A Systematic Review of Research on Immersive Technology-enhanced Writing Education: The Current State and A Research Agenda

Yuting Chen, Ming Li*, Member, IEEE, Changqin Huang*, Member, IEEE, Mutlu Cukurova, Qing Ma

Abstract—Immersive technology has received extensive attention in both L1 and L2 writing education. Its unique capabilities to offer virtual experiences alongside real-world experiences can create authentic learning environments that support students’ experiential learning and enable the observation of events beyond the confines of traditional classrooms. However, there has been a lack of systematic analysis of recent publications in this area. To address this gap and improve the research and practice of writing education, a systematic review was conducted to examine the literature on immersive technology in writing education (ITWE). In this review, 37 articles (30 SSCI-indexed papers from the Web of Science (WoS) database and 7 additional articles from a meticulous forward-backwards scan of the references of these studies) were analyzed. The analysis focused on theoretical foundations, participants, types of adopted immersive technology, methods and research findings. Our review shows that although most studies revealed positive outcomes, a significant number lacked a solid theoretical foundation to interpret the findings in meaningful ways. Moreover, there is a pressing need for further research on ITWE in middle schools, especially within the realm of English as a foreign language (EFL) courses. In addition, the review identified some potential negative effects of ITWE, which were often attributed to poorly designed instructional activities. It was observed that conventional research methods like questionnaire surveys and interviews, were commonly used in ITWE. However, the potential benefits of emerging areas like learning analytics and AI in Education (e.g., logged actions, facial emotion detection, EEG analysis) were rarely used. The paper is concluded with the current research evidence on emerging directions and opportunities for future trends in empowering writing education with immersive technology.

Index Terms—Virtual reality; Augmented reality; Immersive technology; Writing education; Systematic review

I. INTRODUCTION

Immersive technology, including virtual reality (VR), augmented reality (AR) and mixed reality (MR), have the capacity to dissolve the distinctions between the physical and virtual worlds [1]. Through augmenting the authenticity of virtual experiences, immersive technology empowers users to deeply engage within virtual environments [2]–[5]. VR uses computer-generated technology to create a virtual environment mirroring the real world [7]. AR, on the other hand, overlays virtual objects onto the physical world in real-time, amplifying the user’s perception of reality [8], [9]. MR, encompassing AR and augmented virtuality (AV) [6], defies a singular, universally applicable definition. Instead, it can be delineated through a conceptual framework comprising seven dimensions: “number of environments, number of users, level of immersion, level of virtuality, degree of interaction, input, and output” [10, p1]. For a thorough grasp of the relationships among VR, AR, and MR, it is necessary to consider other concepts such as AV and extended reality (XR). AV is often confused with AR but differs in that it maps images or videos of the real world onto virtual objects, while AR supplements physical reality with virtual information [11], [12]. XR is a newer term that encompasses various forms of immersive technology, including VR, AR, and MR. It denotes the utilization of computer technology and wearables that blend the boundaries between the physical world and virtual environments [13], [14]. XR is often used as a comprehensive term to encompass these technologies or a fusion of them [15]. Fig. 1 illustrates the relationships among VR, AR, MR, AV, and XR suggested by Li et al. [6]. For a concise exposition of the fundamental concepts of VR, AR, MR and AV, along with a thorough elucidation of their distinguishing characteristics, we direct the attention of interested readers to the online column1, accompanied by its corresponding repository of supplementary resources. Research in diverse domains, including entertainment [16], education [17], and healthcare [18], have empirically tested the potential effects of immersive technologies.

Fig. 1. The relationship between the five terms AR, AV, MR, VR, and XR [6]

1Pictures illustrating examples of VR, AR, MR, and AV can be accessed through the following link: https://www.clivemaxfield.com/coolbeans/fundamentals-vr-mr-ar-dr-and-hr/
of incorporating immersive technologies (e.g., VR, AR) in different cases. In particular, the integration of immersive technology enhances the development of multiple language skills, including listening [19], speaking [20], reading [21] and writing [22].

Learning to write in native language (L1) or foreign language (L2) is regarded as one of the most fundamental elements to support the cultivation of student 21st-century key competence [23], [24]. It is also regarded as a holistic manifestation of overall language proficiency [25]. However, for most L1 and L2 language learners, mastering the art of writing is often viewed as a demanding endeavor, entailing memory, planning, text creation, and revision [26]. The difficulty arises because learners often struggle with initiating their writing when they lack relevant background knowledge or are unfamiliar with appropriate words and sentences to articulate their feelings [27]. In particular, regarding L2 writing, cognitive load theory [28] suggests that the heightened cognitive load stemming from students' limited lexical resources or negative emotions, like pressure, tend to be more prominent in L2 writing compared to L1 writing. Immersive technology has the potential to help reduce such cognitive load. For instance, it is perceived as an effective intermediary that helps both L1 and L2 writers in the prewriting stage by facilitating idea generation and word selections. This alleviates the writers' sense of alienation from the writing contexts, analogous to how artists draw inspiration from real-life scenarios to stimulate their creative thinking [22]. Furthermore, researchers have showcased how the implementation of immersive technology can facilitate the acquisition of vocabulary, enhancing descriptive writing while alleviating the constraints posed by writing pressure on L2 learners [29], [30].

Immersive technology is becoming one of the most suitable tools for offering learners an authentic context in learn-to-write processes [27]. It consists of three key components: immersion, interaction and imagination. Immersion, a multifaceted concept, encompasses a state of profound mental engagement where individuals may dissociate from their awareness of the physical world as their attentional state undergoes a shift [31]. It can be understood from four general perspectives: “(a) immersion as a characteristic of the system employed to present the virtual world; (b) immersion as a perceptual response to that system; (c) immersion as a response to an unfolding narrative, the characters within the story world, or the depiction of the world itself; and (d) immersion as a response to challenges that require the utilization of one’s intellectual or sensorimotor skills” [32, p108]. Previous research indicated that immersive technology, with its immersive nature, enhances learners’ sense of presence and engagement in the process of learning to write [29], [33]. Interaction allows learners to actively engage with the virtual environment, manipulating objects, navigating the space, and participating in simulated activities [34], [35]. This interactive nature of immersive technology promotes active writing learning, as learners can directly interact with content and receive immediate feedback, fostering a deeper comprehension of the subject matter [36]. Moreover, it encourages learners to assume command of their writing-learning process and explore different paths, promoting autonomy and self-directed learning [37], [38]. Imagination plays a crucial role in simulating learners’ creative thinking [27], and helps them connect virtual experiences with real-world contexts, thereby enhancing the transferability of writing knowledge and skills [39]. Furthermore, immersive technology has demonstrated its potential in nurturing students’ capacity to vividly articulate the sensory experiences and cognitive processes involved in perceiving and interpreting information from their environment [1]. It has been found to benefit writers by boosting their writing confidence [40], enhancing students’ efficiency in completing the given writing tasks [41], [42], and reducing their cognitive load from single-channel learning [43], [44]. However, it is important to acknowledge the limitations and drawbacks of using immersive technology in writing education as reported in empirical studies. For example, Chen et al. [27] and Barrett et al. [33] reported that the use of VR may cause physical discomfort such as dizziness and motion sickness. Allagui [29] found that the use of AR may not effectively enhance learners’ creativity. These findings suggest that the use of immersive technology should be approached with caution. Despite the existing research on ITWE, there is currently no synthesis of studies that systematically analyses recent publications in this area. Therefore, it is necessary to clarify the current state-of-the-art and establish a research agenda to guide future investigations in ITWE, allowing researchers to navigate this area more effectively.

