A Review of Research on the Use of 360-degree Video Technology in Language Learning

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ABSTRACT: The present study is set to systematically review articles on the use of 360-degree video technology in language learning. The study selected and reviewed twenty-four articles in the following aspects: (1) tools related to 360-degree video technology; (2) languages and skills involved; (3) theories and pedagogical approaches in reviewed articles; (4) methodology of reviewed studies; (5) applications of 360-degree video technology to language learning; (6) reported findings; and (7) reported problems in reviewed studies. The results demonstrated that the tools related to 360-degree video technology can be grouped according to the following three ways of using them: (1) creating or editing videos/images, (2) obtaining videos/images, and (3) viewing videos/images. The participants in most studies recorded or edited 360-degree videos to develop their own learning content, rather than using existing ones. In most studies, the participants used head-mounted displays (HMDs) to view 360-degree videos and low-cost HMDs were used more frequently. Scholars often focused on English and Chinese, and they targeted speaking and writing skills in their research. Various theories were used to frame research and the embodied cognition theory was the most popular. The most commonly used pedagogical approach was task-based learning. Fewer studies focused on students from primary or junior school. Many studies lasted for more than one month. Different language skills were mainly measured using scales or tests. Findings related to learning outcomes, learners' perceptions of using 360-degree video technology and motivation were most frequently reported in the reviewed studies. Finally, problems related to methodology, technology implementation and learning process were identified in the reviewed studies and they are reported in the present research. Based on the results, several suggestions were made and implications derived.

Keywords: 360-degree video technology, Language learning, Review

1. Introduction

360-degree video technology, also called spherical video-based virtual reality (Ye et al., 2021), refers to technology that helps create and watch 360-degree videos and images. Such videos or images can be created by using 360-degree cameras (Rupp et al., 2019). 360-degree videos or images can be viewed by using a smartphone, tablet, computer or head-mounted display (Snelson & Hsu, 2020). Viewers can pan and tilt the phone or use the mouse or the keyboard arrows when using a computer to choose what they want to see. When using HMD, a viewer can turn the head to control the viewing direction (Repetto et al., 2021; Rupp et al., 2019).

To date, 360-degree video technology has been widely applied in various domains of knowledge, e.g., medical education and healthcare (Fukuta et al., 2021; Zulkiewicz et al., 2020), science (Wu et al., 2021), language learning (Huang et al., 2020; Repetto et al., 2021), and sports (Kittel et al., 2019). Researchers explained that 360-degree video technology creates such learning environments in which ethical principles can be maintained and problems related to time and space can be overcome (Concannon et al., 2019). Furthermore, such environments can help virtually experience dangerous situations and increase physical accessibility (Geng et al., 2021). For example, in the study by Herault et al. (2018), medical students learned how to treat patient trauma and to communicate with patients and their relatives effectively in authentic situations created by 360-degree video technology. In the study by Li et al. (2012), students learned about tower crane dismantling (i.e., one of the most dangerous activities in the construction industry) and practiced their skills using 360-degree video technology. Wu et al. (2021) explored the effects of applications of 360-degree video technology to scientific inquiry instruction on learners' problem-solving abilities. Liu et al. (2020) employed 360-degree video technology and cyclists watched them to study sidewalks and paved shoulders. The results reported by scholars such as knowledge gain or acquisition of certain skills were positive in most cases.

Scholars attempted to review existing studies on 360-degree video technology and their applications to assist learning and instruction. Shadiev et al. (2021a) systematically reviewed fifty-two research articles on 360-degree video technology and its applications in the field of education published between 2015 and 2020. They focused

on exploring tools used in the reviewed articles, theories used in reviewed articles, methodologies that were applied by researchers and reported findings. Pirker and Dengel (2021) carried out a systematic review of sixty-four research articles to explore the potential of 360-degree video technology for education. Pirker and Dengel (2021) discussed the use cases, advantages, and limitations of 360-degree video technology in their study. Snelson and Hsu (2020) reviewed twelve research articles on 360-degree video technology applications in education published between 2017 and 2019. The scholars focused on the extent and nature of research on the educational use of 360-degree video technology and the benefits or drawbacks of applications in reviewed studies.

The overview of related review studies showed that they all focus on applications of 360-degree video technology in education in general. That is, there are no studies that explore the use of 360-degree video technology in specific domain knowledge. Therefore, educators and researchers need to address this gap in the literature. So we make the first step in this direction, and as experts in technology-assisted language learning field we carry out the present research to explore the use of 360-degree video technology in language learning by systematically reviewing related research articles.

To begin with, 360-degree video technology has been recognized by scholars as a potential tool to assist language learning. In real life, language learners often lack the authentic language learning environment to practice target languages (Shadiev & Yu, 2023). Fortunately, 360-degree video technology, as one of the types of virtual reality, can provide them with a realistic learning environment because 360-degree video is generated with real-world footage (Snelson & Hsu, 2020). That is, an authentic environment created by 360-degree video technology enables learners to feel immersed and sense of presence in a real language learning environment (Huang et al., 2020). Unlike traditional 3D animation-based virtual reality with complex techniques to develop and expensive cost, 360-degree video technology is affordable and easy to use by instructors and language learners in school settings (Huang et al., 2020). For example, there are many studies in which teachers and students created their own 360-degree video and image content and then used it in the language learning process (Chen & Hwang, 2020; Nobrega & Rozenfeld, 2019).

The literature on 360-degree video technology-assisted language learning is growing, however, as we mentioned earlier, there are no studies that systematically reviewed them. For example, Peixoto et al. (2021) and Parmaxi (2023) focused more on language learning assisted by immersive VR created by using computer-based 3D technology. Dhimolea et al. (2022) suggested that VR can be low- (LiVR) and high-immersive (HiVR). Users experience LiVR on a flat screen and interact with VR content using a mouse or keyboard. On the other hand, users experience HiVR using HMD and interact with content by using the buttons on HMD, a controller, or haptic systems. HMD presents an artificial environment that replaces or replicates users' real-world surrounding contexts so convincingly that users perceive the created environment as being spatially realistic and fully engage with it (Shadiev & Li, 2023). Compared to LiVR, HiVR provides higher levels of immersion. Different technologies can be used to create HiVR; for example, computer-based 3D technology or 360-degree video technology (Kim et al., 2022). These two technologies are different from each other in terms of cost, authenticity, presence and flexibility (see Shadiev et al., 2021a for more details). For example, 360-degree video technology presents content recorded by a camera, so objects, people, and scenes in virtual reality look the same as they are in the real world. For this reason, the degree of authenticity is higher and the cost is lower for virtual reality created by 360-degree video technology.

Therefore, the present review study goes beyond existing studies. First, the scopes of the review studies are different, i.e., previous studies explored PC-based immersive VR or they focused on education in general. In contrast, our study specifically focuses on the usage of 360-degree video technology in language learning context. Since 360-degree video technology has become popular and is being used in language learning in recent years, it is necessary to conduct this review study to fill the existing gap in. Second, dimensions of review studies are different. We consider some important dimensions that were rarely or not explored at all in other studies, such as pedagogical approaches or applications of 360-degree video technology in language learning. Related studies mentioned that 360-degree video technology is developing fast. Many kinds of this technology exist nowadays, and they can be used in different ways (e.g., not only to watch videos or pictures but also to create learning content as a part of the learning process) (Shadiev et al., 2021a). As we focus on the use of 360-degree video technology in the field of language learning, it is very important to know what languages were involved and what skills were targeted in the reviewed articles. For example, what are the most popular languages and skills in this field, and what languages and skills received little attention. Theories were reported in earlier review studies, but because they focused on education in general, such information may have little relevance to the field of language learning. Similarly, methodologies, findings and reported problems can be different between two contexts, i.e., education in general and language learning. Therefore, the present study is set to provide much needed information that can inform and guide future research. To this end, in the present study, the following

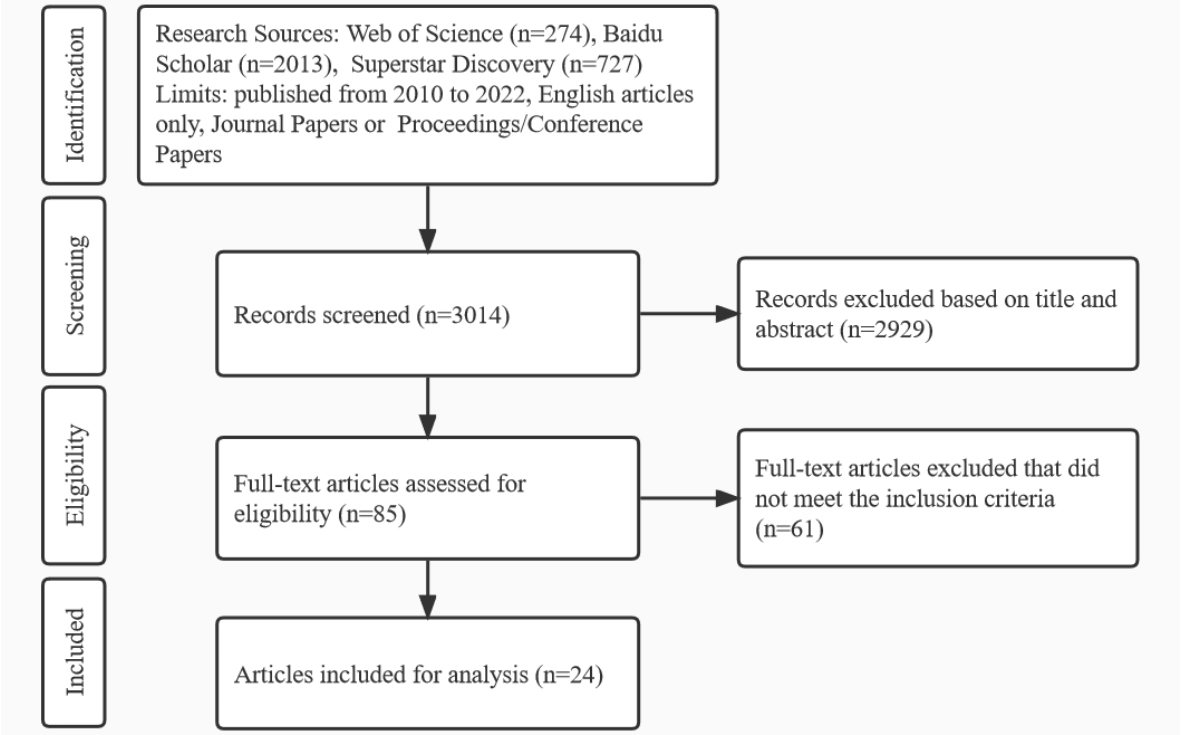
research questions were addressed: (1) What types of 360-degree video technology were used for language learning in reviewed articles? (2) What languages and skills researchers targeted in the reviewed articles? (3) What theories and pedagogical approaches did researchers use in reviewed studies? (4) What methodologies were applied to the reviewed studies? (5) How was 360-degree video technology applied in language learning? (6) What findings did the researchers report? (7) What were reported problems?

