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# Immersive Virtual Reality for Foreign Language Education: A PRISMA Systematic Review

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**ABSTRACT** Immersion is a proven method of learning a foreign language and using Virtual Reality to achieve that immersion has high potential educational benefits. However, there are no recent systematic reviews that combine both foreign language education and immersive Virtual Reality. This systematic review aims to identify features, educational methods, technologies, and gaps of immersive virtual reality for foreign and second language education. PRISMA method was followed to carry out the systematic review. From the analysis of the results, two main conclusions were drawn. Firstly, the relation between immersive Virtual Reality and foreign language learning is quite positive, particularly when compared with conventional pedagogical practices. Not only that, the connection between immersive Virtual Reality and the user's motivation and satisfaction is also quite positive. Lastly, limitations such as the low sample of studies and gaps in the literature are addressed, and directions for future work and the area's progress are pointed out.

**INDEX TERMS** Virtual reality, foreign language, second language, education, learning.

## I. INTRODUCTION

Over time, several definitions were proposed concerning Virtual Reality (VR) which causes it to be somewhat challenging to define. Nonetheless, VR is often referred to as a simulation of a three-dimensional virtual environment (VE), generated by a computer, in which the person can interact with the said environment with, for example, a helmet with an integrated screen. According to Fuchs *et al.* [1], the goal of virtual reality is to enable sensory-motor and cognitive activities in a person or a group, while they are immersed in a digitally created environment. This can be imaginary or a simulation concerning the real world.

VR systems can be classified into three major categories: non-immersive, semi-immersive and immersive [2], [3]. Non-immersive, sometimes designated desktop VR, is the least immersive and least expensive of the VR systems and places the user in the three-dimensional VE and allows interaction but only by means of a traditional graphic workstation with

a monitor, keyboard and mouse [2]–[4]. Semi-immersive VR attempts to preserve a high level of immersion while keeping the simplicity and comfort of the desktop VR or utilising some physical model [3], [5]. Immersive VR (iVR) is often the most expensive and gives the highest level of immersion. This system lets the user go through the virtual world as if it were real and authentic, providing a higher sense of Presence, the feeling of “being there” [3], [6]. Immersion is critical to induce a low level of cybersickness and high levels of Presence [7], the very defining experience of VR [8].

Given the nature of VR technologies, their use has been very beneficial in diverse areas of application such as education. One of the most critical factors on foreign language education is to be regularly exposed to the language being learned [9]. The primary approach usually consists of listening first for a long time and then be asked to speak. However, it must be ensured that whoever is learning is motivated and relieved of the stress and boredom by using, for example, multimedia content [10]. VR adapts traditional multimedia content and significantly raises the user's level of immersion, particularly at the level of visual perception in learning [11].

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As immersion is a proven method of learning a second language [12], using virtual reality to attain immersion provides potential educational benefits.

Although immersive technologies are becoming widespread and can be a game-changer, VR cost reduction and development are relatively recent, and consequently, there are only a small number of studies that have previously investigated the advantages of iVR in foreign or second language education, being them essentially theoretical studies. [13]. The investigation of the VR technologies in foreign language teaching is still largely unexplored [14], [15]. iVR system can be beneficial by bringing language learners closer to the language culture and create realistic simulations that would not even exist in the physical world. Solak and Erdem [16] in 2015 presented a meta-analysis study on VR and second language learning. However, due to the broad definition and categories of VR, the mentioned study only considers a few aspects considered in this systematic review (SR), that is, authentic immersive VR. Notwithstanding, this meta-analysis revealed that the capacities of VR had not been adequately used in foreign language education - acknowledging their review period.

In 2002, Liu *et al.* [17] did a ten-year literature review from 1990 to 2000, on computer use second and foreign language learning. This study reviewed a total of 267 papers sourced from refereed print-based journals and ERIC documents. This research shows that, in that period, the advantages of computer technology use in foreign and second language learning were confirmed and well received. Also, teachers and educators supported this technology as an effective instructional tool. Other findings suggest that “the use of visual media supported vocabulary acquisition and reading comprehension and helped increase achievement scores”.

Chiu [18], in 2013, did a meta-analysis on Computer-assisted language learning vocabulary instruction by examining papers from 2005 to 2011, and collecting data from the following databases: Chinese Periodical Index, Dissertation and Thesis Abstract System of Taiwan, IEEE Xplore, ERIC and Google Scholar. Their study observed that overall, computer-assisted language learning in second language vocabulary revealed positive effects with a medium effect size.

In 2014, Golonka *et al.* [19] evaluated over 350 studies for the effectiveness of technology use in foreign language learning and teaching. Despite the high volume of work published on this topic, there is a lack of evidence about its efficacy. Nonetheless, there is a couple of topics where technology had a positive impact: assisted pronunciation training and in the use of foreign language learning chat. It improved pronunciation and provided feedback effectively. Their investigation also reported moderate support for “claims that technology enhanced learners’ output and interaction, affect and motivation, feedback, and metalinguistic knowledge”.

Nevertheless, there are some literature reviews of different areas of education which covered the genuine VR concept.

In 2011, Mikropoulos and Natsis [20] did a ten-year review of empirical research from 1999 to 2009 on the educational applications of Virtual Reality. This study analysed a total of 53 papers collected from the following databases: ERIC, JSTOR, PapersFirst, IEEE, WilsonWeb, Elsevier, InformaWorld, Mary Ann Liebert, SpringerLink, Wiley Interscience, and MIT. This investigation concluded that most of studies were conducted in schools and colleges, suggesting VR as a full-fledged technology for pedagogical use. It also acknowledges that visual representations prevail, indicating a need for additional investigation on the other multisensory interaction channels. Presence emerged from this research as a significant variable to be considered, although needing further and intensive studies.

