect of VR on language learning is due to the immersive and authentic environment provided, which fosters active participation and interactivity and promotes motivation and engagement (Chen et al., 2022; Parmaxi, 2023;

Peixoto et al., 2021; Zheng et al., 2022). For instance, in a systematic review, Peixoto et al. (2021) found that, compared to traditional pedagogical practices, immersive VR has a more positive effect on foreign language learning. The study revealed that immersive learning environments foster active participation, high interactivity, navigation, interaction with avatars, and even the recreation of cultural places and circumstances, all of which contribute to motivation and satisfaction in users. Chen et al. (2022) conducted a meta-analysis and suggested that VR-assisted language learning can facilitate language knowledge acquisition and enhance affection. This positive effect may be attributed to several features of VR, such as immersive learning, interaction between VR and learners, and authentic language learning settings. This study highlights the potential of VR applications for language learning, offering teachers new options to support their teaching efforts. Similarly, Zheng et al. (2022) identified several VR-related advantages in enhancing language learners' linguistic knowledge and skills. They found that VR-mediated vocabulary learning was enjoyable and motivating and that it provided comprehensible input, simultaneous interaction, and instant feedback. VR can foster language learners' communicative competence by providing diverse scenarios for communication in meaningful and collaborative learning environments and real-life situations.

Teaching Chinese as a foreign language (TCFL) has witnessed significant development in recent years (Chan et al., 2022), with a growing emphasis on integrating technology into the field (Bai et al., 2019; Gao, 2019; Tseng et al., 2019, 2020; Wang & Devitt, 2022; Wang & Xu, 2020). Numerous studies have investigated the effectiveness of VR in TCFL, identifying it as a valuable pedagogical tool for enhancing TCFL. For example, studies such as Chen and Yuan (2023) and DeWitt et al. (2022) have found that VR can enhance vocabulary acquisition and intercultural communication competence. Others, such as Lan and Tam (2022) and Yang et al. (2022), have examined the impact of 360° videos and communication strategies in VR learning environments. Meanwhile, Xie et al. (2021) investigated the use of mobile-based VR in oral proficiency. Studies by Legault et al. (2019) and Lan et al. (2015) explored the effectiveness of multi-user VR learning environments and immersive VR tools in vocabulary acquisition. While there have been some review studies on the use of VR in language learning in general, there is a dearth of reviews exploring the literature on the use of VR in TCFL. This review article aims to address this gap by examining the use of VR in TCFL and its benefits and effectiveness in enhancing language learning outcomes and improving students' motivation and communication skills in authentic learning contexts. It aims to contribute to the growing body of literature on VR in language education and provide valuable insights into the potential of VR for TCFL. The conclusions drawn herein can serve as a basis for guiding future research and informing best practices in this area. To achieve this aim, the following research questions (RQs) are addressed in this study:
RQ1: What are the current trends of VR-related publications in the field of TCFL?

RQ2: In what research settings is VR-supported learning taking place, and which research methods are employed?
RQ3: What are the potential benefits and effectiveness of VR in enhancing language learning outcomes?
RQ4: What are the implications of VR for the field of TCFL and other language teaching contexts, and how can interactive course designs take advantage of these technologies?

2 Methodology

2.1 Identification of journal articles

This review paper relied on journal articles as the primary source of information due to their reputation for providing in-depth and up-to-date scholarly information (Dublin City University, 2022). An extensive search process was undertaken to select relevant journal articles. High-quality peer-reviewed journal articles on the use of VR in TCFL were identified using Scopus as the primary database in the initial stage, followed by Web of Science in the second stage, to maximise the richness and reliability of the search results. For the current review, articles were selected based on two primary screening criteria: (1) they were published in English and (2) they reported on empirical projects conducted at the university level. The identified journal articles provided essential resources for the current project. A keyword search method was employed to ensure a comprehensive search. The selected keywords were directly related to TCFL and were based on a thorough understanding of the research field and concept of keywords. They aided in identifying the main themes of the reviewed articles and gaining insights into the research questions.

2.1.1 Scopus

The search of Scopus was limited to "journals" as the document type.

Table 1 provides information on the journal article selection process using Scopus in Stage 1 of the research project. The table presents the four phases of the selection process, consisting of the search keywords used in each phase, the number of results obtained from the search, and the number of relevant articles identified in each phase.

– In Phase 1.1, the keywords "VR Chinese language" and "Virtual Reality Chinese language" were used to search for relevant articles, resulting in 28 and 79 results, respectively.

- In Phase 1.2, after the topics and abstracts of the identified journal articles had been read, eight and 10 relevant articles were retained for the keywords "VR Chinese language" and "Virtual Reality Chinese language", respectively.
- Phase 1.3 involved cross-checking for duplicates between the lists produced during Phase 1.2. The list associated with the keyword "Virtual Reality Chinese language" was found to cover the list related to the keyword "VR Chinese Language". Consequently, 10 relevant journal articles were retained for further analysis.
- In Phase 1.4, a backward citation search was conducted to locate all the references cited in the identified articles in order to maximise the richness of the sources used for the project. Five relevant articles were identified in this phase. Therefore, in Stage 1 of the research project, a total of 14 search results were obtained, comprising 10 Scopus results and four backward citation search results.