Several reviews with inclusive or cross-correlated relationships to ITWE studies have been reported in recent years. Hein et al. [45] conducted a systematic review on the use of immersive technologies in foreign language learning from 2001 to 2020. Their study was centered on examining the influence of immersive technology on the motivation, success and attitudes of L2 language learners. They also explored the characteristics of immersive technology environments that support L2 learning and discussed their potential applications in L2 learning and teacher training. However, their review did not specifically address how immersive technology affects native language learners’ writing learning. A parallel scenario unfolded in the research endeavors undertaken by Parmaxi and Demetriou [46] and again in Parmaxi’s subsequent study [47]. In another review, Bahari and Gholami [21] examined the obstacles and opportunities in the development of reading and writing skills in technology-assisted language learning from 2015 to 2021. While their study provided very limited content on the obstacles and opportunities in VR-based writing learning, they primarily focused on general educational technologies (e.g., intelligent tutoring system, digital reading, web-based learning ) and their applications for both reading and writing development. Seyyedrezzaei et al. [48] conducted a comprehensive meta-analysis aimed at investigating the comparative efficacy of technology-assisted language learning in relation to EFL writing performance, encompassing 64 studies. However, it is important to highlight that their analysis did not focus on immersive technology-assisted learning, nor did it encompass conclusions about the impact
of technology-enhanced language learning on L1 writing achievements specifically. Williams and Beam [49] undertook a review of 29 empirical studies published in peer-reviewed journals between 2003 and 2017, examining the utilization of technology in writing education. They categorized the utilized techniques into three macroscopic categories, namely online tutoring, web-based writing environments, and hypermedia. While their survey offers a comprehensive overview of the influence of technology applications in writing education, it may not provide useful insights for ITWE scholars, practitioners, and institutional leaders aiming to advance student learning to write and equip L1/L2 writing practitioners with immersive technology-based instructional practice experiences. In an immersive technology-based review, using the stimulus-organism-response (S-O-R) framework as suggested by [50], Suh and Prophet [1] analyzed the effects of applying immersive technology in various contexts (i.e., education, marketing, business and healthcare) from 2010 to 2017. The S-O-R framework reports that internal evaluations of users are triggered by external or environmental cues, which in turn contribute to their behavior [51]. The framework can effectively uncover the interaction among factors such as system attributes, user experience, and consequences of employing immersive technology. In the present study, we used the S-O-R framework to investigate how immersive technology affects the learn-to-write process of learners.

To improve the practice of writing education by leveraging insights from the reviewed studies and assist researchers in tracking the trends of immersive technology within the domain of both L1 and L2 writing education (ITWE), we conducted a systematic review of the existing literature. Although L1 and L2 writing exhibit differences in terms of linguistic proficiency and cultural background, they share many commonalities in terms of cognitive and linguistic processes essential to writing, such as developing ideas, organizing text, and revising drafts [52]. Therefore, discussing L1 and L2 writing together is an important aspect of writing research, contributing to a holistic understanding of writing processes and instructional practices that can benefit both L1 and L2 writers [52]. Our primary aim was to comprehensively synthesize the research findings, offering an overview of the current status of ITWE research. Additionally, we sought to identify areas where research is lacking and set the foundation for future investigations in this area. In our study, we build upon the technology-based learning model put forth by Fu and Hwang [53], which employs a comprehensive interpretation of constructivism and is widely used to identify the current state and establish a research agenda in technology-enhanced learning research. Following their model, we focused on the participants, adopted technologies, research findings, and methods. To further enhance the research context, we incorporated language types as an additional element identified in this review. Additionally, following the suggestion mentioned in [54] regarding the importance of the theoretical foundation for leveraging digital technologies in language education, we included the dimension of theoretical foundation in our framework. Fig. 2 illustrates the whole research framework of ITWE in our study.

Fig. 2. The research framework of ITWE.

The research questions are as follows:

- RQ 1: What major theoretical foundations are adopted in the research on ITWE?
- RQ 2: What type of participants are involved in ITWE?
- RQ 3: What kinds of immersive technologies have been adopted in the research on ITWE?
- RQ 4: What kinds of research methods have been adopted in the research on ITWE?
- RQ 5: What are the findings of the research on ITWE?

II. METHODS

To address the five research questions, we conducted a systematic review following a pre-registered protocol (see Appendix 1). In the selection of the articles, we followed the three phases of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [55], namely, identification of the records, screening for possible eligibility and inclusion of papers (see Fig. 3). The PRISMA guidelines have been widely used in other studies which have undertaken systematic reviews [56]–[58]. It aims to support a transparent approach in systematic reviews and guarantee a reproducible procedure (e.g., search strategy, review protocol).

To ensure the representativeness of the findings included in this review paper, we selected journals from the Social Science Citation Index (SSCI) of the Core Collection of the Web of Science (WoS) database, following many previous review works [59]–[61]. Then, we employed the Boolean expressions “AND” and “OR” to search for publications from the WoS database to retrieve papers from SSCI journals and retrieved a total of 584 papers (see Fig. 1). The period from January 1st 2008 to August 15th 2023, which has witnessed the emergence and adoption of immersive technologies in educational contexts [1], was selected and the document type was set as “article”. Informed by the terms used in the review articles [1], [62], we used the following search string

("VR" OR "virtual reality" OR "AR" OR "augmented reality" OR "MR" OR "mixed reality" OR "SVVR" OR "spherical video-based virtual reality" OR "immersive technology" OR "immersive" OR "virtual world" OR "virtual learning environment") AND ("writing" OR "composition" OR "writing learning" OR "writing instruction" OR "writing course" OR "writing teaching" OR "writing activity" OR

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“developing writing” OR “writing education” OR “writing development” OR “learn to write” OR “training on writing”)

Articles were selected based on the following inclusion criteria: 1) published in English; 2) published between January 1st 2008 to August 15th 2023; 3) examined the effects of at least one of the immersive technology (e.g., VR, AR, MR) on learners’ L1/L2 writing learning achievements; 4) reported empirical evidence (quantitative or qualitative) on students’ L1/L2 writing achievements.

Publications were excluded based on the following exclusion criteria: 1) conference papers, non-reviewed articles, 2) conceptual, theoretical or review articles, 3) articles that concentrate on designing an immersive technology-based learning environment but not its application to L1/L2 writing learning/teaching practices, 4) articles that focus on the L1/L2 writing education but do not incorporate integrated immersive technology into educational practices, 5) articles that focus on L1/L2 language learning but less on writing learning, 6) articles cover other technology-assisted learning (e.g., online learning, flipped learning).

Fig. 3 shows the selection process for the review according to PRISMA. Two researchers with an ITWE research background were employed to read the abstracts of the articles to further exclude articles which were not suitable for our study based on the criteria. They evaluated the abstracts in parallel and disputes that arose during the evaluation were resolved by the first author of this paper. A total of 44 articles were then subjected to full-text screening by the first and second authors independently to determine if they met the criteria for further review. The inter-rater reliability of the two authors is 0.835. Any disputes at this stage were resolved by consensus-based discussion between two professors with ITWE backgrounds. As a result, 14 articles were excluded as 1) Articles focusing on L1/L2 language learning but less on writing learning (N=5), 2) Articles covering other technology-assisted learning (e.g., online learning, flipped learning) (N=1), 3) Articles that focus on the L1/L2 writing education but not integrated immersive technology into educational practices (N=4), 4) Conceptual, theoretical or review articles (N=1), 5) Articles that focus on handwriting education (N=2), 6) articles that focus on the design of an immersive technology-based learning context but not its application to L1/L2 writing learning/teaching practices (N=1). In this stage, a total of 30 articles were chosen for review synthesis.

We conducted snowballing, following the guidelines outlined by [63] for the purpose of 1) identifying papers that may not have been captured by the search query for various reasons, thereby mitigating potential biases introduced by the query construction and database selection. This ensures that the reviewed proceedings closely represent the entirety of published works on this topic, 2) validating the coding framework (see details in Section ??), showing that there is no need to add dimensions after reviewing other papers. This process resulted in the inclusion of three eligible SSCI articles that were identified through a forward and backward scan of references in the included studies. Additionally, we also identified three non-SSCI index articles and one book chapter article that were deemed relevant to our survey topic through a forward and backward scan of references in the selected studies, and included them as they provide valuable insights or information that would contribute to the overall understanding of the subject matter. The first author then reviewed the entire text of 37 articles and discussed with the second author if eligibility was uncertain. These 37 articles met the criteria and were consequently included in the content analysis.

The coding schemes of each dimension are as follows:

- **Theoretical foundations**: As suggested in [61], language learning needs to be cultivated with appropriate pedagogy strategies and theories. Writing is one part of language learning, and it is clear that a reasonable integration of theoretical foundations, including theoretical frameworks, concepts, models and instructional approaches, can better facilitate students’ writing abilities. Therefore, in this study, the aforementioned theoretical foundations (e.g., experiential learning, engagement theory) in ITWE were coded and analyzed.

- **Research/measurement methods**: Pimmer et al. [64] divided research methods into three dimensions, namely, quantitative, qualitative, and mixed methods. Following the study [61], we divided the measurement methods in the reviewed papers into five categories: learning record, classroom observation, interview, questionnaire survey and test. Since one of our reviewed articles used physiological measurement, we added it as one of the measurement methods in our reviewed papers.

- **Participants**: Both the sample size and the learner’s educational level/background were coded in our study. According to [65], we classified the sample size of the reviewed papers into five types, namely, very small (n < 15), small (15 < n < 25), medium (25 < n < 49), big (50 < n < 64) and large (n > 64), and we followed [66] to classify the learner’s educational level/background into six dimensions: primary school students, secondary...
school students, high school students, college students, secondary school teachers.