2. Method

The present review was carried out using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) methodology. It is a generally accepted approach that helps scholars prepare and report systematic reviews and meta-analyses (Shadiev & Wang, 2022). Articles for the present review were searched on Web of Science, Baidu Scholar and Superstar Discovery databases. Web of Science "is one of the most extensive, popular and relevant research databases for the academic community" (Caseiro & Santos, 2018, p. 8). Web of Science contains about 9,000 kinds of world authoritative journals in many different academic disciplines, and it features rich and powerful search functions (Shadiev & Feng, 2023; Shadiev & Li, 2023; Snelson & Hsu, 2020). We also used such Chinese databases as Superstar Discovery and Baidu Scholar because our search for the articles was carried out in China. These two databases are comprehensive China-based search platforms that provide access to a large amount of local and international literature. Therefore, all these three databases are considered as the most authentic citation databases, offer citation indexing of the social sciences, and have been used in many review studies carried out locally and internationally. Considering the two aspects (i.e., 360-degree video technology and language learning) of the subject of our review, and the definition of 360-degree video technology, we identified search keywords and combined them into the following Boolean search string: "360 video" OR "spherical video" OR "panoramic" OR "virtual tour" OR "360 VR" OR "360 virtual reality" AND "language". The following inclusion criteria were adopted in the selection of research articles: (1) articles published from 2010 to 2022 (March); (2) full-text of articles was available; (3) articles were published in English; (4) in journals or conference proceedings; and (5) articles focused on the applications of 360-degree video technology to assist language learning.

The systematic search process of the study is shown in Figure 1. A total of 3,014 papers were found from the search. After titles and abstracts were screened, 2,929 articles that did not match our selection criteria were removed. After reviewing the main text, 61 articles were excluded, and so, 24 articles were selected for the present review. Two researchers were involved in the search and selection process. They searched for articles, independently examined all of them and selected relevant articles based on the above-mentioned criteria. Once there was a difference during the selection process, the researchers discussed it until their agreement.

Figure 1. The selection process of articles



To answer the research questions of the study, the researchers proposed an analytical framework with the following dimensions: (1) tools—the tools and devices used for language instruction and learning; (2) languages and skills—the target languages and skills that were assisted by technology; (3) theories and pedagogical approaches—the theoretical foundations of studies and the approaches that instructors used for language instruction and learning; (4) methodology—included a research method, participants, study duration and data collection; (5) applications of 360-degree video technology to assist language learning—strategies or steps to assist language learning with the technology; (6) findings— reported results in reviewed studies; (7) problems—reported problems in reviewed studies. The framework provided the basis for reviewing articles and coding their content.

After the articles were selected, the researchers analyzed the content using open coding approach. This approach allowed them to segment information and form categories of information related to the phenomena under consideration. Two researchers were involved in the coding process. They read selected articles, and highlighted and coded their content based on the analytical framework. Then, the codes were grouped into different categories and the properties of each category were identified. Finally, the researchers re-examined the reviewed articles and discussed codes and categories under question or if there were any disagreements between researchers until a consensus was reached.

3. Results

3.1 Tools

The results related to tools are summarized in Appendix 1. The results show that tools can be grouped according to the following three ways of using them: (1) creating or editing 360-degree videos/images, (2) obtaining 360-degree videos/images, and (3) viewing 360-degree videos/images. In terms of creating 360-degree videos/images, 360-degree cameras such as Insta 360 (n = 2), Samsung Gear 360 (n = 2) and LG 360 CAM (n = 1) were used. The results show that researchers also used Google Tour Creator (n = 6) and EduVenture® (n = 6) platforms to edit 360-degree videos/images. In terms of obtaining 360-degree videos/images, in this case, the participants in the reviewed studies obtained 360-degree videos/images that were created and shared by other people on different online platforms. For example, Google Expeditions (n = 4) was the most frequently used platform in the reviewed studies for obtaining 360-degree videos/images. Scholars also used Let's date (n = 1) and video hosting sites such as YouTube (n = 2) and Youku (n = 1) to obtain 360-degree video/image learning content. Tools used for viewing 360-degree videos/images can be divided into head-mounted displays (HMDs), mobile phones, and tablets. With respect to HMD, Google Cardboard (n=9) was the most popular tool in the reviewed studies. Other HMDs such as Samsung Gear VR (n = 1), iHarbort ® VR-G (n = 1), VR BOSS Z5 headsets (n = 1), Oculus VR (n = 1), MI VR (n = 1), and VIOTEK goggle (n = 1) were also used. Scholars did not identify HMDs used in seven studies.

3.2 Languages and skills

Target languages are summarized in Appendix 2. According to the results, scholars targeted English (n = 15) and Chinese/Mandarin (n = 6) more frequently. Learners also learned other languages in the reviewed articles, e.g., French (n = 1), German (n = 1) and Korean (n = 1). The results related to skills are reported in Appendix 3. Speaking (n = 9), writing (n = 6), vocabulary (n = 3), listening (n = 2), and reading (n = 1) skills were concerned by researchers in the reviewed studies. Some studies focused on one language skill only and some studies on more than one skill. Other skills such as intercultural competence (n = 3) and intracultural knowledge (n = 1) were also targeted in the reviewed studies. No specific skills were indicated in one study.

3.3. Theories and pedagogical approaches

Theories on which the reviewed studies were based are reported in Appendix 4. According to the results, twelve different theories were identified. Embodied cognition theory (n = 3), experiential learning theory (n = 2), situated learning theory (n = 2), cognitive theory of multimedia learning (n = 2) and the hypothetical model of immersive cognition (n = 2) were used in more than two studies whereas the rest theories were used only once. It should be noted that some studies mentioned more than one theory. Besides, there were ten studies in which scholars did not identify any theories. The results related to pedagogical approaches are summarized in Appendix 5. The results show that task-based learning (n = 19) was the most frequently used pedagogical approach. Other

pedagogical approaches such as experiential learning (*n* = 2), a progressive question prompt-based peer-tutoring approach (*n* = 1), problem-based learning (*n* = 1), dyadic learning (*n* = 1), and collaborative learning (*n* = 1) were also reported in the reviewed studies. It should be noted that there were some studies in which researchers used more than one pedagogical approach. In addition, it is worth noting that there are three studies in which pedagogical approaches were not identified.

3.4. Methodology

The research methods used in the reviewed studies are summarized in Appendix 6. The most frequently used methods were experiment/quasi-experiment (*n* = 10) and mixed methods (*n* = 7). Other methods such as quantitative research (*n* = 3), qualitative research (*n* = 1), and action research (*n* = 1) were rarely used in the reviewed studies. In addition, there were two studies in which research methods were not identified. Appendix 7 presents the data related to participants. The data shows that scholars frequently recruited less than fifty (*n* = 15) participants. There were six studies with participants' number between 51 and 100, and two studies with more than 100 participants. One study did not provide the number of participants. The data in Appendix 8 presents academic level of the participants. The participants were college students (*n* = 17), high school students (*n* = 3), junior school students (*n* = 1), primary school students (*n* = 1), and vocational school students (*n* = 1). Participants from different academic levels in a study can be found in a few reviewed articles. Besides, there were two studies where the academic level of participants was not identified. The study duration of the reviewed studies is summarized in Appendix 9. The studies were grouped based on their duration, i.e., more than one month (*n* = 11), from one week to one month (*n* = 5), and less than one day (*n* = 1). Scholars did not indicate the duration of their studies in seven articles. The results related to data collection are summarized in Appendix 10. According to the results, researchers in the reviewed studies frequently used questionnaires/scales (*n* = 18), interviews (*n* = 14), and tests (*n* = 13). Less frequently used instruments were observation (*n* = 6), recordings (*n* = 5), and student reflection (*n* = 4). Besides, there was one study in which data collection method was not identified.

3.5. Applications of 360-degree video technology to assist language learning

The results related to how 360-degree video technology was applied to assist language learning are summarized in Appendix 11. The results are presented with respect to two main aspects: (a) viewing 360-degree videos/images and (b) creating 360-degree videos/images. During viewing 360-degree videos/images, strategies that students used were interacting with video content (*n* = 8), completing relevant learning tasks (*n* = 5), discussion (*n* = 4), oral presentation (*n* = 4), question and answer (*n* = 3), collaboration (*n* = 3), and peer assessment (*n* = 1). In creating 360-degree videos/images, students followed the following steps: drafting scripts (*n* = 3), evaluating and revising scripts (*n* = 2), creating or editing 360-degree video/image (*n* = 8), presenting 360-degree video/image to others (*n* = 2), viewing others' works (*n* = 3), and giving feedback (*n* = 1).