2.1.2 Web of Science

Stage 2 of the article selection process utilised Web of Science. The search was refined by "language & linguistics" as meso-level citation topics and limited to the document type "article". The selection process consisted of four phases, summarised in Table 2. The table is organised into four phases: 2.1, 2.2, 2.3, and 2.4. The last two columns show the number of articles retained after a backward citation search and cross-checking

Table 1: Journal article selection process using Scopus during Stage 1.

Phases in Stage 1	Keywords	Number of results	Number of articles retained	Number of articles retained	Number of articles found
1.1. Scopus search	VR Chinese language	28	–	–	–
	Virtual reality Chinese language	79	–	–	–
1.2. Screening of identified articles	VR Chinese language	–	8	–	–
	Virtual reality Chinese language	–	10	–	–
1.3. Cross-checking for duplicates	–	–	–	10	–
1.4. Backward citation search	–	–	–	–	4
Total:		107	18	10	4

Note: "–" indicates that the search was not conducted during this phase.

Table 2: Selection process for journal articles during Stage 2 using Web of Science.

Phases in Stage 2	Keywords	Number of search results	Number of articles retained	Backward citation search	Number of articles retained after cross-checking with Stage 1
2.1. Web of Science search	VR Chinese language	8	–	–	–
	Virtual reality Chinese language	11	–	–	–
2.2. Screening of identified articles	VR Chinese language	–	1	–	–
	Virtual reality Chinese language	–	1	–	–
2.3. Backward citation search	–	–	–	0	–
2.4. Cross-checking with Stage 1 for duplicates	–	–	–	–	0
Total:		19	2	0	0

Note: "–" indicates that the search was not conducted during this phase.

with the articles identified in Stage 1. The total number of search results and relevant articles are presented in the last row of the table.

- In Phase 2.1, the keywords "VR Chinese language" and "Virtual Reality Chinese language" were used, resulting in eight and 11 search results, respectively.
- In Phase 2.2, one relevant article was retained for each of the keyword sets "VR Chinese language" and "Virtual Reality Chinese language" after the topics and abstracts of the identified journal articles had been read.
- Phase 2.3 involved conducting a backward citation search to locate all the references cited in the identified articles, with the aim of maximising the richness of the sources for the project. However, no relevant articles were identified in this phase.
- Phase 2.4 involved cross-checking for duplicates between the lists produced during Stage 1 and Stage 2. The journal articles identified during Stage 1 were found to cover the three journals identified during Stage 2. Therefore, a total of 14 journal articles were selected for the final data analysis.

2.2 Data coding and analysis

The current review analysed 14 journal articles. Table 3 describes the coding and analysis process used in the study. It involved systematically categorising and organising the data into themes to identify patterns and relationships. The coding

Table 3: The summary of the two stages of the data coding and analysis process.

Stages	Activities	Number of reviewed articles
1	– Coding data	2
	– Categorising findings under themes	
	– Analysing coded data	
	– Finalising codes for the reviewed articles	
	– Pilot testing the coding scheme	
2	– Coding and analysing all 12 reviewed articles	12
	– Categorising findings into themes for data presentation and discussion	
	– Identifying patterns and relationships across the articles	
	– Developing a conceptual understanding of the issues	

process was divided into two stages. In the first stage, the researcher coded the data from the first two articles. This stage involved carefully going through the articles and systematically categorising the findings under themes. The researcher analysed the coded data to ensure that he had accurately captured the main ideas and concepts in the articles. He then finalised the codes to ensure that they would work effectively for the other 12 reviewed articles. In the second stage, he coded and analysed the other 12 reviewed articles. The findings were categorised into themes for the data presentation and discussion. The researcher also identified patterns and relationships across the articles, which helped in developing a conceptual understanding of the issues (Hennink et al., 2011). This stage involved a more detailed analysis of the data.

Table 4 presents the coding framework used to review the research on the use of VR in TCFL. The framework was organised according to the four research questions (RQ1, RQ2, RQ3, RQ4) posed in this review. It also consisted of the main categories and sub-categories of data collected for each research question. For RQ1, the main category was “publication trends”, and the sub-categories were “years of publication” and “associated journals”. This helped in identifying the time frame and relevant journals for the research review. For RQ2, the main categories were “research settings” and “research methods”. The sub-categories under research settings were “participants” and “VR platforms”, and those under research methods were “research designs” and “data collection tools”. For RQ3, the sub-categories under “effectiveness” were “linguistic growth” and “communication skills”, and those under “benefits” were “learner motivation” and “authentic learning context”. For RQ4, the main category was “implications and areas for future research”,

Table 4: The coding framework for reviewing research on the use of VR in TCFL.

Research questions (RQs)	Main categories of the collected data	Sub-categories of the collected data
RQ1	Publication trends	– Years of publication
		– Associated journals
RQ2	Research settings	– Participants
		– VR platforms
	Research methods	– Research designs
		– Data collection tools
RQ3	Effectiveness of using VR in TCFL	– Linguistic growth
		– Communication skills
	Benefits of using VR in TCFL	– Learner motivation
		– Authentic learning context
RQ4	Implications and areas for future research	– Pedagogical implications
		– Future directions and recommendations for this field of research and practice

and the sub-categories were “pedagogical implications” and “future directions and recommendations for this field of research and practice”.