- **Adopted technologies**: In our study, the immersive technologies adopted in writing education were categorized as VR, AR, MR and SVVR. It should be noted that the term “VR” in the present study covered all VR types and no further distinctions were made between for instance fully immersive VR and semi-immersive desktop VR with different degrees of freedom.

- **Language types**: As suggested in [61], we classified the languages being learned in the reviewed papers into three types: Chinese, English, and Korean.

- **Findings of ITWE**: To establish a comprehensive classification for investigating the impacts of immersive technology on writing education, we adopted the S-O-R framework developed by Suh and Prophet [1]. This framework includes three aspects (see Table II, III, IV for details): stimuli, organism, and response. It has been generally employed for the exploration of user experience and behavior when using immersive technologies ([1], [67]). In addition, individual differences (e.g., gender, age) in immersive technology use also play a crucial role in influencing learners’ responses and experience of immersive technology [1]. Therefore, we categorized the reviewed papers into the following four categories: stimuli, organism, response and others. We went through the results, discussion, and conclusion sections of the reviewed papers to find out whether the employment of immersive techniques proves effective in writing education from the feedback of stimuli, organsisms, responses, and other aspects. For example, if the articles reported visual effects of immersive technology on students’ writing learning, it was categorized as “visual stimuli”. If the articles discussed the gesture response function of immersive technology on students’ writing learning, it was coded as “interaction stimuli”.

Two researchers who are experienced in conducting research coding work were employed to independently code the relative content on the theoretical foundations, research/measurement methods, sample size and educational background of the participants, the adopted technologies, language types and the findings of ITWE in the 37 included papers. All relevant content was extracted, then grouped and summarized into a table of similar content for subsequent coding. This bottom-up coding approach aids in mitigating subjective biases and enables the researchers to report the details of the reviewed articles in an objective manner [61]. Their coding work was calculated using Cohen’s kappa based on their labels. Each label was transformed into Arabic numbers, for example, the language types were coded as 1 (Chinese), 2 (English) and 3 (Korean). The value of Cohen’s kappa of theoretical foundation ($k = 0.836$), research/measurement methods ($k = 0.741$), participants ($k = 1.00$), adopted technologies ($k = 0.836$), language types ($k = 1.00$) and findings of ITWE ($k = 0.637$) show high inter-coder reliability [68]. Their coding results were also checked collectively by themselves. For inconsistent codes, the two researchers re-examined the articles and held face-to-face discussions, and finally reached a consensus.

### III. Results

Fig. 4 shows that there is an upward trend to conduct research on ITWE, especially in the years 2021 and 2022. The papers reviewed in our study were published in 20 different journals and a book chapter (see Fig. 5). The journal in which the majority of papers were published is *Computer Assisted Language Learning, British Journal of Educational Technology, and Education and Information Technology*, followed by the other leading journals in the field of educational technology (e.g., *Computers and Education, Journal of Science Education and Technology*).

![Data distribution by publication year](image)

**Fig. 4.** Data distribution by publication year.

#### A. Theoretical foundations

Previous studies have claimed that having an understanding of the current theoretical foundations is necessary to analyze the existing immersive technology-enhanced applications in education [69]. In our study, we conducted a comprehensive review of theoretical frameworks and instructional approaches adopted in ITWE studies to undertake an in-depth analysis. Table I summarizes the theoretical foundations adopted in reviewed papers, with a total of 14 theory foundations identified across 15 articles. One of the studies described the use of self-determination theory (SDT) as a guiding framework for implementing ITWE. SDT is a theory centered around the intrinsic psychological needs and inherent growth tendencies of individuals, addressing aspects of human motivation and personality [70]. The study highlighted the potential of VR to create motivational learning environments aligned with SDT principles, leading to increased engagement and academic achievement [37]. Specifically, Chen et al. [37] explored the relationship between students’ perceived relatedness, self-efficacy in descriptive writing, satisfaction with writing and their self-concept in a VR-based learning environment, guided by SDT. Five of the studies applied theoretical frameworks or models to shape immersive technology-enhanced writing activities, including Experiential learning theory (ELT). In ELT, there is a significant emphasis
on the role of experience in the learning process, as highlighted by [71]. Researchers have suggested that the authentic experience provided by SVVR drives learners to achieve better performance [43]. For example, Huang et al. [43] and Yang et al. [39] designed an experiential SVVR learning model to aid student in crafting descriptive articles. They divided their learning procedures into four steps: concrete experience, reflective observation, abstract conceptualization, and evaluation and revision. Another theoretical framework employed in ITWE studies is the Engagement theory, which emphasizes the meaningful engagement of learners in activities [72]. Chen et al. [73] used engagement theory in the design of a VR-based writing curriculum, integrating the three principles of engagement theory (relate, create, donate) to facilitate students’ writing engagement. The Hayes’ writing model [74], focusing on the cognitive and affective dimensions of the writing process, formed the basis for immersive technology-enhanced writing activities in studies by Lin et al. [41] and Wang [42]. These activities investigated both the cognitive and affective dimensions of the writing process. Furthermore, the deep exploration of ITWE has shown promise in extending existing theories. Chen et al. [27] proposed a new experiential learning model which referred to both the experiential theory and deep learning theory (a theory that indicates that a deep learning approach aids students in achieving a more profound comprehension of the material and related questions and have higher-quality learning outcomes than surface-learners [75], comprising six steps, namely, concrete experience, provoke thought, abstract conceptualization, reflective observation, abstract extension and evaluation, and revision and writing. The Technology acceptance model (TAM), a model that explains and predicts specified behavior, has also been utilized in ITWE studies. Barrett et al. [33] analyzed and developed a new TAM specifically tailored for high-immersion VR learning contexts. It includes six dimensions: interaction, immersion, imagination, perceived usefulness, perceived ease of use and intention to use. Two additional theoretical frameworks are the Motivational learning model, which emphasizes learners’ motivation during activities [76], and the generative learning theory, which prioritizes aiding learners in actively comprehending information through mental reorganization and integration with prior knowledge [77]. In a recent study, Li et al. [78] employed a motivational AR approach to facilitate the writing abilities of pupils, involving four stages: attention, relevance, confidence, and satisfaction. Chen et al. [79] utilized a generative learning-supported SVVR approach to enhance primary school students creative writing, encompassing four stages: selecting, organizing, integrating, and imagining.

In addition to the theoretical frameworks and models, four frequently-used instructional approaches were also used to design the immersive technology-enhanced writing activities. Lin et al. [40] designed their VR tasks based on computer-supported collaborative learning (CSCL), aiming to enhance students’ linguistic, discoursal, sociocultural, strategic, interactional, and formulaic aspects in the process of scaffolding immersive VR learning. On the basis of this study, Xu et al. [80] applied a digital storytelling VR-based approach to support students’ writing self-efficacy and flow experience. In [81], both the double-loop learning and single-loop learning approaches were adopted to design two different SVVR-based activities. A comparative analysis was carried out to examine the differences in the students’ writing achievements and learning engagement between the two groups. Furthermore, Hsu and Chan [82] employed a content and language-integrated learning (CLIL) approach to design VR-based writing activities. This approach aimed to design targeted learning activities that combined information technology, geography, and Chinese writing, thereby enabling collaboration between teachers in natural science and social science disciplines. Chen and Kent [83] designed a task-based virtual learning environment aimed at aiding at-risk English language learners in enhancing their motivation to learn, task engagement and proficiency in reflective English writing.

B. Participants characteristics

As shown in Fig. 6, the most-investigated participants are college students (18 out of 37), followed by primary school students (9 out of 37), high school students (5 out of 37), secondary school students (4 out of 37) and secondary school teachers (1 out of 37). The numbers of studies for L1 writing (N = 19) and L2 writing (N = 18) was almost equal. Among L2 writing studies, 16 articles investigated EFL (English as a foreign language) writing, and two articles investigated CSL (Chinese as a second language) writing. We also found an interesting phenomenon that primary school students were mostly surveyed in L1 writing studies (9 out of 9 articles), while college students were mostly surveyed in L2 writing studies (14 out of 18 articles) which might be due to the late start of L2 education in many countries.

As is shown in Fig. 7, it is worth noting that, in three of the top five regions (i.e., Taiwan, Mainland of China, and Hong Kong), learners are native speakers of Chinese. However, it is not the most commonly learned language in the reviewed papers (see Fig. 8). This is because ten of the papers identified...
## THEORETICAL FRAMEWORKS, MODELS AND INSTRUCTIONAL APPROACHES.