3.6. Findings

Findings reported in the reviewed studies are summarized in Appendix 12. Scholars frequently reported findings related to learning outcomes (*n* = 21), perceptions of using technology (*n* = 12), and motivation (*n* = 7). In addition, scholars reported their findings related to cognitive load (*n* = 3), self-efficacy (*n* = 3), language anxiety (*n* = 3), learning behaviors (*n* = 2), and thinking skills (*n* = 2). Findings related to learning outcomes included speaking performance (*n* = 7), writing performance (*n* = 5), vocabulary performance (*n* = 3), intercultural communicative competence (*n* = 2), listening performance (*n* = 1), reading performance (*n* = 1), intercultural knowledge (*n* = 1), and problem-solving abilities (*n* = 1). Learning behavior included engagement (*n* = 1) and patterns (*n* = 1). Thinking skills included creative thinking tendency (n=1) and critical thinking skills (*n* = 1). The results related to the affordances of 360-degree video technology are summarized in Appendix 13. The results can be divided into the following aspects: creating authentic context (*n* = 22), providing immersive experience (*n* = 20), facilitating language learning (*n* = 12), providing learning content/material (*n* = 11), giving a sense of presence (*n* = 10), enabling interaction with learning content (*n* = 10), increasing motivation (*n* = 5), reducing speaking anxiety (*n* = 3), improving self-efficacy (*n* = 1), and promoting creative tendency (*n* = 1).

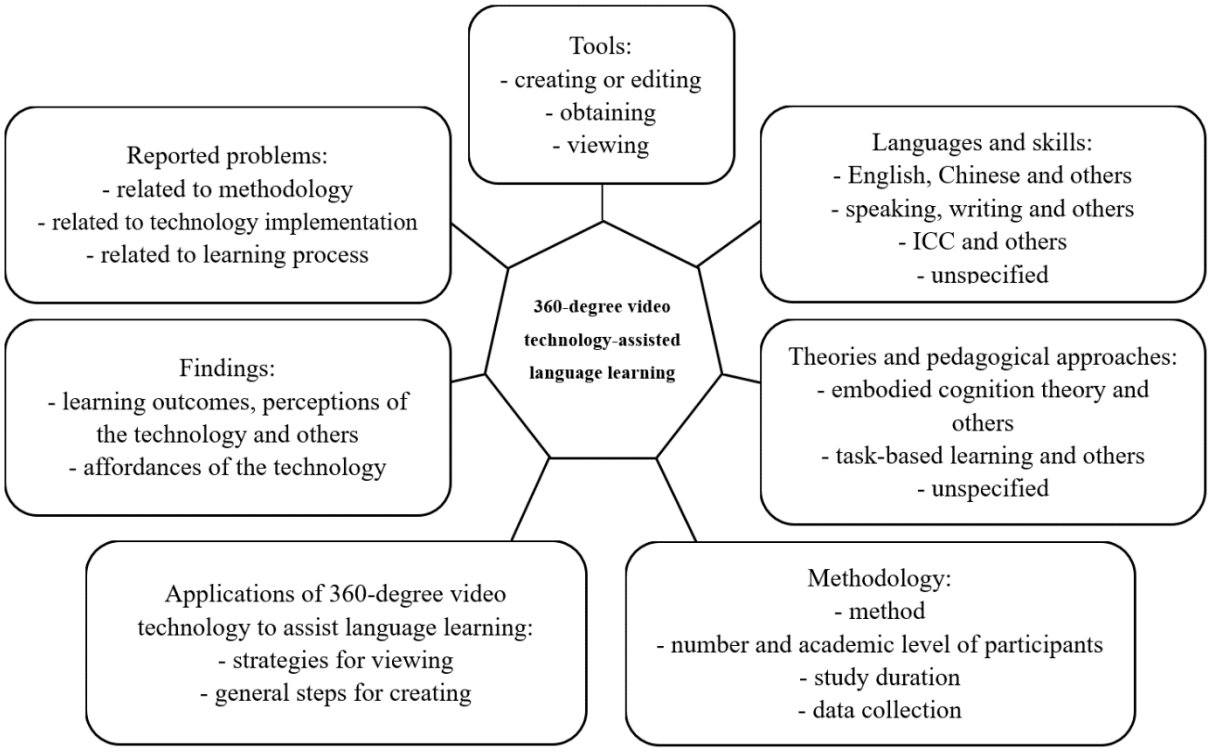
3.7. Reported problems

The problems identified in the reviewed studies can be grouped into the following categories: methodology, technology implementation, and learning process. The most frequently reported methodological problems (Appendix 14) were small sample size (n = 7), data collection strategy (n = 6), short period (n = 5) and lack of a control group (n = 4). In addition, there were other problems such as participants (n = 2), experimental design (n = 1) and lack of formal assessment of English proficiency (n = 1). In the technology implementation category (Appendix 15), the most frequent problems were physical problems (n=9) and technical difficulties (n = 7). Less frequently reported problems included low quality of videos (n = 2), length of videos (n = 2), small number of devices (n = 2), novelty effect (n = 2), unfamiliarity with technology (n = 1), missing texts (n = 1), unsuitable VR goggle size (n = 1) and increased cognitive load (n = 1). The problems related to the learning process (Appendix 16) included lack of adequate feedback from the instructor (n = 2), lack of attention to the learning status of participants (n = 1), lack of consideration of participants' technological competency (n = 1), participants' insufficient understanding of the project instruction (n = 1), participants' inaccurate pronunciation or unfamiliar vocabulary (n = 1) and distraction (n = 1).

4. Discussion

Figure 2 is an overall representation of the results of the present review study in such dimensions as (1) 360-degree video technology, (2) target languages and skills, (3) theories and pedagogical approaches, (4) research methodology, (5) applications of 360-degree video technology to assist language learning, (6) reported findings, and (7) reported problems. Figure 3 includes our suggestions for educators and researchers in the field based on the results.

Figure 2. An overview of our findings

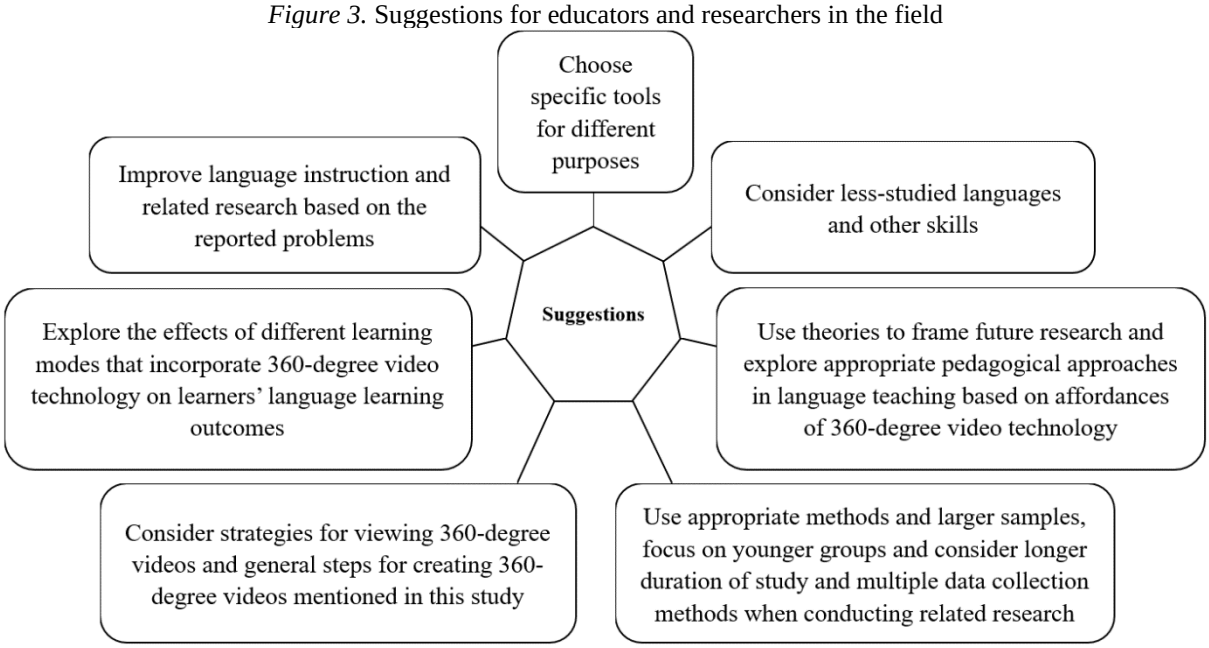


4.1. Tools

The findings revealed that 360-degree video tools can be divided into three categories based on their usage, i.e., creating or editing 360-degree videos/images, obtaining 360-degree videos/images, and viewing 360-degree videos/images. With respect to creating 360-degree videos, researchers or learners often used 360-degree camera because it can capture all perspectives and directions through multiple built-in lenses. Due to its simplicity of operation, not only instructors used it to develop instructional materials, but also language learners to build their own learning content. In terms of obtaining 360-degree videos/images, instructors and language learners could

access and view existing 360-degree videos on various platforms (e.g., YouTube and Youku). Google Expeditions was frequently used to view 360-degree virtual tours. This platform is preloaded with thousands of scenes (Ebadi & Ebadijalal, 2020; Xie et al., 2019), so users can explore built-in sites in a 360-degree mode, such as iconic landmarks, architecture, or historical heritage. As for viewing 360-degree videos/images, language learners used HMDs to view 360-degree videos more frequently than mobile phones or tablets. The possible reason is that HMDs can provide an immersive experience for learners and they are affordable nowadays because of their low cost (e.g., Google Cardboard). Learners can rotate their heads to reorient the video when using HMD. For instance, participants in Shadiev et al. (2021a) used HMDs to watch 360-degree introduction videos created by their foreign partners to know them, their cultural background, and their school life better.

Figure 3. Suggestions for educators and researchers in the field



Our findings suggest that participants created their own 360-degree videos/images more frequently than just simply obtained 360-degree videos/images elsewhere. This implies that participants in more studies did not use existing content but created their own that could better fit their learning or instructional goals and needs. So, educators and researchers need to notice that such work (i.e., to create videos/images) requires substantial time and effort for planning, shooting, evaluating and revising content, and so this should be considered in the future when they plan to design language learning and teaching activities. To edit videos, the participants used Google Tour Creator or EduVenture® frequently because these platforms enabled adding interactive multimedia elements (e.g., text, images or sound) to 360-degree videos to make them more interactive and useful for language learning. However, it is worth noting that Google Expeditions & Tour Creator are no longer available to users since June 30, 2021. However, many of the 360-degree virtual tours from Expeditions can be found on Google Arts & Culture. Educators and researchers can look for more alternative platforms to help them edit 360-degree videos. One such potential platform is WondaVR and it enables adding multimedia elements such as text, image, quiz, score card, etc. As 360-degree video technologies are very popular nowadays, we believe that more editing platforms will emerge in the market in the nearest future.