3 Findings

This section presents the research results based on 14 journal articles published between 2010 and 2023. It analyses them in a number of respects such as the publication trends, the research settings of the reviewed projects, the research methods employed in the reviewed projects, the effectiveness and benefits of using VR in TCFL, as well as implications and areas for future research.

3.1 Publication trends of reviewed articles

The publication dates of the reviewed articles indicate a time span from 2010 to 2023 (see Appendix I). This suggests that interest in the use of VR for TCFL has been steadily increasing over the years, with researchers and educators constantly exploring new ideas and applications. In the earlier years, from 2010 to 2015, there were fewer studies on this topic, but they were pioneering works that may have helped lay the groundwork for later research. In the more recent years, from 2019 to 2023, there has been an increase in the number of studies on this topic. This trend

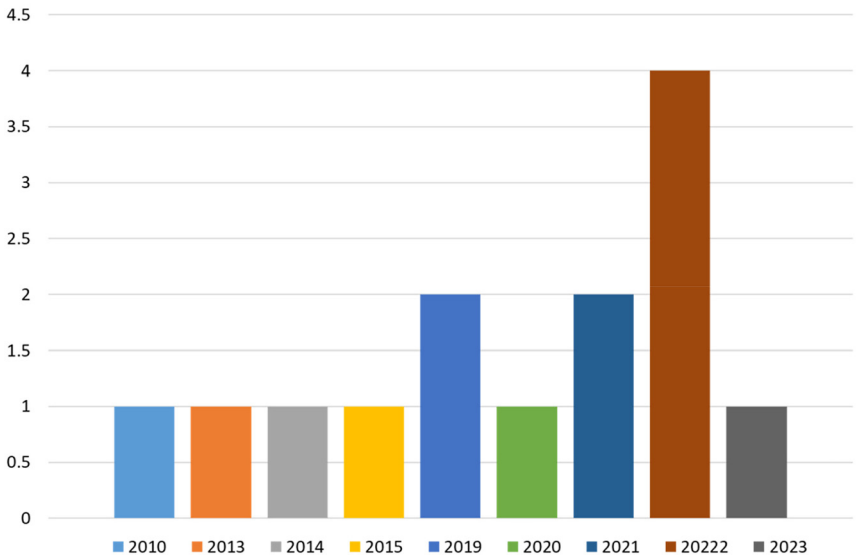

Figure 1: Annual publications of journal articles, relevant to VR supported Chinese learning.

reflects a growing recognition of the potential of VR for TCFL as well as the increasing availability of VR tools and platforms for educators. The majority of the studies were published in 2019, 2021, and 2022, with the highest number of publications in 2022, indicating a recent surge in interest in the use of VR and immersive technologies in Chinese language education. Figure 1 depicts the annual publications of journal articles related to VR-supported Chinese learning.

The articles were published in a diverse range of journals covering various topics related to technology and Chinese language learning, indicating a growing interest in the integration of technology into Chinese language education and the multidisciplinary approach taken by researchers in this field. Most of the articles were published in specialised academic journals focused on computer-assisted language learning (CALL) and educational technology research and development, such as *Computer Assisted Language Learning*, *Educational Technology Research and Development*, *TechTrends*, and *Language Learning & Technology*. The focus of these journals on technology in language education makes them a natural fit for such studies. It is interesting to note that many articles were published in *Computer Assisted Language Learning*, emphasising its significance in the field of CALL. Some articles were published in general education technology or communication journals, such as *Interactive Learning Environments*, *Universal Access in the Information Society*, and *SAGE Open*, likely indicating the growing interest in the use of

technology for language education beyond the language learning field. Moreover, open access journals may facilitate wider dissemination of the research findings to a broader audience. One article was published in *Computational Intelligence & Neuroscience*, highlighting the interdisciplinary approach to language learning. This suggests that the use of VR technology in language education is not pertinent only to language education but also to education and technology in general. Figure 2 displays the journals and the corresponding number of relevant articles. While most journals are focused on technology, the diversity of publishing opportunities and the interest in this field suggest a range of perspectives.

3.2 Participants

There was wide variation in the proficiency levels of the participants covered in the 14 reviewed articles on the use of VR in TCFL, ranging from beginners (DeWitt et al., 2022; Lan & Tam, 2022; Lan et al., 2015; Legault et al., 2019; Yang et al., 2022) to advanced (Xie et al., 2019, 2021) and those speaking a heritage language (Lan, 2014). Some studies included participants of varying proficiency levels. For example, Zhang (2022) worked with 11 international students from various countries at the elementary, intermediate, and advanced proficiency levels, while Wang et al. (2021) recruited 28 undergraduate students at the beginner and intermediate levels, and Barrett et al. (2020) worked with 33 learners at the beginner, intermediate, and advanced proficiency levels. Ming et al. (2013) divided their participants into novice, intermediate, and experienced levels based on pronunciation scores. In contrast,