<table>
<thead>
<tr>
<th>Theoretical foundations</th>
<th>Description</th>
<th>References</th>
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<tbody>
<tr>
<td>Experiential learning theory</td>
<td>The application of this theory suggests that the authentic experience provided by SVVR drives learners to achieve better performance. It consists of four stages: concrete experience, reflective observation, abstract conceptualization, and evaluation and revision</td>
<td>[27], [39], [43]</td>
</tr>
<tr>
<td>Deep learning theory</td>
<td>The application of this theory suggests that the authentic nature of SVVR can promote learners’ ability to understand, transfer and apply knowledge, thereby enhancing their cultivation of creative thinking and deep writing skills</td>
<td>[27]</td>
</tr>
<tr>
<td>Engagement theory</td>
<td>The application of this theory suggests that virtual learning environments can provide engaging approaches that are hard to be achieved via conventional methods, which further promote learners’ engagement</td>
<td>[73]</td>
</tr>
<tr>
<td>Self-determination theory</td>
<td>The application of this theory suggests that VR-enhanced writing courses contribute to personal motivation, learning engagement and academic performance</td>
<td>[37]</td>
</tr>
<tr>
<td>Generative learning theory</td>
<td>The application of this theory suggests that SVVR-based environments can promote learners to actively process and internalize information by mentally restructuring and incorporating it with their existing knowledge. This, in turn, empowers learners to apply their newfound knowledge in other situations.</td>
<td>[79]</td>
</tr>
<tr>
<td>Hayes’s writing model</td>
<td>The application of this theory suggests that the use of AR technique in writing learning can promote learners’ beliefs and attitudes, task schemas, text production, topic knowledge, genre knowledge and linguistic knowledge</td>
<td>[41], [42]</td>
</tr>
<tr>
<td>Technology acceptance model</td>
<td>The application of this theory suggests that learners’ behavioral intentions of using VR in writing education are greatly influenced by their perceived usefulness and perceived ease of use</td>
<td>[33]</td>
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<tr>
<td>Motivational learning model</td>
<td>The application of this theory suggests that integrating AR techniques into writing learning can promote students’ motivation to engage in the writing process</td>
<td>[78]</td>
</tr>
<tr>
<td>Computer-supported collaborative learning</td>
<td>The application of this instructional approach suggests that scaffolding immersive VR-based learning is effective in supporting learners in collaborative writing learning</td>
<td>[40]</td>
</tr>
<tr>
<td>Digital storytelling</td>
<td>The application of this instructional approach suggests that learners exposed to a virtual world are able to engage in student-centered learning and facilitate them to express more ideas and thoughts</td>
<td>[80]</td>
</tr>
<tr>
<td>Double/single-loop learning</td>
<td>The application of these two instructional approaches suggests that learners exposed to a contextualized SVVR learning context through interactions with teachers or peers will increase their learning engagement and reduce their anxiety in writing</td>
<td>[81]</td>
</tr>
<tr>
<td>Content and language integrated learning</td>
<td>The application of this instructional approach highlights the significance of giving equal emphasis to both language and content, enabling students to engage in a curriculum that integrates language acquisition with subject matter comprehension</td>
<td>[82]</td>
</tr>
<tr>
<td>Task-based learning</td>
<td>The application of task-based instructional approach offers contextual, engaging, and authentic opportunities that integrate language skills, promote critical thinking, and prepare learners for real-world communication, resulting in improved writing proficiency and lifelong skills</td>
<td>[83]</td>
</tr>
</tbody>
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### Table I

<table>
<thead>
<tr>
<th>Participants</th>
<th>L1 writing</th>
<th>L2 writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary school teacher</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>High school student</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Secondary school student</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Primary school student</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>College student</td>
<td>4</td>
<td>14</td>
</tr>
</tbody>
</table>

![Fig. 6. Participants in the reviewed papers.](image)

the effects of immersive technology-enhanced English writing among EFL learners [30], [33], [40], [41], [82]–[87].

Fig. 9 shows that the bulk of the studies had a sample size which was either medium (25 < n < 49, 29.7%) or large (n > 64, 32.4%). A few studies had a big sample size (50 < n < 64, 13.5%), small sample size (15 < n < 25, 13.5%) or very small sample size (n < 15, 10.8%).

### C. Adopted immersive technologies

The findings of our study show reveal that four different technologies (VR, SVVR, AR and MR) were adopted in the reviewed articles (see Fig. 10). Among these technologies, immersive VR was the most commonly used, with 16 out of 37 articles utilizing it to enable users to completely immerse themselves in a virtual environment. Typically, 3D
modelling and animation software (e.g., Maya, 3Ds Max) were used to develop virtual scenes. For example, Patera et al. [88] designed an immersive virtual environment to support students’ imaginative writing using their native language. The participants in the virtual learning environment exhibited higher motivation, engagement, and quicker writing initiation compared to traditional methods. In [80], a multi-user virtual platform (Second Life) was employed to develop a digital storytelling environment for students’ writing. This platform stimulated the students’ imaginations and encouraged more creative writing because they were able to create, operate, move or modify virtual objects, which was then enacted in their writings.

The next most frequently used technology, found in 13 out of the 37 articles, was spherical video-based virtual reality (SVVR). SVVR is a low-cost immersive VR with a relatively low technical threshold that gained popularity after 2016. It presents the learning context through 360-degree spherical VR videos. Many researchers used the EduVenture VR platform (http://ev-cuhk.net/) to process the SVVR learning materials. For example, Lin et al. [40] utilized the EduVenture VR platform to compose and execute the SVVR materials to support EFL students’ dyadic learning of English. Similarly, Chen et al. [27] utilized the EduVenture VR platform to develop SVVR learning materials aimed at fostering students’ deep writing in their native language.

AR emerged as the third most frequently used technology in the reviewed papers, appearing in 7 out of 37 papers. AR provides learners with real-time interactive learning experience by overlaying objects in text, image or video formats onto the physical world [89]. Various development software packages (e.g., Metaverse Studio, Unity for Mobile AR) were adopted to constitute the AR learning environment. For instance, Lin et al. [41] used Unity for Mobile AR to develop an AR ubiquitous writing learning environment, aiming to enhance EFL writing instruction. In a similar vein, Koc et al. [35] developed AR-based learning materials using Metaverse Studio to promote EFL students’ expository text writing. Furthermore, an intriguing study introduced the utilization of Microsoft HoloLens 2 smart glasses to harness the multimodal capabilities within MR environments, facilitating the creation of multimodal stories by upper elementary school students [90].

D. Adopted methods

The outcomes of our review, as displayed in Fig. 11, reveal that 64.86% of the reviewed articles (24 articles) employed mixed methods to examine the effects of ITWE, 24.3% used a quantitative method (9 articles), 10.81% applied a qualitative method (4 articles). The quantitative method uses directly...
quantifiable measurement tools (e.g., questionnaire surveys, tests) to collect data, whereas the qualitative method uses indirectly quantifiable measurements (e.g., videos, interviews) to collect data [91]. A mixed-method approach uses both quantitative and qualitative methods to collect data.

As for the measurement methods used in the reviewed studies, 27 articles (72.97%) employed a test as their measurement method (see Fig. 12). For example, [42] explored the efficacy of incorporating AR-based learning materials to enhance high school students’ acquisition of writing skills. This study used tests to evaluate students’ writing achievements across four dimensions: subject, content control, article structure and wording. Similarly, Huang et al. [43] used a test to explore the influence of an SVVR-based approach on high school students’ descriptive article writing. They assessed student achievement in organization, content, appearance and vocabulary use. Chen et al. [27, p10] and Yang et al. [39, p7] identified the effectiveness of using SVVR technology in Chinese writing courses, both employing tests as a measurement method. The students’ writing scores were measured based on four dimensions, namely, “thematic coherence, structural integrity, linguistic expressiveness and creative thinking”. We found that most of the published papers used a test and a four-dimensional evaluation scale to assess student writing performance [35], [40], [73].

The second and third most widely used measurement methods were questionnaire surveys (20 articles) and interviews (21 articles). More than half of the reviewed papers used at least one of these as their measurement method, and a few studies (10 articles) employed both methods, with interviews often complementing and providing further insights to strengthen the questionnaire results. For instance, Huang et al. [43] adopted a questionnaire to collect information on students’ creativity tendency, cognitive load, learning motivation, and self-efficacy toward writing activities. They also conducted interviews with the students who used the SVVR approach. The objective of employing interviews in their study was to confirm the consistency between the conclusions drawn from the questionnaire analysis and the interview findings. Yang et al. [39] employed a questionnaire to collect data on students’ level of learning behavioral engagement and the state of their reading habits. The finding from the interviews were found to align with the quantitative analysis results from the questionnaires. Li et al. [81] used a questionnaire survey to uncover the connections between the four subscales of learning engagement (social, behavioral, emotional, and cognitive aspects) in SVVR-based writing activities. To verify the results of the questionnaires, they conducted interviews with the participants from the two groups (those who studied with double-loop SVVR approach and those who studied with single-loop SVVR approach).