4.2. Languages and skills

With regard to the target languages, English and Chinese were the most commonly used languages in the reviewed studies. The reason for this may be that they are popular languages and are spoken by a large number of people around the world. Besides, other languages such as French, German and Korean were also used but not so frequently. In future studies, researchers and educators may consider paying attention to lesser-involved languages and explore the potential and effectiveness of applying 360-degree video technology to support learning them.

Our results showed that language output (such as writing and speaking) received more attention. It is possible that the improvement of language output skills is more dependent on the affordances of 360-degree video technology. In traditional writing activities, students may not have a deep perception and experience of writing topics, which allows for limited depth of expression. In addition, speaking can be challenging for language

learners without an authentic target language learning environment. However, 360-degree video technology can help address these limitations, e.g., create an authentic and immersive learning context, which may help learners gain a deeper perception and understanding of writing topics and provide them with a realistic communication environment. For example, Chen and Hwang (2020) adopted 360-degree video technology to provide a realistic sociocultural environment for English-speaking practice. Yang et al. (2021) proposed a system based on 360-degree video technology to set a simulated environment enabling learners to have in-depth perception in descriptive paper writing.

Language input skills also attracted the interest of researchers. In terms of vocabulary learning, 360-degree videos can support language learners to recognize new words through multimodal information. In Repetto et al. (2021), objects and verbs from 360-degree video scenes were listed as target words, and there were voice descriptions in videos to guide students to pay attention to them. With respect to reading skills, Abd Majid et al. (2020) developed reading lessons and questions based on 360-degree video materials. Students were asked to complete a set of reading comprehension activities after viewing video materials. For listening skills development, Ji et al. (2019) provided EFL learners with 360-degree videos to watch and then made them practice their listening skills.

We also found that reviewed studies focused on such abilities as intercultural communicative competence or intercultural knowledge. Perhaps, educators and researchers have considered applications of 360-degree video technology in such intercultural learning contexts because of its technological affordances. For example, in Shadiev et al. (2021b), Chinese students learned English and they were partnered with Indonesian students to practice language skills. 360-degree video technology was used by students to record learning content related to their culture and traditions in English. Students from two countries communicated with each other through exchanging created 360-degree video content. In this way, students were engaged in learning English and culture. Therefore, based on our results, it is suggested that 360-degree video technology can be used to assist language skills development. However, scholars should not limit their focus to language skills only, other abilities can be developed too, e.g., intercultural communicative competence or intercultural knowledge because they are closely related to language skills.

4.3. Theories and pedagogical approaches

The results showed that embodied cognition, experiential learning, situated learning, cognitive theory of multimedia learning, and the hypothetical model of immersive cognition were the most frequently used theories. Scholars based their research on these theories. According to the embodied cognition, cognitive processes are based on sensory-motor experiences (Barsalou, 2008). Repetto et al. (2021) used immersive 360-degree video as learning material where the target words were presented along with visual, auditory and motor inputs, which offered an embodied experience to learners. Experiential learning theory views learning as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). Scholars argued that 360-degree video technology has the potential to enable experiential learning due to its ability to create authentic and immersive experience and that students' knowledge aroused when they had the transformation of experience (Huang et al., 2020; Yang et al., 2021). According to situated learning theory (Lave & Wenger, 1991), knowledge should be learned through full participation in sociocultural practices. In Chen and Hwang (2020), learners could practice speaking in real sociocultural contexts created by the interactive virtual reality environment. For this reason, scholars based their research on the situated learning theory (Chen & Hwang, 2020; Xie et al., 2019).

It is worth noting that scholars in eleven studies did not indicate what theories they used, accounting for nearly half of all review studies. A relevant and sound theory could provide scientific guidance for the application of 360-degree video technology in language learning. It is suggested that researchers indicate theories used in their articles, as this may help readers to better understand the relationship between theoretical foundation, methodology, and results.

The findings showed that several pedagogical approaches were employed. Task-based learning was the most frequently used pedagogical approach. Completing language-related tasks in the real context created by 360-degree video technology can facilitate the development of language skills. Task-based learning emphasizes learning by doing and means that students need to use the target language to complete tasks assigned by teachers. For example, students in Xie et al. (2021) were required to act as museum guides and to introduce a famous attraction in Chinese with the assistance of Google Expeditions. Experiential learning approach was employed in two studies. This approach enables knowledge construction through four learning modes: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). Huang et al. (2020)

and Yang et al. (2021) developed 360-degree video systems for descriptive paper writing based on the four stages. No pedagogical approaches were identified in three reviewed studies. It is suggested that researchers indicate such information explicitly in the future, as the pedagogical approaches can help readers understand the context and reasons for the design of learning activities.

The use of emerging technologies to assist language learning does not necessarily lead to effective learning; what is more important is that educators incorporate effective pedagogical approaches. As 360-degree video technology is an emerging technology, it may take some time to explore how its application can be integrated with pedagogical approaches. Therefore, educators can refer to the aforementioned pedagogical approaches, and adapt them to learning situations. Furthermore, in the future, researchers and educators can explore more appropriate pedagogical approaches supported by technology to facilitate the development of students' language skills.

4.4. Methodology

In terms of the methods employed, experiment/quasi-experiment and mixed methods were the most frequently used ones. Experiment/quasi-experiment involves control of certain factors according to research objectives and hypotheses in order to investigate correlations or cause-effect relationships among research variables. Experiment/quasi-experiments were often used in reviewed studies to examine the effects of learning intervention on language learning outcomes, learners' motivation, cognitive load, or language anxiety. For example, in Chien et al. (2020), a peer-assessment approach was proposed using 360-degree video technology and an experiment was conducted to evaluate the effectiveness of the approach on learning outcomes. The results showed that the peer-assessment approach had better effects on learning outcomes (e.g., speaking performance, learning motivation, critical thinking, and decrease of learning anxiety) compared to the non-peer-assessment approach. Mixed methods usually combine multiple data collection methods, e.g., quantitative and qualitative. Mixed methods can provide a more reliable basis for research findings and explore the reasons behind the findings. In addition, the shortcomings of each single method can be avoided. Lin and Wang (2021) adopted mixed methods research to investigate how the VR creative project might have influenced learners' creative self-efficacy and intrinsic motivation toward VR technology. Quantitative data were collected through the intrinsic motivation inventory and the creative self-efficacy student scale, while qualitative data were mainly collected via an open-ended survey. It is suggested that researchers should choose their research methods properly based on the purpose of their research.

Our results revealed that participants of different numbers and academic levels participated in the reviewed studies. Most studies were carried out with less than fifty participants. This may be due to some objective constraints (e.g., tool or participants' availability or experimental space). University students were frequently recruited in reviewed research. Perhaps this is because such participants have better experience in language learning and they are more experienced in using technology. Furthermore, relatively few studies involved participants from other academic levels, e.g., primary or junior school. This could be due to their limited experience in both language learning and technology usage. Based on our findings, we suggest that future research may consider focusing on younger age participants more. The instructor may consider designing learning activities appropriately. For example, the instructor may create 360-degree videos and provide them for young learners (instead of asking them to create their own videos or searching them online) so that they can learn through experience and observation. Also, young participants need to be instructed and constantly guided by educators or researchers to achieve better language learning outcomes.

The majority of the reviewed studies were conducted for more than one month. One possible reason is that learners need systematic training before using 360-degree video technology, especially in terms of creating and editing 360-degree videos/images. For example, in Yeh et al. (2021), the instructor taught students how to create panoramas and add interactive elements in the first several weeks. Then students watched these videos/images and so training and learning activities increased the length of the study. Another reason is that some of the studies had many language learning activities, which included, for example, both students watching 360-degree instructional videos and students making their own videos. In Chen and Hwang (2020), the participants were required to ask and answer directions with the help of a 360-degree video. After that, they were asked to plan a trip itinerary using Tour Creator, and finally give an oral presentation of their work. What's more, the development of language abilities can't be achieved in a short period of time. As a result, educators and researchers should consider longer periods for their research in order to ensure that students have adequate technical training and language practice.

We found that researchers used a variety of data collection methods. Questionnaires/scales, interviews and tests were the most commonly used ones. Questionnaires/scales are often used in studies because they can facilitate the rapid collection of large amounts of data from lots of participants. For example, Chen et al. (2021b) adopted several questionnaires to measure multiple factors, including those related to students' motivation, self-efficacy, degrees of anxiety, and cognitive load. Interviews were used to collect qualitative data that can support quantitative results subjectively. In many studies, interview data were mainly used to substantiate and explain the quantitative findings. For instance, in Xie et al. (2021), interview content was transcribed and analyzed to provide possible explanations for the quantitative data. Another frequently used data collection method was a test. Usually, tests were used to assess whether learners' performance improved in a particular aspect after the implementation of the instructional intervention, and thus, generally included pre-tests and post-tests for comparison. For example, Shadiev et al. (2021b) conducted a pre-test and a post-test of English at the beginning and end of the semester respectively to investigate the effects of learning activities supported by 360-degree video technology on students' English performance.

Language skills were mainly measured using scales or tests. For speaking, usually, learners' oral performance or speaking training was recorded and then scored by the instructor or their peers according to the speaking rating scale (Chen & Hwang, 2020; Chien et al., 2020; Ebadi & Ebadijalal, 2020). With regard to the ability to write, learners were asked to write essays on a particular topic, which were then scored by the instructor based on an essay assessment scale (Huang et al., 2020; Dolgunsöz et al., 2018; Yang et al., 2021). In addition, for vocabulary measurement, researchers adopted a bilingual translation test to check learners' level of vocabulary mastery (Repetto et al., 2021). Regarding reading skills, learners were required to take a pre-test and post-test of reading questions (Abd Majid et al., 2020). With respect to listening, a listening comprehension test was adopted to measure the learners' comprehension of the authentic material in the experiment (Ji et al., 2019).