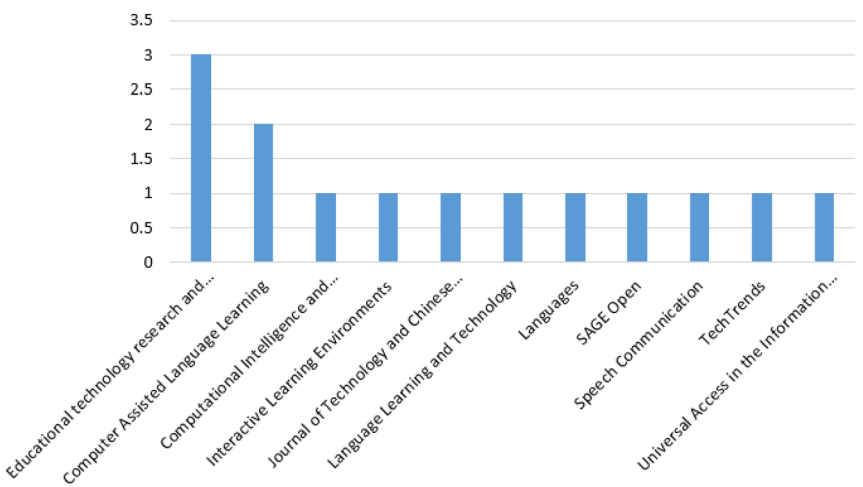

Figure 2: Journals and numbers of relevant articles.

Chen and Yuan (2023) did not specify the proficiency levels of their 30 international students of Chinese, and Grant and Huang (2010) worked with 112 first-year Chinese language and culture students in Australia but did not detail their language proficiency levels. These studies can inform the development of effective language teaching methods and materials for participants at different proficiency levels. It was evident that the participants' language proficiency level was a critical aspect of their background in this field. The reviewed articles encompassed a broad range of sample sizes, with some comprising only six participants (Yang et al., 2022) and others over 100 (Grant & Huang, 2010). The range of sample sizes reflects the diversity of the population of Chinese language learners and provides a diverse set of data from which to draw. However, smaller sample sizes may have less statistical power and may be less representative of the larger population.

Among the 14 reviewed articles, most of the research settings were located in China, the United States, and Australia. This suggests that VR technology has been employed among diverse learning groups across a range of countries. However, a few countries dominate the use of VR in TCFL. Several articles provided information on the origin of their participants. For instance, Zhang (2022) had 11 participants from various countries, including the United Kingdom, Russia, Ghana, South Africa, Morocco, Nigeria, Zimbabwe, and Bangladesh. Yang et al. (2022) had six first-year university students in Australia, while Lan and Tam (2022) had 36 participants from Vietnam. DeWitt et al. (2022) had 30 participants from Malaysia and one from India. The variety of backgrounds provides a rich source of information to better comprehend the multi-faceted aspects of the language learning process. Nonetheless, it also highlights the need for a careful consideration of the context-specific characteristics in order to develop effective language learning strategies and materials as well as the importance of recognising the needs of Chinese language learners from diverse cultural and linguistic backgrounds.

3.3 Platforms of VR integrated into TCFL

VR technology has been widely incorporated into various Chinese language courses and programmes to enhance learning outcomes. Specific studies focused on language learning courses and programmes, such as Chinese as a second language vocabulary (Chen & Yuan, 2023; Lan et al., 2015; Legault et al., 2019), Chinese writing (Lan & Tam, 2022), and oral proficiency (Xie et al., 2021). Other projects concentrated on intercultural communication, such as DeWitt et al. (2022). These studies highlighted the potential of VR platforms for language learning and the variety of platforms available for use. For instance, Chen and Yuan (2023) used a Chinese-learning VR app based on Mondly VR and Oculus Quest 2 for vocabulary learning. Zhang (2022)

utilised an A-frame framework and JavaScript to construct a virtual supermarket environment. Yang et al. (2022) used a well-developed Second Life site called Chinese Island for language learning. Lan and Tam (2022) used Google Cardboard with a smartphone to watch 360° videos before writing, while DeWitt et al. (2022) used a mobile phone and Google Tour. Xie et al. (2021) used Google Cardboard and Google Expeditions for language learning. Wang et al. (2021) created an immersive 3D virtual environment called Chinese Island using Second Life. Barrett et al. (2020) used Mozilla Hubs as a MUVRLE for language learning. Legault et al. (2019) compared immersive VR and word-paired association for language learning. Xie et al. (2019) studied college students' use of interactive VR tools for learning Chinese as a foreign language, while Lan et al. (2015) compared traditional and virtual learning environments for Chinese word learning using Second Life. Lan (2014) examined the effectiveness of Second Life in improving the oral output of overseas Chinese students learning Putonghua. Ming et al. (2013) utilised an immersive and interactive Mandarin edutainment system within virtual learning environments to learn Mandarin. The analysis of platforms for TCFL with VR technology revealed a diverse range of options, demonstrating the potential of VR technology to provide immersive language learning experiences for learners of Chinese across language levels and relevant areas and skills in TCFL.