Classroom observation (6 out of 37 articles), learning records (7 out of 37 articles) and physiological measurements (1 out of 37 articles) were also used as measurement methods in several articles. The classroom observation method was used to analyze students’ classroom learning behaviors and their question-answering performance [22], [27], [78], [88], [90], [92]. The learning records method was used to record the classroom learning process when students were completing their learning tasks (e.g., concept maps, paintings, reflection) [40], [41], [83], [87], [90], [92], [93]. Additionally, a physiological measurement method was used to examine whether the students’ hemodynamic responses change with the occurrence of critical thinking [94].

E. ITWE Findings

As aforementioned, the S-O-R framework [1] were used to guide the analysis of the ITWE findings, focusing on three aspects: stimuli, organism and response.

1) Findings on the elements of the stimuli aspect: As shown in Table II, stimuli in the context of enhancing writing learning can be categorized into two main elements: sensory and perceptual. Sensory stimuli are directly perceived by students’ physical senses and encompass visual, auditory and haptic aspects [1]. Visual stimuli, which include three-dimensional presentations integrating text, pictures, and videos, were the most widely reported factor among the reviewed articles (37 out of 37 articles). In [41], for example, they indicated that the visual stimuli within an authentic AR learning environment enhanced the students’ motivation, long-term memory and self-regulated cognition in L2 writing. Auditory stimuli, involving acoustic feedback facilitating interaction between
students and the AR/VR environment, were mentioned in several studies. For instance, Wang [42] indicated that acoustic feedback in the virtual learning environment provided guidance for students to avoid aimless learning tasks in L1 writing. Haptic stimuli, tangible interactive interfaces enabling physical interaction with virtual objects, were discussed in four articles. Patera et al. [88] claimed that tangible feedback from the VR environment enhanced students’ presence in the process of L1 writing learning. Furthermore, Lin et al. [40] employed a scenery-based virtual reality which incorporated visual, auditory, and textual input to present virtual scenarios. Their study found that utilizing multi-channel input may reduce the cognitive load caused by single-channel cognition for L2 writing learners [40]. In line with the multimedia learning theory [95], which asserts that individuals learn more effectively when presented with a combination of words and visual than from words alone, the combination of visual and auditory information can enhance learning and retention.

Therefore, it is suggested that integrating relevant images, graphics, animations and videos with texts is more effective than presenting text alone.

As shown in Table II, perceptual stimuli refer to the perceptual experience received from the students’ sensory stimuli (i.e., interaction (45.95%), immersion (54.05%), imagination (37.84%)) and their perceptions of the features of immersive technologies (i.e., flow (2.7%) and perceived usability (35.14%)) [1]. For example, Chen et al. [37] found that authentic interaction provided by the virtual learning environment helped students reach a state of immersive learning, which in turn, stimulated their imagination in relation to the writing tasks. In addition, when students experience a state of flow during a writing task, they are likely to develop increased writing awareness and a positive learning attitude toward the process of writing learning [80]. Similarly, if a student feels that immersive technology enables them to achieve a goal easily, effectively, usefully, and efficiently, they will have a satisfactory level of perceived usability of the technology and they are also likely to have a positive learning attitude towards writing tasks [29], [30], [33], [37], [40], [41], [73], [84], [85], [93], [97], [99].

2) Findings on the elements of the organism aspect: In our study, the organism aspect refers to a student’s internal assessment (i.e., mental reactions) as feedback on the use of immersive technology (see Table III). Learning engagement, motivation, and participation were the most reported in the reviewed papers (23 out of 37 papers). For example, when learning motivation is stimulated, students’ abilities to explore and inquire are enhanced [38], leading to increased attention toward the process of writing learning and the extraction of valuable information from learning materials [39]. Another element in this aspect of writing education is to promote students’ confidence (e.g., self-efficacy, confidence) in the process of writing learning (9 out of 37 papers). When a student has high levels of self-efficacy in relation to the writing tasks, they are more likely to fully express their thoughts during classroom learning or in their writing scripts [40]. Furthermore, affect, which includes enjoyment and curiosity, is also mentioned in the reviewed papers (16 out of 37 papers). For instance, Lin et al. [41] reported in their study that the ubiquitous AR approach facilitates positive affect throughout the L2 writing learning process.

3) Findings on the elements of the response aspect: In our study, the response aspect refers to the influence of immersive technology utilization. As illustrated in Table IV, learning effectiveness, learning attitude, learning perceptions, task efficiency, and cognitive load were frequently used as response variables. Within the domain of writing education, researchers have consistently observed positive outcomes resulting from the integration of immersive technologies. Specifically, 36 articles reported enhancement in the process of L1 and L2 writing learning (e.g., learning behaviors, critical thinking, long-term retention) and writing achievements (e.g., performance, skills, abilities). These studies found that the virtual environment provided a new and immersive simulated world that enabled students to experience situations not possible in the real world, thereby assisting them in transforming abstract ideas into specific writing scripts, further enhancing their writing performance [35], [73], [92]. Furthermore, twelve articles reported an improvement in learning attitudes and perceptions towards writing tasks. When learning perceptions or self-efficacy are stimulated, students develop a positive learning attitude [29], [30], [35], [38], [40], [42], [79], [84], [86], [90]. Five articles reported on the favorable influence of immersive technologies on task efficiency. Specifically, the immersive learning environment enriched the students’ ideas, facilitated quicker initiation of writing the first paragraph (especially for low achievers) [42], expediting the completion of the first stage of writing [88], and facilitate a better understanding of the writing topic [29]. Moreover, immersive technology demonstrated its effectiveness in helping students in optimizing their learning time for completing assigned writing tasks [22]. Additionally, the studies indicated that the integration of immersive technologies can reduce writing pressure and tension for students during the learn-to-write process [29], [83], [84], and stimulate multichannel learning to alleviate the cognitive load in the process of writing learning [43], [44].

In addition to the positive outcomes of immersive technologies in L1 and L2 writing education, negative outcomes were also reported in several papers (see Table IV). Four articles reported that the lack of proper guidance from the teacher resulted in students failing to achieve their own learning objectives [40], [41], [73], [88]. Additionally, two articles suggested that this approach may divert students’ attention from the learning content to the immersive environment itself [73], [97]. For instance, Chen et al.’s study [73] reported that the SVVR-based necessitated heightened classroom management and attentiveness, as students sometimes spent excessive time exploring the virtual environment or inadvertently overlooked the writing tasks they were meant to complete. While some researchers identified that immersive technologies did not add any cognitive load in relation to students’ learning, two other studies reported the opposite, claiming that the rich input of media resources might lead to an increase in the learners’ cognitive load, which appear to negatively affect their writing performance.
Similarly, four studies claimed that the rich input of content from AR/VR is restricted or not useful to entice learners’ creativity. They argued that while immersive technologies provide creative materials, they might not effectively foster creative thinking, and the abundance of media resources could increase students’ reliance on their imagination [29], [39], [42], [88]. Moreover, researchers reported various drawbacks associated with the incorporation of immersive technologies in writing education. In nine articles, it was observed that the use of wearable devices, especially for individuals with nearsightedness, could lead to physical discomfort for students during the learning process. For instance, Lin et al. [40] documented cases where participants experienced dizziness while using VR goggles, largely attributable to nearsightedness. Moreover, eight articles highlighted the intricate and less user-friendly nature of AR/VR tools can pose challenges for students, especially for younger learners. For example, in a study by Mills and Brown [92] with 44 elementary school students, some struggled to locate their virtual brushes for connecting lines and surfaces. Additionally, eight studies have pointed out technical problems that students may encounter in their writing learning process, potentially impeding the effectiveness of immersive technologies. For instance, in [30], participants mentioned the need for an enhanced display quality of information related to scenic spots in the learning environment. One article also pointed out that being unskilled with VR/AR equipment can result in significant waste of time [73].

4) Findings on the elements of the other aspect: In addition to the elements from the stimuli, organism, and response aspects, researchers have also discussed the effects of elements of other aspects (e.g., gender, teachers’ instructional burden) on ITWE. For example, Patera et al. [88] found that, compared with girls, boys usually write less and were not easily motivated.