Most studies collected data from multiple sources. The reason for this is that such an approach can make results more rigorous and robust. For instance, in Xie et al. (2019), class observations and the audio-recorded discussions between researchers were used to triangulate the data. Therefore, future studies may consider the data collection sources relevant to their research questions or hypotheses. Some data collection techniques that received little attention in reviewed studies can also be considered (i.e., observation, recordings or student reflection). In addition, physiological data can also be collected because it can reflect the objective physiological condition of learners during the language learning process. Finally, future studies may focus on multiple sources of data to make their findings and conclusions more robust.

4.5. Applications of 360-degree video technology to assist language learning

Our review revealed two different ways to use 360-degree video technology in language learning, i.e., students view 360-degree videos/images and students create 360-degree videos/images. Some studies had only one way to use this technology (e.g., Huang et al., 2020), while others included both (e.g., Chen & Hwang, 2020). During viewing process, interacting with video content was a very common strategy and it appeared in different forms, e.g., learners could click on interactive elements in the video/image to get more detailed information. For example, in Monteiro and Ribeiro (2020), after clicking on a text icon, the viewer saw one targeted word appear in context, together with a related image, which could facilitate students' vocabulary learning. Oral presentation strategies were also used. For instance, students in Chen et al. (2021b) were asked to introduce the museum. Question and answer strategy (i.e., a student answering questions asked by his partner) was also used. For example, a learner viewed the 360-degree video with HMD and answered questions about a destination asked by his partner (Lin et al., 2021). In Chen et al. (2021b), students took on the roles of tutors and tutees, with the tutors asking questions and the tutees answering them.

After viewing the 360-degree videos, students were asked to discuss the content of the videos and share their thoughts about it (Abd Majid et al., 2020; Chen et al., 2021a). In addition, participants were asked to complete relevant tasks, such as completing a writing assignment, answering a set of reading comprehension questions, etc., to assist students' learning and test their learning effectiveness. Furthermore, a peer assessment strategy was found in reviewed studies. In Chien et al. (2020), both groups were asked to interact in the VR environment and talk to virtual characters in English. Students' voices and viewed content were recorded. Afterwards, participants in the experimental group viewed the peers' recorded content and gave feedback about their speaking performance. Based on the results, it is suggested that when implementing technology-assisted language learning activities, educators can develop interactive 360-degree VR content as teaching resources, allowing students to learn through experience and interaction. In addition, when designing learning activities, educators can refer to the above-mentioned strategies and choose the appropriate ones for effective instruction and learning.

Another way to use 360-degree video technology is to create content in which language learners can use target languages to describe it. Some steps for creating content may include: drafting scripts, evaluating and revising scripts, creating or editing 360-degree video/image, presenting 360-degree video/image to others, viewing others' works and giving feedback. In some reviewed studies, students were asked to write narrative texts for theirs 360-degree videos in advance (drafting scripts). After that, scripts were submitted to their instructor for evaluation (evaluating scripts). Then, students revised their drafts based on the instructor's comments (revising scripts). Alternatively, students discussed their scripts in groups and then refined them based on discussion and provided feedback. After scripts were finalized, students used a 360-degree camera to shoot videos (creating content). They also used some tools to edit their own 360-degree content, and to add some interactive elements, e.g., text, image or voice (editing content). Finally, students presented their works to others (presenting content). In other cases, students watched their peers' videos and gave feedback (viewing others' works and giving feedback). For example, in Chen and Hwang (2020), students created their VR tours using their own 360-degree photos or images from Google Street View. After that, they published it in Poly and presented content to peers. For future studies, we suggest that students should be trained on how to make and edit 360-degree VR content in advance and provided with a complete production guide. This will help their production process and avoid some technical problems.

4.6. Findings

According to the results, learning outcomes, perceptions of using 360-degree video technology and learning motivation were the three aspects that researchers most often focused on. We found that many studies reported positive language learning outcomes. That is, learners had better performance in certain language skills or other abilities with the intervention of 360-degree video technology or certain learning mode. For example, Repetto et al. (2021) reported that students who received the training with 360-degree videos learned more words than those in the control group. In Chien et al. (2020), students, who learned with the VR-based peer-assessment approach, performed better on English speaking tests than those who learned with the VR-based non-peer-assessment approach.

With respect to perceptions, language learners generally had positive perceptions of using 360-degree video technology. The technology promoted writing immersion (Yang et al., 2021) and enabled learners to practice speaking in an authentic environment (Ebadi & Ebadijalal, 2020) and to experience the sense of "being there" (Lin et al., 2021). The real-life view provided by 360-degree video technology sparked an interest to learn learning material (Xie et al., 2019).

In addition, some studies examined learners' motivation in the context of interventions with different learning modes, and they reported different results. For instance, according to Chen and Hwang (2020), VR increased the learning motivation of the field independent learners more than those of the field dependent learners. Huang et al. (2020) found that the VR learning approach in the descriptive article writing course could not stimulate learners' intrinsic or extrinsic motivation. In Chen et al. (2021b), no significant difference in motivation between students who learned under progressive question prompt-based peer-tutoring and conventional question prompt-based peer-tutoring approaches was found.

These findings provide a reference for future related research. Future research can explore the effects of different learning modes on students' language learning performance. In addition, when considering learners' learning experiences, researchers could use not only questionnaires or scales, but also some physiological measurement instruments to obtain objective data on students' psychological states during learning.

In language learning, affordances of 360-degree video technology are defined as the "application possibilities" due to its qualities or properties. According to the reviewed studies, we found that the affordances of this technology could support language learning. 360-degree video technology can create an authentic environment for language learners to practice their language skills because it can provide scenes filmed in the real world. For example, in Chen and Hwang (2020), the instructor created the campus tour using 360-degree campus images (e.g., campus main entrance or library) from Google Street View's extensive library, allowing learners to experience real-life scenarios. Learners may feel immersed in the environment when wearing HMD. Meanwhile, this technology may provide learners with a sense of presence (Lin et al., 2021), making them feel like they are actually there. In support of language instruction, 360-degree videos can be developed as learning materials and provide learning content for learners. For instance, Repetto et al. (2021) downloaded and edited several 360-degree videos, and extracted the target words to be learned. Thus, learners could learn the target words by watching the video materials. Developers can add interactive information to 360-degree video materials, which may increase interaction between students and learning content (Chen & Hwang, 2020; Chien et al., 2020;

Huang et al., 2020; Yang et al., 2021). When learners click icons in the 360-degree VR environment, some interactive information will pop up, which enables learners to gain additional knowledge. Learners can also interact with people in the 360-degree videos (Berns et al., 2018; Chien et al., 2020; Song, 2019).

Scholars reported about positive effects of integrating 360-degree video technology on language acquisition. For example, Monteiro and Ribeiro (2020) claimed that 360-degree video technology can contribute to foreign language vocabulary learning. Scholars found that learning with 360-degree videos can enhance students' learning motivation (Abd Majid et al., 2020; Chen & Hwang, 2020; Nobrega & Rozenfeld, 2019) and reduce their speaking anxiety (Chen & Hwang, 2020; Chien et al., 2020; Xie et al., 2019). In addition, Huang et al. (2020) reported that the Chinese writing VR learning system can promote students' writing self-efficacy and creative tendency. Therefore, educators and researchers should continue to explore the potential of 360-degree video technology in language teaching and learning based on its affordances.

4.7. Reported problems

The reported problems are related to methodology, technology implementation, and learning process. In terms of methodology, small sample size, data collection strategy, short period, and lack of a control group were the most frequently reported ones. Scholars claimed that the number of participants in the experiment was small, which could affect the generalizability of the results (Chen et al., 2020; Ebadi & Ebadijalal, 2020; Lin & Wang, 2021). There were also problems with the data collection strategy, such as a single source of data (Chen et al., 2021a) and measurement instruments that needed to be improved (Chien et al., 2020; Lin et al., 2021). Such problems may limit the possibility of obtaining more complete experimental results. In addition, since the development of language skills requires a long time and some studies lasted short-term, there could be different findings about learning outcomes from studies that are carried out for a longer time (Chien et al., 2020; Ebadi & Ebadijalal, 2020; Yang et al., 2021). Scholars also argued that there was a lack of a control group (Chen et al., 2021a; Lin & Wang, 2021; Shadiev et al., 2021b; Xie et al., 2019) to compare the differences in learning outcomes in settings with and without the intervention.

The most frequently mentioned technology implementation-related problems were physical discomfort and technical difficulties. In the reviewed studies, scholars reported that some participants experienced physical discomfort when they watched 360-degree videos using HMD (e.g., dizziness, fatigue, and nausea) (Dolgunsöz et al., 2018; Monteiro & Ribeiro, 2020; Lin et al., 2021). Technical difficulties included the lack of internet connectivity, incompatibility of software with specific mobile phones or difficulty in editing videos (Monteiro & Ribeiro, 2020; Chien et al., 2020; DeWitt et al., 2022). These issues negatively affected participants' learning experience and outcomes.

The lack of adequate feedback from the instructor was the most mentioned problem in the learning process. Scholars claimed that the instructor did not provide feedback regularly and timely due to time constraints and big number of students (Ebadi & Ebadijalal, 2020; Xie et al., 2021). In this case, possible problems with students' learning performance were not corrected in time.

These problems should be considered and addressed in future studies. Researchers should expand the sample size, carefully define the data collection strategy, and arrange learning activities to last for longer time. To help learners overcome physical discomfort, it is also possible to expose those learners to 360-degree video before the learning activity. Using HMDs for longer time and more frequently can help them get used to the VR learning environment. Participants should be trained in advance and given guidelines for solving potential technical problems. It is also recommended that researchers and educators integrate feedback in language learning and instruction as well as encourage peer feedback and assistance.