3.4 Research methods

The trends in research design reflect the diverse research approaches adopted to address research questions. To gain a more comprehensive understanding of research questions, there is an increasing trend towards the use of mixed methods that combine qualitative and quantitative data collection and analysis processes, as evidenced in some reviewed articles (Chen & Yuan, 2023; Legault et al., 2019; Wang et al., 2021; Xie et al., 2021). In addition, qualitative research methods such as case studies (Xie et al., 2019; Yang et al., 2022; Zhang, 2022) were used for in-depth explorations of research questions. However, there was a preference for experimental and quasi-experimental designs (DeWitt et al., 2022; Lan, 2014; Lan & Tam, 2022), which involved manipulating independent variables to determine their effects on dependent variables. Quantitative research methods (Barrett et al., 2020; Grant & Huang, 2010; Ming et al., 2013), such as collecting and analysing numerical data, continued to be used to investigate research questions.

The reviewed studies used different methods and tools to collect data. Chen and Yuan (2023) employed vocabulary tests, a VR-based questionnaire, and interviews to collect both quantitative and qualitative data in a mixed methods approach. Zhang (2022) collected qualitative data through questionnaires and personal

interviews. For Yang et al. (2022), the main data sources included audio recordings of students' communication in VR and interview data. Lan and Tam (2022) used Pearson's correlation coefficient and interviews in an experimental design. DeWitt et al. (2022) obtained data on students' learning experience using a survey on learning Chinese culture through VR and interviews. Xie et al. (2021) collected data through oral presentations, class observations, reflection papers, and individual interviews in a sequential explanatory mixed methods design. Wang et al. (2021) used a mixed methods approach by employing a survey and individual and focus group interviews to collect both quantitative and qualitative data. Barrett et al. (2020) used a post-participation questionnaire to measure seven constructs. Legault et al. (2019) collected behavioural performance data through an alternative forced-choice recognition task. Xie et al. (2019) collected data from class observations, reflections, and individual follow-up interviews. Lan et al. (2015) did not specify the data collection tools used, while in Lan (2014), an experimental design was used in Stage 1, and a quantitative approach was employed in Stage 2 to assess performance and attitudes toward Mandarin. Ming et al. (2013) used questionnaires, and Grant and Huang (2010) conducted a post-lesson survey.

The analysis of the data collection tools used in the reviewed articles identified several themes. First, a wide variety of tools were deployed to gather information about students' learning experiences in the context of VR, including mixed methods approaches, questionnaires, interviews, audio recordings, observations, and correlation coefficients. Qualitative data were commonly collected through questionnaires, interviews, and observations, while quantitative data were collected though vocabulary tests and performance tasks. Second, the articles emphasised the importance of collecting data from multiple sources to gain a comprehensive understanding of the research questions. Third, technologies such as VR and screen recording software were used to collect data. The reviewed articles illustrated the diverse range of data collection tools and methods used in research and underscored the importance of selecting appropriate tools to answer research questions and gain a deeper understanding of the phenomenon under investigation.

3.5 Linguistic growth

Most of the reviewed articles focused on the use of VR technology and immersive learning environments to promote linguistic growth. These articles indicated that technology, particularly VR and immersive environments, can enhance language learning and aid in the development of language skills. They also explored how technology can enhance the student learning experience. According to the articles, the use of VR was shown to have a positive impact on language learning by improving

vocabulary retention, communication skills, and cultural understanding. For instance, Chen and Yuan (2023) discovered that VR-based vocabulary learning improved engagement and offered immediate, learner-friendly scaffolding for students. Similarly, Yang et al. (2022) found that VR environments provided a more comfortable and engaging learning experience for language learners, resulting in increased communication confidence. Lan and Tam (2022) suggested that immersive experiences utilising 360° videos enhanced motivation and performance in Chinese language writing. Moreover, several studies highlighted that VR and immersive technologies provide an authentic and contextualised learning experience that can boost language learning. For example, Wang et al. (2021) found that learners of Chinese benefited from interacting with objects and non-player characters on Chinese Island, which reflected "real language" and "real life". Ming et al. (2013) observed that the open, shared, and interactive properties of VR improved learners' communication abilities and created a genuine social community. However, some studies identified challenges in the use of VR and immersive technologies for language learning. For instance, Barrett et al. (2020) found that issues with interaction within the virtual environment affected learners' perceived ease of use of the technology. Similarly, Zhang (2022) noted that limitations relating to the online teaching space, such as network connectivity delays, and decreased interaction between students, as potentially impacting the quality and quantity of student interactions.

3.6 Communication skills

Technology has played a significant role in improving intercultural communication abilities, particularly in foreign language instruction. It is evident that technology-based language education can offer a productive and immersive learning experience. A recurring theme in the reviewed articles centred on the utilisation of VR in enhancing intercultural communication proficiency in TCFL. This theme delved into how VR can improve language and cultural competencies, including the ability to communicate effectively with individuals from diverse cultural backgrounds. VR has been found to be an effective means of enhancing intercultural communication proficiency, boosting vocabulary acquisition, and refining oral and written Mandarin proficiency. For example, DeWitt et al. (2022) explored the use of VR in developing intercultural communication competence in Mandarin and found positive results. Yang et al. (2022) found that virtual experiential language learning environments created a more comfortable, authentic, and engaging learning experience for language learners in their communications, leading to increased confidence in communication and the use of communication strategies such as

code-switching, self-repetition, fillers, and expanded response. Lan and Tam (2022) reported that learners of Chinese who had an immersive experience outperformed those who did not and that their motivation in Chinese language writing was enhanced and maintained.