Wang et al. [85] stated that immersive VR-based writing instruction methods could to some extent reduce the teachers’ burden in the process of EFL teaching. [42] reported that the AR-based method was particularly suitable for designing writing activities related to outdoor topics. Pack et al. [86] demonstrated a notable positive correlation between the participants’ antecedent conditions and their participation in learning to write. Moreover, researchers claimed that ITWE facilitates students’ autonomous learning [37], [38], [97], inquiry-based learning [41] as well as shapes students’ self-identify as writers [37]. We also found an interesting phenomenon reported by three studies [29] for L2 writing, [42], [88] for L1 writing that the AR-based approach is more effective for students with weak/low writing achievement than those with good writing achievement.
TABLE IV
FINDINGS ON THE ELEMENTS OF THE RESPONSE ASPECT.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Factor</th>
<th>Definition</th>
<th>Frequency</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive outcomes</td>
<td>Learning effectiveness</td>
<td>The effects of incorporating immersive technologies into writing education, including enhancements in the processes of writing learning (i.e., critical thinking, learning behaviors) and writing achievements (i.e., writing performance, skills, abilities, question answering qualities, long-term retention and others).</td>
<td>36</td>
<td>[29], [33], [35], [37], [38], [73], [96] [27], [34], [43], [44], [81], [85], [97] [30], [40], [42], [84], [94], [101] [22], [39], [99], [82], [86], [93], [100] [78]–[80], [83], [87], [88], [90], [92]</td>
</tr>
<tr>
<td>Learning attitude/ perceptions</td>
<td>Enhancement of attitude/perception/autonomy towards learning tasks, and materials after learning with AR/VR</td>
<td>12</td>
<td>[22], [29], [35], [38], [40], [73] [30], [79], [84], [96], [90], [92]</td>
<td></td>
</tr>
<tr>
<td>Task efficiency</td>
<td>Enhancement in efficiency (e.g., help students to start the first paragraph more quickly; assist students to bypass the first stage of writing more quickly; help students to understand the writing topic more easily; assist students in optimizing their learning time to accomplish assigned writing tasks)</td>
<td>5</td>
<td>[22], [29], [41], [42], [85]</td>
<td></td>
</tr>
<tr>
<td>Cognitive load</td>
<td>Reduce the cognitive load from single-channel learning.</td>
<td>2</td>
<td>[43], [84]</td>
<td></td>
</tr>
<tr>
<td>Pressure/tension</td>
<td>Reduce the writing pressure and tension</td>
<td>3</td>
<td>[29], [83], [84]</td>
<td></td>
</tr>
<tr>
<td>Negative outcomes</td>
<td>Aimless</td>
<td>Lack of proper guidance from the teacher results in students’ failure to achieve their own learning objectives</td>
<td>4</td>
<td>[40], [41], [73], [88]</td>
</tr>
<tr>
<td>Cognitive overload</td>
<td>Rich input of media resources from AR/VR leads to an augmentation in learners’ cognitive load</td>
<td>2</td>
<td>[33], [73]</td>
<td></td>
</tr>
<tr>
<td>Restrict creativity</td>
<td>Rich input of content from AR/VR restricts or is not useful to entice learners’ creativity</td>
<td>4</td>
<td>[29], [39], [42], [88]</td>
<td></td>
</tr>
<tr>
<td>Distracted attention</td>
<td>Rich input of media resources from AR/VR distracts the learners’ attention away from the writing learning tasks</td>
<td>2</td>
<td>[73], [97]</td>
<td></td>
</tr>
<tr>
<td>Physical discomfort</td>
<td>Physical discomfort caused by the use of AR/VR (e.g., motion sickness, dizziness, disorientation)</td>
<td>9</td>
<td>[27], [33], [40], [99] [85], [83], [86], [93], [100]</td>
<td></td>
</tr>
<tr>
<td>Time-consuming</td>
<td>Being unskilled with VR/AR equipment can waste a lot of time</td>
<td>1</td>
<td>[73]</td>
<td></td>
</tr>
<tr>
<td>Inconvenient operation</td>
<td>Complex and inconvenient operation of AR/VR tools may cause trouble for students when using AR/VR tools</td>
<td>8</td>
<td>[29], [30], [40], [73] [42], [83], [90], [100]</td>
<td></td>
</tr>
<tr>
<td>Technical/content problems</td>
<td>Problems with the AR/VR technologies (e.g., lack of interactivity, interactivity is not smart enough; poor video quality/content) (the connection between thescenery and educational themes needs to be more pronounced) or during the process of using AR/VR technologies (e.g., the Internet connection is not reliable, connection problems)</td>
<td>8</td>
<td>[27], [29], [84], [97] [30], [83], [93], [100]</td>
<td></td>
</tr>
</tbody>
</table>

IV. DISCUSSION AND FUTURE SUGGESTIONS

By examining the reviewed papers, we observed growing attention towards ITWE in the recent two years, possibly due to the urgent demand for authentic learning (e.g., experiential learning, contextual learning) in traditional writing education [39], [43]. Additionally, the increasing maturity of immersive technology and its prominent application value in other disciplines have led teachers to adopt a positive attitude towards its implementation in writing education [92]. However, scant research has been conducted on ITWE and more research in the future is needed. The five research questions were discussed as follows.

A. RQ1: What major theoretical foundations are adopted in the research on ITWE?

The major theoretical foundations utilized in the research on ITWE were identified using a content analysis method. Through the content analysis of the reviewed papers, we found that (1) most studies tend to apply theories, models or instructional approaches to shape immersive technology-enhanced writing activities [27], [33], [39]–[43], [73], [78]–[80]. This is because researchers generally believe that a well-designed technology-enhanced instructional activity is often developed based on valid theoretical foundations [54]. The results of the reviewed studies generally consistently show a positive effect of incorporating educational/learning theories, models and instructional methods into the design and implementation of immersive technology-enhanced writing activities. This highlights the practical value of ITWE as a means of providing technical support for traditional writing education. (2) Research exploring whether the implementation of ITWE can be conceptualized to form new theoretical frameworks is still in its infancy, with only two studies referring to their specific immersive technology-enhanced contexts to modify and formulate new theories/models [27], [33]. This further indicates that ITWE is in the early stage of its development, emphasizing the necessity for additional research in the future. The field of immersive technology-enhanced writing is relatively new and rapidly evolving. Existing theoretical frameworks may not fully address the unique challenges and opportunities presented in this context. Enhancements to theoretical frameworks can help researchers explore and understand novel aspects of immersive writing, such as the impact of VR, AR, or other emerging immersive technologies on writing processes and outcomes. (3) The number of studies describing and verifying the frameworks of specific theories and models in ITWE is relatively low. Among the 37 articles reviewed, 22 studies did not provide information about their theoretical foundations, indicating that the majority of ITWE research lacks theoretical grounding. However, theoretical guidance is crucial in technology-enhanced education research as it helps clarify the research purpose for readers [54]. It is recommended that future research focuses on identifying the theoretical foundations used to guide ITWE studies. This will significantly augment our comprehension of a specific element or phenomenon. First, theories provide a useful foundation for describing, elucidating and forecasting the phenomena it pertains to [102]. For instance, in the current survey, it is evident that experiential learning theory stands out as one of the most widely applied frameworks that could...
serve as a robust basis for future ITWE research. What distinguishes immersive technologies is their capacity to provide authentic learning experiences that are often beyond the reach of other technologies. With its strong emphasis on concrete experiences within students’ learning processes, experiential learning theory reasonably explains the practical application value of immersive technologies in writing education. Second, research studies that integrate theory, and then show potential refinements to the theory based on its empirical findings, are considered strong contributions to the literature due to theoretical advancements provided [103], [104]. Third, the use of theory enhances the generalizability of research findings to a wider audience [105], [106].

B. RQ2: Who are the participants in the research on ITWE?

Our study revealed five main features of the participants. (1) The most-investigated participants were Chinese students, although the most-used language for writing was English. This is because several papers identified the effects of immersive technology-enhanced English writing among EFL learners [35], [40], [41]. (2) College students were the most extensively researched group, with 18 articles dedicated to their study. Many of these studies (14 articles) specifically explored the effects of immersive technology-enhanced writing in second language (L2) contexts, with 13 articles focusing on EFL and 1 article on CSL. College students were chosen as the target group due to their urgent need to improve their English writing skills, and their accessibility within academic institutions facilitated recruitment for researchers [34], [107]. Additionally, the immersive learning method provides a stimulating and engaging environment, motivating college students to enhance their English writing proficiency, and potentially improving their learning efficiency and performance [41]. Furthermore, learning to write in a non-native language presents challenges for many EFL students [41]. The immersive learning environment enabled students to deeply immerse themselves in the writing learning context, facilitating knowledge internalization and enhancing their learning achievements [34]. However, it is worth noting that while EFL writing education has received significant attention from ITWE researchers, the majority of research studies have focused on college students (13 articles), with relatively few studies (3 articles) on K-12 students. This might be due to the practical considerations in primary and middle schools regarding the use of immersive technology, as well as the potential ethical challenges of getting access to these students for ITWE research. Even so, the study of ITWE in EFL classes for K-12 students holds significance and warrants further attention. (3) The number of research studies of ITWE specifically targeting primary, middle and high school (K-12) students is relatively small compared to studies focused on college students. This discrepancy can be attributed to the following several reasons. First, immersive technologies may have been less accessible and less commonly used in K-12 school settings compared to higher education or specialized training environments. The availability and affordability of immersive technology tools and resources might have limited the number of studies conducted within K-12 contexts. Second, conducting research studies with K-12 students involves practical considerations, such as obtaining parental consent, coordinating with schools and teachers, managing participant recruitment, and ensuring that potentially more strict ethical considerations are met. These factors may have added to the complexity and challenges to researchers, potentially impacting the number of studies conducted in these spaces. Third, immersive hardware is typically designed and developed for adult learners and operationalization of such technology in K-12 contexts may be particularly challenging for teachers and students. However, given the importance of developing writing skills at an early age and the positive results of some of the reviewed studies here, more research on ITWE for K-12 students is encouraged. (4) The sample size used in the reviewed papers was usually reasonable. Although many of the reviewed papers view sample size as the main reason why their conclusions may not be generalized [27], [39], [41], [43], the application value of ITWE is likely to eventually overcome the limitation of sample size as researchers explore ITWE for students of different ages, in different disciplines and from different regions. As the field of ITWE continues to develop, it is expected that studies will encompass larger and more diverse samples, allowing for broader generalizations and a better understanding of the impact of immersive technologies on writing education across various student populations.