4.8. Similarities and differences with related review studies

Compared with other review studies, some results of the present study are similar and some are different. For example, related studies explored tools that the instructors and students used for watching 360-degree videos (Parmaxi, 2023; Peixoto et al., 2021; Pirker & Dengel, 2021; Shadiev et al., 2021a). However, the present study explored not only tools for viewing 360-degree videos, but also tools for creating, editing and obtaining 360-degree videos. Shadiev et al. (2021a) reported that the most commonly employed theory was situated learning theory, while the present study found that embodied cognition theory was used most frequently in 360-degree video technology-assisted language learning research. In addition, no review studies explored pedagogical

approaches used in reviewed studies. Thus, our study fills the gap in some missing aspects, e.g., theoretical foundation or pedagogical approaches, and extends the current knowledge of this field.

In contrast to the present study, Parmaxi (2023), Peixoto et al. (2021), Pirker and Dengel (2021) and Shadiev et al. (2021a) paid no attention to the research methods used in reviewed studies. Our results showed that the majority of participants were from university, which is in line with the findings of Shadiev et al. (2021a) and Pirker and Dengel (2021). In terms of the duration of the study, we found that most studies were conducted over a month, which is inconsistent with other review studies. For example, Shadiev et al. (2021a) reported that most studies were conducted in less than one day, and Parmaxi (2023) found that the majority of the studies employed VR for about 1-10 tasks or sessions. We found that questionnaires/scales, interviews and tests were the most commonly used data collection method, which was similar to Shadiev et al. (2021a). Parmaxi (2023), Peixoto et al. (2021), and Pirker and Dengel (2021) did not explore how the data was collected in reviewed studies. Therefore, our results can help future researchers determine research methods, numbers and academic level of participants, study duration and data collection methods. Earlier review studies (Parmaxi, 2023; Peixoto et al., 2021; Pirker & Dengel, 2021; Shadiev et al., 2021a) did not focus on applications of 360-degree video technology to assist language learning. Therefore, the present study can provide educators and researchers with some references on strategies that can be adopted in language learning activities.

Previous review studies found that most of the studies reported the potential and benefits of technology in education (i.e., using VR in language education or using 360-degree video technology in education). Our study focused on using 360-degree video technology in language learning specifically. Also, we explored the affordances of 360-degree video technology to assist language learning, which can be a reference for educators and researchers in designing technology-assisted language learning activities.

Regarding the problems, Parmaxi (2023), Pirker and Dengel (2021) and Shadiev et al. (2021a) mentioned some problems or disadvantages related to the application of the technology, whereas this study explored problems not only about technology implementation but also about the methodology of the studies and the learning process. Therefore, the problems reported in our study can help educators to avoid possible issues in language teaching and learning, and can also help future researchers to better conduct relevant research.

5. Conclusion

In this study, we reviewed articles on the applications of 360-degree video technology in language learning based on seven dimensions. A general agreement was found on the potential and effectiveness of using 360-degree video technology for language learning. Therefore, future researchers and educators can refer to our results when designing their language learning activities assisted by 360-degree video technology. In addition, we provide several educational tips for educators and researchers with respect to the seven dimensions covered in the present research that can be helpful in future teaching and learning practices supported by 360-degree video technology. First, the specific tools associated with the 360-degree video technology need to be determined based on the designed language learning activities. The tools can be used for language teaching and learning in such diverse ways as creating, editing, obtaining, and viewing 360-degree videos/images. Therefore, educators and researchers need to decide how their language learners are going to use them based on their teaching goals and objectives, technological capacity, users' skills to use them, and available time. In the future, studies may focus on English and Chinese as well as other languages that received little attention. Language learning activities can focus on diverse skills including language output and input. Furthermore, other closely related skills (e.g., intercultural communicative competence) can be considered too. Theories need to be used to frame future research, thus making it more scientific. As for pedagogical approaches, in addition to task-based learning, educators can make the most out of the affordances of 360-degree video technology to explore new language teaching approaches, such as experiential learning, collaborative learning or problem-based learning. Educators and researchers need to choose appropriate methods based on their research purpose, try to collect multiple data, adopt a larger sample size, and consider their study lasts longer to make it more robust. As 360-degree video technology is an emerging technology, researchers and educators can consider the above strategies and steps in the process of applying it to assist language learning. Future research can explore the effects of different learning modes that incorporate 360-degree video technology on learners' language learning outcomes. Finally, the problems reported by scholars deserve attention in the design of future language learning activities. That is, educators and researchers may get acquainted with reported problems before they design their language learning activities supported by 360-degree video technology. For example, they may first try to understand what are potential problems and how to avoid or address them more efficiently.

The research field on the use of 360-degree video technology in language learning is still emerging. For this reason, we were able to find only twenty-four articles that met our inclusion criteria. This is one important sign for educators and researchers to actively do research in the field to enrich it with theoretical, technological, and pedagogical knowledge. On the other hand, even though our study reviewed only twenty-four articles, it offers current knowledge of the field which may guide educators and researchers in the design and implementation of their future studies.

Three limitations need to be acknowledged regarding our review study: (1) Technologies are emerging and developing very fast, and at the same time, some technologies are outdating or are no longer supported. One example is the Google Expeditions platform which was the most frequently used technology in the reviewed studies. However, it is no longer supported by Google company since 2021. Perhaps, some other tools that are listed in the present review study will be discontinued or outdated in a few years. Some technologies that were listed in the present review study can be robust and affordable enough to last much longer. On the other hand, some new tools may also emerge very quickly and they are not included in this review study. (2) It is possible that using other data sources and inclusion/exclusion criteria for selecting related studies would yield a different number of articles. (3) Finally, some reviewed articles did not include important information related to the aspects covered in the present study, e.g., tools used, theories, pedagogical approaches or methodological details. Therefore, we were unable to collect and report all necessary information. Educators and researchers need to consider these issues in their future research. Furthermore, educators and researchers need to explore the use of 360-degree video technology in other domains of knowledge as there is a huge gap in the literature.

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Appendix

Appendix 1. Tools

Category	Tool	Frequency	Reference
I. Creating or editing 360-degree videos/images with:			
360-degree Camera	Insta 360	2	Shadiev et al. (2021b), Song (2019)
	Samsung Gear 360	2	Ji et al. (2019), Song (2019)
	LG 360 CAM	1	Smith & Townsend (2021)
	Unspecified model	1	Chien et al. (2020)
Google Tour Creator	-	6	Chen et al. (2021c), Chen & Hwang (2020), DeWitt et al. (2022), Huang et al. (2020), Lin & Wang (2021), Nobrega & Rozenfeld (2019)
EduVenture®	-	6	Chen et al. (2021b), Chen & Hwang (2020), Chien et al. (2020), Lin et al. (2021), Yang et al. (2021), Yeh et al. (2021)
II. Obtaining 360-degree videos/images from other sources such as:			
	Google Expeditions	4	Ebadi & Ebadijalal (2020), Monteiro & Ribeiro (2020), Xie et al. (2021), Xie et al. (2019)
	YouTube	2	Abd Majid et al. (2020), Dolgunsöz et al. (2018)
	Youku	1	Yang et al. (2021)
	Let's date!	1	Berns et al. (2018)
	Unspecified source	1	Repetto et al. (2021)
III. Viewing 360-degree videos/images with:			
Head-Mounted Display	Google Cardboard	9	Abd Majid et al. (2020), Chen et al. (2021c), Chen & Hwang (2020), Huang et al. (2020), Lin & Wang (2021), Monteiro & Ribeiro (2020), Song (2019), Xie et al. (2021), Xie et al. (2019)
	Samsung Gear VR	1	Dolgunsöz et al. (2018)
	iHarbort ® VR-G	1	Repetto et al. (2021)
	VR BOSS Z5 headsets	1	Nobrega & Rozenfeld (2019)
	Oculus VR	1	Shadiev et al. (2021b)
	MI VR	1	Shadiev et al. (2021b)
	VIOTEK goggle	1	Song (2019)
	Unspecified model	7	Berns et al. (2018), Chen et al. (2021a), Chen et al. (2021b), DeWitt et al. (2022), Lin et al. (2021), Smith & Townsend (2021), Yang et al. (2021)
Mobile phone	-	16	Abd Majid et al. (2020), Berns et al. (2018), Chen & Hwang (2020), Chien et al. (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Ji et al. (2019), Lin et al. (2021), Lin & Wang (2021), Monteiro & Ribeiro (2020), Repetto et al. (2021), Smith & Townsend (2021), Xie et al. (2021), Xie et al. (2019), Yeh et al. (2021)
Tablet	-	2	Chien et al. (2020), Xie et al. (2019)

Appendix 2. Languages

Language	Frequency	Reference
English	15	Abd Majid et al. (2020), Chen et al. (2021b), Chen et al. (2021c), Chen & Hwang (2020), Chien et al. (2020), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Ji et al. (2019), Lin et al. (2021), Lin & Wang (2021), Monteiro & Ribeiro (2020), Repetto et al. (2021), Shadiev et al. (2021b), Smith & Townsend (2021), Yeh et al. (2021)
Chinese/Mandarin	6	Chen et al. (2021a), DeWitt et al. (2022), Huang et al. (2020), Xie et al. (2021), Xie et al. (2019), Yang et al. (2021)
French	1	Nobrega & Rozenfeld (2019)
German	1	Berns et al. (2018)
Korean	1	Song (2019)

Appendix 3. Skills

Skill	Frequency	Reference
I. Language skills such as:		
Speaking	9	Berns et al. (2018), Chen et al. (2021b), Chen & Hwang (2020), Chien et al. (2020), Ebadi & Ebadijalal (2020), Lin et al. (2021), Nobrega & Rozenfeld (2019), Xie et al. (2021), Xie et al. (2019)
Writing	6	Chen et al. (2021a), Dolgunsöz et al. (2018), Huang et al. (2020), Lin et al. (2021), Nobrega & Rozenfeld (2019), Yang et al. (2021)
Vocabulary	3	Chen et al. (2021c), Monteiro & Ribeiro (2020), Repetto et al. (2021)
Listening	2	Berns et al. (2018), Ji et al. (2019)
Reading	1	Abd Majid et al. (2020)
II. Other skills:		
Intercultural Competence	3	DeWitt et al. (2022), Shadiev et al. (2021b), Song (2019)
Intracultural knowledge	1	Yeh et al. (2021)
III. Unspecified		
-	1	Smith & Townsend (2021)