Interactive course design has also been explored in distance international Chinese education (Zhang, 2022). Wang et al. (2021) demonstrated that learners of Chinese benefited from interactions with objects and non-player characters on Chinese Island, which reflected "real language" and "real life" in the target language environment. These findings correspond to Lin and Lan's (2015) analysis of interactive communication as one of the research trends in language learning in the VR environment. However, some limitations were noted in the use of technology in language learning, such as a decrease in the proportion of interaction among students due to network lag and delay (Zhang, 2022) and difficulties interacting within the virtual environment, which affect learners' perceived ease of use of the technology (Barrett et al., 2020).

3.7 Learner motivation

Some of the reviewed articles explored the effectiveness of VR in language learning and its potential in enhancing student motivation. Lan and Tam (2022) found that 360° videos increased engagement and motivation in basic Chinese writing, while Zhang (2022) suggested that cognitively inspired distance international Chinese education improved students' motivation and engagement. Huang et al. (2021) developed a new model of design collaboration among learners and found that it enhanced students' motivation and engagement in VR 3D modelling. Barrett et al. (2020) investigated the use of the technology acceptance model and multi-user VR learning environments for Chinese language education and found that immersion had a decisive influence on the learners' perceived usefulness of VR and on their motivation to learn. Legault et al. (2019) found that immersive VR for second language vocabulary learning promoted students' motivation, engagement, and retention. Overall, these reviewed articles indicate that VR technology has the potential to be an effective and motivating tool for language learners, especially when it offers immersive language learning experiences. Communication, interaction, technology acceptance, and use are some of the key factors that can contribute to the motivation of language learners using VR.

Several themes emerged from the reviewed articles, highlighting the benefits of using VR for language learning. First, the immersive and interactive nature of VR provides a unique and engaging learning experience. It offers a stimulating and interactive learning environment that can increase students' motivation to learn. VR

provides opportunities for collaborative learning, enabling students to work together and learn from each other. Second, the immersive nature of VR allows students to interact with the learning content. VR has been found to enhance language learning retention by providing an interactive and engaging learning environment. Third, the use of VR in TCFL offers students a positive technological experience. The reviewed articles suggest that students are motivated to learn when they have access to technology that they deem engaging and interactive.

3.8 Authentic learning context

Authentic learning contexts provide learners with immersive, real-world learning environments that enhance their learning experiences. The reviewed articles explored the effectiveness of using VR technology to create such contexts, demonstrating positive effects on language learning, including improved language skills, increased engagement, and better retention of learning outcomes. They highlighted the importance of authentic learning contexts in language acquisition and underscored the value of providing learners with opportunities to apply their knowledge in real-world settings to deepen their understanding of course material. These learning contexts aimed to provide learners with an environment in which they could fully engage with the Chinese language and culture. Chen and Yuan (2023) found that VR provided an authentic and repetition-enabled learning context. In an immersive environment, a higher rate of engagement in interactions and multimodal, immediate, and learner-friendly scaffolding benefited students' VR-based vocabulary learning. Lan and Tam (2022) developed an immersive Chinese language course involving the use of authentic materials and real-life scenarios to create a more authentic learning experience.

The participants in Legault et al. (2019) learnt 30 words in immersive VR and 30 words via word-paired association. The study found that the learning context had a differential effect on the learners, with less successful learners showing a significant improvement in immersive VR instruction compared to those in the word-paired group, while the successful learners demonstrated no significant benefit from either learning condition. DeWitt et al. (2022) sought to enhance learners' understanding of cultural differences and similarities and develop their communication skills in multicultural contexts. They highlighted the importance of intercultural competence in a globalised world and the potential of VR to provide immersive intercultural experiences. Xie et al. (2021) found that VR tools can improve oral presentations by enabling contextualised authentic learning. Additionally, Wang et al. (2021) found that online resources such as Chinese Island can provide an authentic context for learning, promote high-quality language learning experiences, and reflect "real

language" and "real life" in the target language environment. Finally, Legault et al. (2019) and Ming et al. (2013) found that immersive VR instruction and authentic learning experiences had a positive impact on learning outcomes and enhanced students' motivation to learn.

The reviewed articles highlight how technology can facilitate authentic and interactive learning contexts that improve language proficiency, cultural awareness, and communication skills. An important aspect of this review project was the exploration of the social context for students' learning activities in VR-supported learning environments. Students interacted with others: By sharing the responsibility for learning activities with others, they were able to construct their knowledge and make meaning of their learning. Such authentic learning environments allowed students to immerse themselves in the target language and culture as well as develop their ability to express themselves and accomplish tasks in real-life situations. The benefits of authentic learning contexts align with the aims of the Common European Framework of Reference for Languages (2020), which emphasises that language learning should prepare learners to act in real-life situations. By leveraging technology to create immersive and interactive learning environments, language learners can develop the skills they need for effective communication in a range of contexts.