C. RQ3: What immersive technologies have been adopted in the research on ITWE?

As for the immersive technologies adopted in the reviewed papers, we found that VR was the most-used technology in ITWE both in the early (2008-2015) and later (2016-2023) years. SVVR, one of the immersive VRs, was frequently implemented in ITWE in recent years [27]. Researchers indicated that SVVR is a more convenient immersive technology due to its ease of implementation and low cost [59], [108], [109]. AR is used relatively less (7 out of 37 articles). There may be two reasons for this. On the one hand, the immersion of AR itself is not as good as VR, which may greatly reduce the students’ sense of presence and the effect of experiential learning [1]. On the other hand, AR is a technology that is suitable for writing activities conducted outdoors [42], which may make the whole writing activity more time-consuming [73]. However, several researchers have pointed out that AR is suitable for educational applications because it can cause less dizziness for the learner in the learning process and it will not hinder the interaction or communication among their peers or with the teacher [110]. The application of AR in education has both advantages and disadvantages, thus, some minor disadvantages in using AR to support students’ writing learning may be overcome by integrating appropriate instructional methods (e.g., game-based learning, problem-based learning). As reported in [111], the incorporation of game-based learning and AR-assisted learning activities could increase the learners’ sense of presence and immersion. Also, of the four articles which apply AR in writing education, no research was found...
that adopted AR in primary schools. In the future, more research on integrating different instructional methods into AR-enhanced writing education is needed, especially for primary school students. In addition, the restricted integration of MR in educational applications can be ascribed to the historical complexity and high implementation costs associated with the technology. These factors have rendered it less accessible, particularly for educational institutions grappling with budgetary constraints.

D. RQ4: What research methods have been adopted in the research on ITWE?

With regard to the research methods used in the reviewed papers, the results show that above half of the research used mixed methods (both quantitative and qualitative methods), 24.4% of the studies used quantitative methods, and 10.8% of the studies employed qualitative methods. These results suggest that researchers tended to adopt mixed methods in their studies rather than use the quantitative or qualitative method only, and often argued that the mixed method approach takes advantage of the features of both quantitative and qualitative methods. In [39], [112], the qualitative method was adopted to complement the conclusions drawn by the quantitative findings. In addition, we found that there was scant research on ITWE which only used a qualitative method compared to the number of studies which used a quantitative method. This limited usage of qualitative methods in ITWE research may be due to the views held by some researchers. As exemplified by Elaish et al. [113], some researchers argue that the conclusions based on qualitative methods may be limited and may lack scientific traceability and generalization. Hence, in the future, how to make full use of the advantages of the quantitative analysis method and expand its application efficiency in the field of ITWE is worth considering.

In terms of the measurement methods adopted in the reviewed papers, it was found that more than half of the studies adopted testing as one of the measurement methods. This is because phased tests can objectively reflect changes in the writing ability of learners after a period of learning and directly demonstrate the effects of ITWE. Also, questionnaire surveys and interviews were frequently used to measure the learning effects of ITWE. These two measures are often used to measure variables that are difficult to measure by testing (e.g., learning motivation, self-efficacy). However, an overview of the content of the reviewed papers shows that seven studies [22], [27], [40], [41], [83], [88], [92] mentioned the effects of ITWE on the learning process (i.e., online learning records, classroom learning behaviors). The three measurement methods (tests, questionnaire surveys and interviews) lead to an outcome-oriented research trend without much attention being paid to the process of classroom learning using ITWE. Writing is “a recording process involving dynamic behaviors, which is closely connected with the authentic context” [27, p1]. In particular, research on ITWE often emphasizes the process of students’ authentic learning (e.g., experiential learning, contextual learning). Therefore, the qualities of the process of classroom writing learning are worthy of research attention in future studies on ITWE.

E. RQ5: What are the findings of the research on ITWE?

Our study reported on four aspects of the implementation effects of the research on ITWE. In terms of stimuli, ITWE researchers frequently highlighted visual, auditory and haptic aspects, as these three dimensions contribute to the sensory stimuli generated by immersive technology. On the basis of these sensory stimuli, students can engage in perceptual experience, including interaction, immersion, and imagination, enabling them to develop perceptions of immersive technology features (i.e., flow and perceived usability) [1]. One possible reason for this phenomenon is the compelling nature of immersive technology as a stimulus, which can effectively motivate learners to engage in writing activities. This immersive experience stimulates them to actively integrate and adapt their existing knowledge within the writing context, fostering a deeper understanding and proficiency in this skill [101]. Furthermore, it is widely acknowledged that writing education poses challenges due to its higher-order cognitive nature, which requires learners to express their experience, knowledge and perception in a logical and systematic manner [43]. This can often lead to a short-term memory load within a single cognitive channel [27]. Interestingly, immersive techniques with their multisensory characteristics can partially alleviate the cognitive load associated with single-channel learning, thereby improving overall learner performance [39]. Although some of the reviewed papers have indicated that the rich multi-channel information input might increase students’ cognitive load [33], [73], these drawbacks can be mitigated through well-designed instructional activities [114]. Additionally, our findings indicated the majority of studies documented the implementation effects of ITWE stimuli through the utilization of self-reported questionnaires or qualitative interviews. The rationale behind this approach is that scholars sought to gain a more profound understanding of participants’ sensory responses and perceptions toward the assigned learning tasks [54]. Nonetheless, it is worth noting that researchers have acknowledged the potential for biased outcomes due to the subjective nature of questionnaire surveys and interviews [115]. Thus, it is recommended that future research on ITWE incorporates multimodal measurement methods to collect data pertaining to the stimuli aspect. This approach will help mitigate potential biases and contribute to a more comprehensive understanding of the topic.

In terms of the organism aspect, students’ mental reactions (e.g., learning engagement, self-efficacy; affect) were assessed to uncover their feedback on the use of immersive technology. Mixed results were found on the effects of ITWE in these variables. For example, Huang et al. [43] investigated the use of SVVR in a Chinese descriptive writing course to determine its impact on high school students’ learning motivation. They discovered no significant enhancement in both intrinsic and extrinsic motivation dimensions. However, during qualitative interviews, students mentioned that the utilization of SVVR in writing courses stimulated their motivation at a deeper level. Another study by Hsu and Chan [82], focusing on senior high school students’ Chinese descriptive writing skills, demonstrated that VR-based instruction effectively
facilitated motivation. One possible reason for the diversity of findings in studies could be the short duration of the interventions conducted. The limited intervention period might not have allowed sufficient time for the full impact of immersive technology to manifest and for students to fully adapt to the new approach. Therefore, conducting longer-term interventions that provide ample time for students to acclimate to the technology and for any potential effects to emerge might yield more consistent results and a deeper understanding of the impact of immersive technology on students’ mental reactions. This idea is supported by studies presented in [84], [97], where the authors conducted longer intervention periods and found that implementing VR in writing education can indeed enhance college students’ motivation for EFL writing. In addition, we found that most studies used self-reported questionnaire surveys or interviews to collect data relating to the organism aspect in ITWE-related works. To avoid biased results which may be caused by these self-reported measurements, future studies can adopt multimodal learning analytics (e.g., facial emotion detection, EEG, classroom discourse analysis) to obtain a more accurate and convincing conclusion [116].