Appendix 4. Theories

Theory	Frequency	Reference
Embodied cognition theory	3	Chen et al. (2021c), Repetto et al. (2021), Xie et al. (2019)
Experiential learning theory	2	Huang et al. (2020), Yang et al. (2021)
Situated learning theory	2	Chen & Hwang (2020), Xie et al. (2019)
Cognitive Theory of Multimedia Learning	2	Lin et al. (2021), Monteiro & Ribeiro (2020)
The Hypothetical Model of Immersive Cognition	2	Xie et al. (2021), Xie et al. (2019)
The Dual Coding Theory	1	Lin et al. (2021)
Cognitive load theory	1	Ji et al. (2019)
Social learning theory	1	Chien et al. (2020)
Sociocultural theory	1	Lin et al. (2021)
Constructivist learning principle	1	Berns et al. (2018)
Engagement theory	1	Ebadi & Ebadijalal (2020)
Self-determination theory	1	Chen et al. (2021a)
Unspecified	10	Abd Majid et al. (2020), Chen et al. (2021b), DeWitt et al. (2022), Dolgunsöz et al. (2018), Lin & Wang (2021), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Smith & Townsend (2021), Song (2019), Yeh et al. (2021)

Appendix 5. Pedagogical approaches

Pedagogical approach	Frequency	Reference
Task-based learning	19	Abd Majid et al. (2020), Chen et al. (2021a), Chen et al. (2021b), Chen et al. (2021c), Chen & Hwang (2020), Chien et al. (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Huang et al. (2020), Lin et al. (2021), Lin & Wang (2021), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Song (2019), Xie et al. (2021), Xie et al. (2019), Yang et al. (2021), Yeh et al. (2021)
Experiential learning approach	2	Huang et al. (2020), Yang et al. (2021)
PQP-PTVR learning (a progressive question prompt-based peer tutoring approach to VR-enhanced learning)	1	Chen et al. (2021b)
Problem-based learning	1	Chen et al. (2021c)
Dyadic learning	1	Lin et al. (2021)
Collaborative learning	1	Smith & Townsend (2021)
Implicit and explicit strategies	1	Monteiro & Ribeiro (2020)
Unspecified	3	Berns et al. (2018), Ji et al. (2019), Repetto et al. (2021)

Appendix 6. Method

Method	Frequency	Reference
Experiment/ Quasi-experiment	10	Chen et al. (2021c), Chen et al. (2021b), Chen & Hwang (2020), Chien et al. (2020), DeWitt et al. (2022), Huang et al. (2020), Ji et al. (2019), Lin et al. (2021), Repetto et al. (2021), Yang et al. (2021)
Mixed-method	7	Abd Majid et al. (2020), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Lin & Wang (2021), Monteiro & Ribeiro (2020), Shadiev et al. (2021b), Xie et al. (2021)
Quantitative research	3	Berns et al. (2018), Chen et al. (2021a), Yeh et al. (2021)
Qualitative research	1	Xie et al. (2019)
Action research	1	Nobrega & Rozenfeld (2019)
Unspecified	2	Smith & Townsend (2021), Song (2019)

Appendix 7. Number of participants

Number	Frequency	Reference
1-50	15	Abd Majid et al. (2020), Berns et al. (2018), Chen et al. (2021b), DeWitt et al. (2022), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Lin & Wang (2022), Lin et al. (2021), Monteiro & Ribeiro (2020), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Song (2019), Xie et al. (2021), Xie et al. (2019), Yang et al. (2021)
51-100	6	Chen et al. (2021c), Chen & Hwang (2020), Chien et al. (2020), Huang et al. (2020), Ji et al. (2019), Yeh et al. (2021)
> 100	2	Chen et al. (2021a), Repetto et al. (2021)
Unspecified	1	Smith & Townsend (2021)

Appendix 8. Academic level of the participants

Academic Level	Frequency	Reference
College students	17	Abd Majid et al. (2020), Berns et al. (2018), Chen et al. (2021c), Chen et al. (2021b), Chen & Hwang (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Ji et al. (2019), Lin & Wang (2021), Lin et al. (2021), Monteiro & Ribeiro (2020), Shadiev et al. (2021b), Smith & Townsend (2021), Song (2019), Xie et al. (2021), Xie et al. (2019), Yeh et al. (2021)
High school students	3	Chien et al. (2020), Huang et al. (2020), Repetto et al. (2021)
Junior school students	1	Chen et al. (2021a)
Primary school students	1	Yang et al. (2021)
Vocational school students	1	Shadiev et al. (2021b)
Unspecified	2	Ebadi & Ebadijalal (2020), Nobrega & Rozenfeld (2019)

Appendix 9. Study duration

Duration	Frequency	Reference
>1 month	11	Chen & Hwang (2020), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Lin & Wang (2021), Lin et al. (2021), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Smith & Townsend (2021), Xie et al. (2021), Xie et al. (2019), Yeh et al. (2021)
1 week -1 month	5	Chien et al. (2020), DeWitt et al. (2022), Huang et al. (2020), Repetto et al. (2021), Yang et al. (2021)
< 1 day	1	Chen et al. (2021b)
Unspecified	7	Abd Majid et al. (2020), Berns et al. (2018), Chen et al. (2021a), Chen et al. (2021c), Ji et al. (2019), Monteiro & Ribeiro (2020), Song (2019)

Appendix 10. Data collection

Evaluation	Frequency	Reference
Questionnaire/Scale	18	Berns et al. (2018), Chen et al. (2021a), Chen et al. (2021b), Chen et al. (2021c), Chen & Hwang (2020), Chien et al. (2020), DeWitt et al. (2022), Ebadi & Ebadijalal (2020), Huang et al. (2020), Ji et al. (2019), Lin et al. (2021), Lin & Wang (2021), Monteiro & Ribeiro (2020), Nobrega & Rozenfeld (2019), Repetto et al. (2021), Shadiev et al. (2021b), Yang et al. (2021), Yeh et al. (2021)
Interview	14	Abd Majid et al. (2020), Chen et al. (2021b), Chen et al. (2021c), Chien et al. (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Huang et al. (2020), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Song (2019), Xie et al. (2021), Xie et al. (2019), Yang et al. (2021)
Test	13	Abd Majid et al. (2020), Chen et al. (2021b), Chen et al. (2021c), Chen & Hwang (2020), Chien et al. (2020), Dolgunsöz et al. (2018), Huang et al. (2020), Ji et al. (2019), Lin et al. (2021), Monteiro & Ribeiro (2020), Repetto et al. (2021), Shadiev et al. (2021b), Yang et al. (2021)
Observation	6	Ebadi & Ebadijalal (2020), Monteiro & Ribeiro (2020), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Xie et al. (2021), Xie et al. (2019)
Recordings (audio or video)	5	Chen & Hwang (2020), Ebadi & Ebadijalal (2020), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Xie et al. (2021)
Student reflection	4	Lin et al. (2021), Song (2019), Xie et al. (2021), Xie et al. (2019)
Unspecified	1	Smith & Townsend (2021)

Appendix 11. Applications of 360-degree video technology to assist language learning

Category	Example	Frequency	Reference
I. Strategies for viewing 360-degree videos or images			
Interact with video content	Interact with the pop-ups in VR environment by pressing the action button on HMD, click the record button to answer the questions presented by the system, interact with foreign teachers and local students by replying to people	8	Berns et al. (2018), Chen & Hwang (2020), Chien et al. (2020), Huang et al. (2020), Monterio & Ribeiro (2020), Nobrega & Rozenfeld (2019), Song (2019), Yang et al. (2021)
Complete relevant exercise tasks	Complete the related exercise tasks, e.g., complete a writing task or answer a set of reading comprehension after viewing	5	Abd Majid et al. (2020), Chen et al. (2021a), Dolgunsöz et al. (2018), Huang et al. (2020), Yang et al. (2021)
Discussion	Discuss the observations after viewing	4	Abd Majid et al. (2020), Chen et al (2021c), Shadiev et al. (2021b), Song (2019)
Oral presentation	Introduce a specific location in target language with the assistance of 360-degree virtual tour, e.g., museum, a famous attraction	4	Chen et al. (2021b), Ebadi & Ebadijalal (2020), Xie et al. (2021), Xie et al. (2019)
Question and answer	Participants who were watching the 360-degree video practiced giving destination information as they answered detailed questions posed by their partner	3	Chen et al. (2021b), Chen & Hwang (2020), Lin et al. (2021)
Collaboration	Collaborate in pairs to complete learning tasks	3	Chen et al. (2021b), Chen & Hwang (2020), Lin et al. (2021)
Peer assessment	Watch peers' films and conduct peer assessment	1	Chien et al. (2020)
II. General steps for students to create 360-degree videos or images			
Draft scripts	Draft oral scripts	3	Lin & Wang (2021), Shadiev et al. (2021b), Smith & Townsend (2021)
Evaluate and revise scripts	Submit the drafts to the instructor for editing and evaluation, discuss scripts' content in groups	2	Lin & Wang (2021), Shadiev et al. (2021b)

Create or edit 360-degree video/image	Use 360-degree camera to shoot 360-degree video, use Google Tour Creator or EduVenture to edit virtual tour	8	Chen et al. (2021c), Chen & Hwang (2020), DeWitt et al. (2022), Lin & Wang (2021), Nobrega & Rozenfeld (2019), Shadiev et al. (2021b), Smith & Townsend (2021), Yeh et al. (2021)
Present 360-degree video/image to others	Give an oral presentation	2	Chen & Hwang (2020), Nobrega & Rozenfeld (2019)
View others' works	Watch peers' 360-degree VR content, watch partner's video	3	Lin & Wang (2021), Shadiev et al. (2021b), Yeh et al. (2021)
Give feedback	Evaluate peers' videos	1	Yeh et al. (2021)