4 Implications and areas for future research

The previous section addressed the first three research questions: current trends in VR-related publications in the field of TCFL, the research settings where VR is used to support learning, and the potential benefits and effectiveness of VR in enhancing language learning. The potential benefits and effectiveness of VR in enhancing Chinese language learning are consistent with the findings in broader language learning contexts. The sample contained several works showing similar results, including studies on language learning by Chen (2016), Lai and Chen (2023), Lan (2015), Lan et al. (2019), Tai et al. (2020) and Wang et al. (2020), a study on communication skills by Ou Yang et al. (2020), a study on engagement and motivation by Hu (2021), and studies on immersive and interactive learning contexts by Lan (2020b) and Legault et al. (2019). These findings are also supported by review studies conducted by Chen et al. (2022), Peixoto et al. (2021) and Zheng et al. (2022), although Chen et al. did not focus on motivation. This section contains a new theme addressing RQ4, that is, the implications of VR in TCFL and potential future research areas.

4.1 Implications

The reviewed studies demonstrate the transformative potential of technology in language learning, especially in the field of Chinese education. By providing an immersive and engaging learning environment, VR technology can help learners interact with Chinese language and culture, leading to improved language learning outcomes, attitudes, confidence, motivation, and communication skills. Furthermore, VR technology enables learners to engage in authentic learning contexts. Integrating VR technology into language learning has significant implications for both Chinese language education and foreign language acquisition.

- First, VR technology has the potential to enhance language learning outcomes and can be effective in improving various aspects of language learning, such as vocabulary acquisition, intercultural communication competence, oral proficiency, and writing skills. Proper design and evaluation are essential to ensuring the effectiveness and appropriateness of technology-enhanced language learning programmes. Educators must carefully plan and assess these programmes to meet learners' needs and achieve desired outcomes.
- Second, VR technology can offer immersive and engaging learning experiences. The immersive and interactive nature of VR technology provides a more engaging and personalised learning experience and helps learners to stay motivated and interested in learning the language. Educators need to design technology-based language learning activities that are interactive and engaging and that follow cognitive science principles to enhance student learning outcomes. It is crucial to consider learners' perceptions and experiences to increase their acceptance of and engagement with the technology when designing technology-based language learning tools.
- Third, VR-enhanced language learning can help overcome geographical and linguistic barriers. Consequently, VR-enhanced language learning can be particularly beneficial for learners facing geographical and linguistic barriers to language learning.
- Furthermore, VR-enhanced language learning can benefit from interdisciplinary collaboration. Several studies involved collaboration among language educators, technology developers, and researchers from other fields, highlighting the importance of interdisciplinary collaboration in developing effective technology-enhanced language learning programmes.

Despite the potential benefits, there are challenges in the implementation of VR-enhanced language learning. These challenges can be classified into logistical and learner-related issues. Logistical issues encompass technical difficulties such as

Internet connectivity and sound quality, which can impact the quality of the learning experience. Learner-related issues include engagement and technology literacy. The learning environment plays a critical role in achieving favourable learning outcomes; therefore, it is critical to ensure that students have access to such an environment to maximise their potential. In some instances, learners may not be acquainted with VR technology or may not feel comfortable using it, which may hinder their learning experiences. It is important to address these issues to fully realise the benefits of technology-enhanced language learning. According to Barrett et al. (2020, p. 3), "one of the challenges of exploring the affordances of a particular VR learning environment, or any new technology for that matter, is that many potential users may not be digitally literate". This argument also applies to teachers, who may face challenges in facilitating student learning through this technology.

4.2 Areas for future research

While the reviewed articles provide valuable insights into the potential of emerging technologies for language learning, it is crucial to comprehensively address their limitations and investigate their impact on language learning outcomes. To overcome these limitations, future studies should employ larger and more diverse samples, examine multiple language skills, and explore different educational contexts. Moreover, future research could investigate the potential of emerging technologies in supporting language learning for various age groups and language proficiency levels. There are several areas of consideration for future research:

- Using larger and more diverse samples: Some studies had small sample sizes, which limited the generalisability of their findings. To increase the generalisability of future research, larger and more diverse samples of language learners should be involved.
- Considering a broader population of learners: Many of the reviewed articles focused on international students or overseas Chinese learners. Future research should consider a wider population of language learners to determine whether the benefits of VR are generalisable across different learner populations.
- Comprehensive understanding of VR: Some studies only focused on specific aspects of language learning, such as vocabulary or writing, which may not reflect the full potential of VR for language learning. Future research should investigate the full range of potential applications of VR in language learning.
- The use of control groups: Some studies lacked control groups, which made it difficult to determine whether the observed language learning improvements were due to the use of VR or other factors. Future research should aim to include control groups to better understand the effectiveness of VR interventions.

– An examination of long-term impacts: Many studies undertook short-term interventions that did not provide data on the long-term impact of VR on language learning. Future research should investigate the long-term impact of VR on language learning outcomes.