The response outcomes of ITWE yield a mixture of positive and negative results. Indeed, the reviewed papers provide strong evidence that immersive technologies serve as effective platforms for learning and training, encompassing factors such as learning effectiveness, perceptions, and task efficiency. This effectiveness is often attributed to the immersive nature of these technologies, which create a sense of presence, thereby enhancing learners’ motivation to participate in writing courses. As a result, learners exhibit increased levels of generative processing. Meaningful learning with ITWE relies on learners using their limited cognitive capacity to engage in appropriate learning behaviors and thinking for generative processing [117]. However, it is important to acknowledge that pitfalls regarding the use of ITWE have also been reported by researchers including cognitive overload, restricted creativity, and distracted attention. The immersive nature of these technologies can sometimes lead to distractions, such as extreme emotional arousal and increased levels of irrelevant perceptual stimuli [73], [88]. These distractions may captivate learners’ attention, causing them to engage in extraneous processing while reducing their focus on essential learning processes [117]. Consequently, the immersive environment may divert learners’ attention from the core content and objectives of the lesson [73], [97]. When the learners are using cognitive processing capacity for extraneous processing, it becomes unavailable for essential and generative processing, which are crucial for constructing meaningful learning outcomes [117].

V. LIMITATIONS

The limitations of this systematic review must be acknowledged. First, only 30 papers were published in SSCI journals from 2008 to 2023 from one database (WoS) and 7 manually added studies were reviewed in our study. Thus, the most-researched topics reported in this study may be incomplete. In the future, articles from other databases (Scopus, ERIC) can be included to ensure the range of articles being retrieved is broad enough, as more technical works may appear in these avenues. Second, this study involves no results on the duration of each experiment, because we found most studies either did not state the duration of their experiment clearly or it was not reported at all. Future studies may consider this factor as one of the review contents. Finally, we found that 22 of the reviewed articles contained no information related to the theoretical foundation of the study. To obtain complete information, two of the researchers involved in our study followed standardized protocols to carefully review these 22 articles, but no information was given on the theoretical methods that were used. Therefore, the results of our study may not completely reveal the theoretical foundations used in ITWE. This information should be included in future studies because it is one of the important factors to guide the research.

VI. CONCLUSION AND IMPLICATIONS

In an attempt to improve ITWE practices based on the findings of the reviewed studies, as well as to help researchers track trends in immersive technologies in the field of L1/L2 writing, this paper reviewed 37 papers published in the last fifteen years in terms of their (1) theoretical foundations, (2) participants, (3) adopted immersive technologies, (4) research methods, and (5) research findings. The results provide useful insights for ITWE scholars, practitioners, and institutional leaders aiming to promote student learning to write and equip L1/L2 writing practitioners with innovative instructional practice experiences. The implications for future research and practice are as follows:

1) Although most studies revealed positive outcomes, a theoretical foundation appears to be missing to interpret these findings in many ITWE studies. Future studies should ensure that the theoretical foundation of empirical research is made more explicit as this can help researchers generalize their findings across a variety of contexts [105]. 2) More research on ITWE for middle schools is needed, especially in EFL (English as a foreign language) classes. L2 writing remains challenging for many secondary school students due to limited English language input and their limited capacity to utilize vocabulary and grammar [118]. Future research endeavors could delve into how immersive technology can enhance the EFL writing skills of middle school students. This can be achieved by the incorporation of multimodal educational data in longitudinal studies, promising substantial contributions to the research in this field. 3) Some of the negative effects of ITWE are associated with poorly designed instructional activities. Thus, it is suggested that appropriate instructional methods should be integrated to facilitate the efficiency of ITWE. 4) Traditional research methods, such as questionnaire surveys and interviews, are currently the most commonly used research methods in ITWE, while some promising opportunities from the emerging fields of learning analytics and AI in education are rarely used. The integration of AI-supported learning analytics, as noted by [119], holds promise in augmenting human decision-making processes. It acts as a supportive tool rather than a replacement for human...
decision-making, positively impacting the speed and accuracy of human decisions. Moreover, this method can extend human observational capacities, enabling the inference of processes beyond the human eye’s perception or interpretation [119]. Nevertheless, it is imperative that AI algorithms are designed and deployed ethically to avoid biases or discrimination in decision-making processes. Future studies are expected to draw more convincing conclusions and gain more confidence in the reported empirical results using innovative learning analytics or tools. Regardless, another research implications of this survey study is the need for a broader scope in future ITWE investigations utilizing (and potentially improving) more innovative state-of-the-art research methodologies from applied AI and learning analytics.

Furthermore, there are noteworthy instructional implications for teachers and educational designers. They sought to strive for a harmonious equilibrium between technology-driven and traditional instructional methods. This human-centered approach to technology ensures that it serves as a complementary tool, enriching established instructional practices rather than replacing them [119]. These activities should be infused with appropriate instructional methodologies that seamlessly align with predetermined learning objectives and guiding principles. This integration has the potential to improve the effectiveness of immersive technology-driven writing interventions. Furthermore, prioritizing learner-centered instructional design is crucial. By tailoring immersive technology-based activities to cater to individual needs, preferences and values, more engaging and effective experiences can be cultivated for teachers [120] and learners [121].

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Changqin Huang received the Ph.D. degree in Computer Science and Technology from Zhejiang University, China, in 2005. He completed two Postdoctoral Fellowship positions with the ECNU-TCL Joint Workstation on Educational Technology and the Sun Yat-sen University on Computer Science and Theory. Dr. Huang had completed visiting research at University of California Irvine, USA, in 2011, and La Trobe University, Australia, in 2018. He is currently a Distinguished Professor with Zhejiang Normal University, China, and also the director of the Key Laboratory of Intelligent Education Technology and Application of Zhejiang Province, China. His research interests range from Big Data in Education to Machine Learning and Intelligent Education. He has published several papers in prestigious journals in Computer Science and Educational Technology, including IEEE TPAMI, Computers & Education, IEEE Transactions on Learning Technologies, Computers in Human Behavior, British Journal of Educational Technology, Educational Technology & Society, etc. He acted as PI for many projects related to AI and Its Applications in Education.

Dr. Huang is a Guangdong Specially-Appointed Professor (Pearl River Scholar). He serves as an Associate Editor of IEEE Transactions on Learning Technologies.

Yuting Chen is presently engaged in pursuing her Ph. D. degree in the Key Laboratory of Intelligent Education Technology and Application of Zhejiang Province, at Zhejiang Normal University, China. She has published several papers in the domains of Education and Educational Research, including Computers & Education, British Journal of Educational Technology, Education and Information Technologies, etc. Her current research interests include immersive technology-enhanced writing education, learning sciences and technologies, VR/AR/XR in education, etc.

Ming Li is currently a “Shuang Long Scholar” Distinguished Professor at the Key Laboratory of Intelligent Education Technology and Application of Zhejiang Province, Zhejiang Normal University, China. He received his PhD degree from the Department of Computer Science and IT at La Trobe University, Australia, in 2017. He completed two Postdoctoral Fellowship positions with the Department of Mathematics and Statistics, La Trobe University, Australia, and the Department of Information Technology in Education, South China Normal University, China, respectively. He has published in top-tier journals and conferences, including IEEE TPAMI, Artificial Intelligence, Computers & Education, British Journal of Educational Technology, Education and Information Technologies, Australasian Journal of Educational Technology, NeurIPS, ICML, DCAI, etc. He is a regular reviewer for top journals including IEEE TLT, British Journal of Educational Technology, Education and Information Technologies, etc.

Dr. Li is an Associate Editor of Neural Networks, Applied Intelligence, Softcomputing, and Neural Processing Letters.

Qing Ma received her Ph.D. in applied linguistics at the University of Louvain, Belgium, in 2007. She is an associate professor at the Department of Linguistics and Modern Language Studies, The Education University of Hong Kong. Her main research interests include second language vocabulary acquisition, corpus linguistics, corpus-based language pedagogy (CBLP), computer assisted language learning (CALL) and mobile assisted language learning (MALL).

She has developed the Parallel EAP Corpora (http://corpus.eduhk.hk/eap/) for research purposes and the Corpus-Aided Platform for Language Teachers (CAP) (http://corpus.eduhk.hk/cap/) for teaching purposes. She is an experimenter of corpus technology in teaching, and passionate English teacher trainer. Recently, she has established a new corpus-based language pedagogy by theorising and empirically testing it that has positively impacted many pre-service and in-service English teachers. She is the associate editor for two journals: International Journal of Computer-Assisted Language Learning and Teaching (IJCALLT); The Journal of China Association for Computer-Assisted Language Learning (ChinaCALL).

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RQ1: What major theoretical foundations are adopted in the research on ITWE?
RQ2: What type of participants are involved in ITWE?
RQ3: What kinds of immersive technologies have been adopted in the research on ITWE?
RQ4: What kinds of research methods have been adopted in the research on ITWE?
RQ5: What are the findings of the research on ITWE?