Appendix 12. Findings

Category	Code	Example	Frequency	Reference
Learning outcomes	Speaking performance	The content and vocabulary of participants' oral presentations when using VR tools scored significantly higher than when not using VR tools.	7	Chen et al. (2021b), Chen & Hwang (2020), Chien et al. (2020), Ebadi & Ebadijalal (2020), Lin et al. (2021), Nobrega & Rozenfeld (2019), Xie et al. (2021)
	Writing performance	The VR system could promote students' writing performance for content and appearance.	5	Dolgunsöz et al. (2018), Huang et al. (2020), Lin et al. (2021), Nobrega & Rozenfeld (2019), Yang et al. (2021)
	Vocabulary performance	Students who underwent the training with 360-degree videos learned more words.	3	Chen et al. (2021c), Monteiro & Ribeiro (2020), Repetto et al. (2021)
	Intercultural communicative competence	360-degree video technology - supported intercultural learning activities improved students' intercultural communicative competence.	2	DeWitt et al. (2022), Shadiev et al. (2021b)
	Listening performance	The learners who watched 360-degree video journalism did worse in English listening comprehension test.	1	Ji et al. (2019)
	Reading performance	The use of 360-degree video in reading lesson help students understand the reading text better.	1	Abd Majid et al. (2020)
	Intracultural knowledge	Students developed better intracultural awareness through the features of VR technology including panorama, audio, interaction, and structuring.	1	Yeh et al. (2021)
	Problem-solving performance	Exposing students to PBL contexts can develop students' problem-solving performance.	1	Chen et al. (2021c)
Perceptions of using 360-degree video technology	-	The real-life view VR tools offered an authentic context for Chinese language learning, sparked interest in the virtually presented locales, and encouraged students to further explore the target culture.	12	Abd Majid et al. (2020), Berns et al. (2018), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Huang et al. (2020), Lin et al. (2021), Lin & Wang (2021), Monteiro &

				Ribeiro (2020), Repetto et al. (2021), Shadiev et al. (2021b), Xie et al. (2019), Yang et al. (2021)
Learning motivation	-	The use of 360-degree video in reading lesson increased students' motivation.	7	Chen et al. (2021b), Chen et al. (2021c), Chen & Hwang (2020), Chien et al. (2020), Huang et al. (2020), Lin & Wang (2021), Nobrega & Rozenfeld (2019)
Cognitive load	-	The EFL learners who watched 360-degree video journalism had higher cognitive load.	3	Chen et al. (2021b), Huang et al. (2020), Ji et al. (2019)
Self-efficacy	-	VR learning system can enhance students' descriptive article writing self-efficacy.	3	Chen et al. (2021b), Huang et al. (2020), Lin & Wang (2021)
Language Anxiety	-	The peer-assessment-based on 360-degree video technology can reduce students' English learning anxiety.	3	Chen et al. (2021b), Chen & Hwang (2020), Chien et al. (2020)
Learning behaviors	Learning behavior engagement	The degree of learning behavior engagement did not show any difference between the experimental and control groups.	1	Yang et al. (2021)
	Learning behavioral patterns	The tutors and tutees in the experimental group had more interactions and more meaningful communication.	1	Chen et al. (2021b)
Thinking skills	Creative thinking tendency	The learning system can promote students' higher order creativity tendency.	1	Huang et al. (2020)
	Critical thinking skills	The peer-assessment based on 360-degree video technology can enhance students' critical thinking skills.	1	Chien et al. (2020)

Appendix 13. Affordances of 360-degree video technology

Affordance	Frequency	Reference
Create authentic context	22	Abd Majid et al. (2020), Berns et al. (2018), Chen et al. (2021a), Chen et al. (2021b), Chen & Hwang (2020), Chien et al. (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Huang et al. (2020), Ji et al. (2019), Lin et al. (2021), Lin & Wang (2021), Monteiro & Ribeiro (2020), Nobrega & Rozenfeld (2019), Repetto et al. (2021), Shadiev et al. (2021b), Song (2019), Xie et al. (2021), Xie et al. (2019), Yang et al. (2021), Yeh et al. (2021)
Provide immersive experience	20	Abd Majid et al. (2020), Berns et al. (2018), Chen et al. (2021a), Chen et al. (2021b), Chen et al. (2021c), Chen & Hwang (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Huang et al. (2020), Ji et al. (2019), Lin et al. (2021), Lin & Wang (2021), Monteiro & Ribeiro (2020), Nobrega & Rozenfeld (2019), Repetto et al. (2021), Shadiev et al. (2021b), Song (2019), Xie et al. (2021), Xie et al. (2019), Yang et al. (2021)
Facilitate language learning	12	Abd Majid et al. (2020), Chen et al. (2021c), Chen & Hwang (2020), Ebadi & Ebadijalal (2020), Huang et al. (2020), Lin et al. (2021), Monteiro & Ribeiro (2020), Nobrega & Rozenfeld (2019), Repetto et al. (2021), Shadiev et al. (2021b), Xie et al. (2021), Yang et al. (2021)
Provide learning content /material	11	Abd Majid et al. (2020), Chen et al. (2021b), Chen & Hwang (2020), Dolgunsöz et al. (2018), Huang et al. (2020), Ji et al. (2019), Lin et al. (2021), Monteiro & Ribeiro (2020), Repetto et al. (2021), Song (2019), Yang et al. (2021)
Give a sense of presence	10	Abd Majid et al. (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Ebadi & Ebadijalal (2020), Huang et al. (2020), Lin et al. (2021), Monteiro & Ribeiro (2020), Xie et al. (2021), Xie et al. (2019), Yang et

		al. (2021)
Enable interaction with learning content	10	Berns et al. (2018), Chen & Hwang (2020), Chien et al. (2020), Huang et al. (2020), Lin et al. (2021), Monteiro & Ribeiro (2020), Nobrega & Rozenfeld (2019), Song (2019), Yang et al. (2021), Yeh et al. (2021)
Increase motivation	5	Abd Majid et al. (2020), Chen et al. (2021c), Chen & Hwang (2020), Nobrega & Rozenfeld (2019), Yang et al. (2021)
Reduce speaking anxiety	3	Chen & Hwang (2020), Chien et al. (2020), Xie et al. (2019)
Improve self-efficacy	1	Huang et al. (2020)
Promote creative tendency	1	Huang et al. (2020)

Appendix 14. Problems related to methodology

Problems	Description	Frequency	Reference
Small sample size	The number of participants is small	7	Chen et al. (2021c), Ebadi & Ebadijalal (2020), Lin & Wang (2021), Nobrega & Rozenfeld (2019), Xie et al. (2021), Xie et al. (2019), Yang et al. (2021)
Data collection strategy	Insufficient data for analysis or measure instruments used need to be improved, etc.	6	Chen et al. (2021c), Chen et al. (2021b), Chen et al. (2021a), Chien et al. (2020), Lin et al. (2021), Xie et al. (2019)
Short period	The time of the learning activities is short	5	Chien et al. (2020), Ebadi & Ebadijalal (2020), Huang et al. (2020), Lin et al. (2021), Yang et al. (2021)
Lack of a control group	There was only one experimental group in the study	4	Chen et al. (2021a), Lin & Wang (2021), Shadiev et al. (2021b), Xie et al. (2019)
Problems related to participants	Single group of participants such as single major of participants, single educational level of participants	2	Chen et al. (2021c), Dolgunsöz et al. (2018)
Experimental design	Such as an unbalanced partnership in intercultural learning activity	1	Shadiev et al. (2021b)
Lack of formal assessment of English proficiency	students have not been formally assessed on English proficiency prior to the beginning of the study	1	Repetto et al. (2021)

Appendix 15. Problems related to technology implementation

Problems	Description	Frequency	Reference
Physical discomforts	Such as dizziness, eye fatigue and nausea	9	Chen & Hwang (2020), DeWitt et al. (2022), Dolgunsöz et al. (2018), Lin et al. (2021), Abd Majid et al. (2020), Monteiro & Ribeiro (2020), Repetto et al. (2021), Song (2019), Xie et al. (2019)
Technical difficulties	Such as lack of internet connectivity, slow internet speed, incompatibility of software with specific mobile phones, difficulty to edit videos and different volumes of software	7	Chien et al. (2020), DeWitt et al. (2022), Ebadi & Ebadijalal (2020), Monteiro & Ribeiro (2020), Song (2019), Xie et al. (2021), Xie et al. (2019)
Low quality of videos	The quality of videos is low and thus participants encountered visibility issue	2	Dolgunsöz et al. (2018), Abd Majid et al. (2020)
Length of videos	The length of videos should be shorter	2	Chien et al. (2020), Shadiev et al. (2021b)
A small number	The number of devices (e.g., cameras) is	2	Nobrega & Rozenfeld (2019),

of devices	small		Smith & Townsend (2021)
Novelty effect	The higher questionnaire score for the experimental group might be due to participants' novelty for new technology	2	DeWitt et al. (2022), Huang et al. (2020)
Unfamiliarity with the technology	Participants' insufficient knowledge about VR led to difficulties in using the technology	1	Lin & Wang (2021)
Missing the text shown	Participants may miss the text shown because they are focused on another part of the video	1	Abd Majid et al. (2020)
Unsuitable VR goggle size	The size of VR goggle is unsuitable	1	Dolgunsöz et al. (2018)
Increased cognitive load	The high cognitive load in the VR environments	1	Ji et al. (2019)

Appendix 16. Problems related to learning process

Problems	Description	Frequency	Reference
Lack of adequate feedback from instructor	The instructor was not able to provide a lot of feedback to participants during their presentations due to the constraint of class time	2	Ebadi & Ebadijalal (2020), Xie et al. (2021)
Lack of attention to the learning status of participants	The researchers needed to pay attention to the users' learning status during the learning process	1	Chen et al. (2021b)
Lack of consideration of participants' technical competency	Some factors of learners' technology competency were not adequately considered	1	Chen & Hwang (2020)
Participants' insufficient understanding of the project instruction	Participants did not fully understand the project instructions	1	Lin & Wang (2021)
Participants' inaccurate pronunciation or unfamiliar vocabulary	Inaccurate pronunciation or unfamiliar vocabulary hindered followers' interactions with the presenters	1	Xie et al. (2019)
Distraction	Participants become absorbed in the technology at the expense of language use	1	Ebadi & Ebadijalal (2020)