5 Conclusions

This review paper has provided valuable insights into the empirical use of VR in the field of TCFL. The reviewed articles highlighted the potential benefits of VR technology in enhancing the learning experiences of Chinese language learners. VR offers unique affordances that can facilitate language learning through immersive learning, interaction, and authentic language learning settings. The use of VR in Chinese language learning has also been found to be effective in enhancing intercultural communication competence. Learners can communicate in diverse scenarios, collaborate in meaningful and authentic learning environments, and engage in real-life situations. The authentic learning contexts provided by the immersive and authentic environment in VR can enhance motivation and engagement, leading to improved language proficiency, performance, and specific linguistic skills. The reviewed articles emphasised the importance of providing learners with opportunities to apply their knowledge in real-world settings to deepen their understanding of course material.

This review study has several limitations. First, the sample size of this study was relatively small, comprising only 14 journal articles. Second, although Scopus, Web of Science, and backward citation searches were utilised to identify relevant studies, it is possible that some data sources were inadvertently overlooked. Third, the review focused primarily on the use of VR technology in university settings, which may not be generalisable to other learning contexts. However, the results suggest that as VR technology continues to advance, it presents exciting opportunities for language learners to participate in immersive and interactive learning experiences that can deepen their understanding of the target language and culture. The results also provide valuable pedagogical insights that can assist teachers in improving their teaching practices and language learners in enhancing their experiences in TCFL.

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Appendix I

Summary of the selected journal articles

Authors	Publication year	Journals	Research site	Number of participants	Participants language level	Course type	Course duration	Type of VR platforms	Research design	Data collection methods
Chen & Yuan	2023	*Computer Assisted Language Learning*	University, China	30	Not specified	VR-based vocabulary learning	Two sessions of 30 min each	– Mondly VR – Oculus Quest 2	Mixed methods	– Vocabulary tests – A VR-based vocabulary learning questionnaire – Semi-structured interviews
Zhang	2022	*Computational Intelligence & Neuroscience*	University, China	11	Elementary, intermediate, and advanced International Chinese	Distance international Chinese education interactive course	Not specified	– An A-frame framework – JavaScript (JS) language	Case study	– Questionnaires – Interviews
Yang et al.	2022	*SAGE Open*	University, Australia	6	Beginners	A beginner Chinese language unit	One semester	– Second life	Case study	– Audio recordings – Interviews

(continued)

Authors	Publication year	Journals	Research site	Number of participants	Participants language level	Course type	Course duration	Type of VR platforms	Research design	Data collection methods
Lan & Tam	2022	*Educational Technology Research and Development*	University, China	36	Beginners	Immersive CSL course	4 weeks, 3 h per week	– Google cardboard device – Smartphone to watch 360° videos	Experimental design	– Pearson's correlation coefficient – Interviews
DeWitt et al.	2022	*Educational Technology Research and Development*	Polytechnic, Malaysia	31	Beginners	Mandarin as a foreign language	Weeks	– Mobile phone – Google Tour	Quasi-experimental research	– A survey – Interviews
Xie et al.	2021	*Computer Assisted Language Learning*	University, USA	12	Advanced	Advanced Chinese course	One semester	– Google cardboard – Google expeditions	Sequential explanatory mixed-methods design	– Recordings of oral presentations – Class observations – Participants' reflection papers – Interviews
Wang et al.	2021	*Computer Assisted Language Learning*	A regional Australian University	28	Beginner and intermediate levels	Online activity space	One semester	– Second life	Mixed methods	– Survey – Interviews
Barrett et al.	2020	*Interactive Learning Environments*	Sino-British University, China	33	Beginner, intermediate and advanced levels	A unique lesson	An average session time of 27.9 min	– Mozilla Hubs	Quantitative analysis	– Post-participation questionnaire

(continued)

Authors	Publication year	Journals	Research site	Number of participants	Participants language level	Course type	Course duration	Type of VR platforms	Research design	Data collection methods
Legault et al.	2019	*Languages*	Pennsylvania State University	64	No knowledge of Mandarin Chinese	Two learning sessions	Not specified	– Immersive VR	Mixed counter-balanced design	– An alternative forced-choice recognition task.
Xie et al.	2019	*TechTrends*	University, USA	12	Advanced	Advanced Chinese language	One semester	– Google cardboard – Google expeditions	A case study	– Class observations – Student reflections – Interviews
Lan et al.	2015	*Educational Technology Research and Development*	Pennsylvania State University, USA	31	No knowledge of Mandarin Chinese	A training study	18 days	– Second life	Not specified	– Immediate testing and delayed post-testing sessions – The mixed-effects modelling method
Lan	2014	*Language Learning & Technology*	University, China	44	Not specified	A two-stage action study	11 weeks	– Second life	An experimental design	– Recordings of teaching and classroom talking – Dependent-sample t-test

(continued)

Authors	Publication year	Journals	Research site	Number of participants	Participants language level	Course type	Course duration	Type of VR platforms	Research design	Data collection methods
Ming et al.	2013	*Speech Communication*	Not specified	Not specified	Novice, intermediate, and experienced learners	A Mandarin edutainment course	Approx. 30 h	– A Mandarin edutainment system	Quantitative research	– Questionnaire
Grant & Huang	2010	*Journal of Technology and Chinese Language Teaching*	University, Australia	112	First year Chinese language and culture students	An undergraduate Chinese language and culture teaching programme	Not specified	– Second life	Quantitative research	– Post-lesson survey

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