Other work that reports on the reviews of VR and Education was published in 2015 by Freina and Ott [21]. The authors reported on a 2013 and 2014 scientific literature and identified the advantages and potentials about the use of iVR and head-mounted displays (HMD) in education. After searching the academic databases Web of Knowledge, Google Scholar, and Scopus, this study analysed 93 papers. This review reported that iVR had been mostly used in university or pre-university learning students or adult training, and a very small number referred to younger elementary students. Most of the selected papers are from the education area. Both university education and adult training show a significant percentage of papers reporting applications in the medical fields. The authors explain that the primary motivation for using VR is that it allows living and experimenting with situations that cannot be accessed physically.

Kavanagh *et al.* [22] presented two separate thematic analyses in 2017. The first study investigated the applications and reported motivations provided by educators in academic literature for producing virtual reality educational systems and the second detailed difficulties associated with that sort of development. They examined the following five databases: ACM Digital Library, IEEE Xplore, Web of Science, ERIC, and Scopus. The 99 selected papers showed that the bulk of studies use VR to increase the students’ motivation. Their analysis also showed tendencies to apply VR only in specialised situations demanding realistic simulations or training purposes. Concerning reported issues and limitations of VR systems, there are problems with the cost; training; software and hardware usability accounting for much of the data, especially software usability issues.

This SR is a follow-up of other studies carried out by the research team in this area of the use of iVR for teaching and learning foreign languages, where it was identified the need for broader research in this area. Since there are only a few numbers of examinations in the area concerning iVR, the thought of analysing studies and researches and their techniques and approaches regarding immersive VR in foreign language education seemed a legitimately good idea. The objectives of this SR are the following:

- Identify the features of iVR systems for foreign and second language education;
- Identify the educational methods used, the target audience and language level;
- Analyse the impact of iVR in foreign and second language education;
- Identify the gaps in the literature;
- Provide future research directions.

This systematic review aims to help researchers, educators, and teachers quickly review the potential benefits and research perspectives regarding the use of iVR systems for foreign language learning.

## II. METHODS

This systematic review was conducted using the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) methodology, which is a recognised approach from Liberati *et al.* [23]. The review was conducted from March 2020 to January 2021.

### A. ELIGIBILITY CRITERIA

Eligibility criteria are essential in assessing the validity, applicability, and comprehensiveness of a review [23]. It is worth noticing that the exclusion criteria were designed to be incremental. For example, if the article was rejected by the exclusion criteria 1, the article is automatically excluded, and no further verification of additional exclusion criteria is done.

#### Inclusion criteria (IC)

**IC-1** - The paper has one of the following terms in the title, abstract or keywords:

“Virtual Reality” or equivalent expressions;

“Immersion” or equivalent expressions;

“Foreign Language” or equivalent expressions;

**IC-2** - Research Article or Proceedings / Conference Article;

**IC-3** - The paper is written in English.

#### Exclusion Criteria (EC)

**EC-1** - The paper is not available;

**EC-2** - Study is not written in English;

**EC-3** - The paper does not consider Immersive Virtual Reality;

**EC-4** - The paper does not consider teaching/learning of a foreign/second/other language;

**EC-5** - The study is theoretical (e.g. proposes a framework).

### B. SEARCH STRATEGY

The first stage of the search strategy consisted of data retrieval from databases by entering the search string build upon IC-1 in the following databases: Scopus, Web of Science, ACM Digital Library, Mary Ann Liebert, EEE Xplorer, and SpringerLink. These databases are recognised as significant reliable sources of high-quality publications from Computer Science and Engineering areas. We started with a simple string representing the three main aspects of this

SLR, “Virtual Reality” AND “Immersion” AND “Foreign Language”. However, to guarantee a more comprehensive search, synonyms and neighbouring words were added. Thus, the following search string was defined:

(“Virtual Reality” OR “VR” OR “Virtual Worlds” OR “Virtual Environments” OR “3D”) AND (“Immersion” OR “Immersive” OR “HMD” OR “CAVE” OR “Head-mounted display” OR “360”) AND (“Second Language” OR “Foreign Language” OR “English” OR “Language”). Since year limits were not established, all the related research was recovered. The retrieved papers were imported to Mendeley using the BibTex format. This permitted to erase the duplicated papers, adjust, and export it to a spreadsheet.

### C. STUDY SELECTION

For every retrieved paper, the title, abstract, and keywords were confronted with the eligibility criteria. This phase evolved the reading of each abstract of the retrieved papers in an unblinded standardised manner by two researchers, independently. In cases where there was no consensus, the articles were retained for more careful analysis in the phase of full-text analysis.

### D. DATA COLLECTION PROCESS

We developed a data extraction sheet for the data collection process, taking into account the SR goals to ensure that all the pertinent data was retrieved. The considered variables that started to be collected were the Article Data: type of publication, year and keywords. Regarding the type of setup, we registered if the studies were conducted with HMD, Mobile/Smartphone VR, CAVE or other. In the case the subjects used HMD, we reported which specific model it was; some of the most used - HTC VIVE, Oculus Quest, Oculus Rift - or another variety of HMD. An important variable to collect was what type of platform the studies used, namely an online platform, an application, a mobile app. In case the studies that used applications build using a game engine, we reported if they were using one of the top engines - Unity, Unreal Engine, GameMaker, Godot, AppGameKit - or other. There was also the variable for when studies did not mention what game engine they were using. Concerning the content type, the variable could have been either Virtual Environments or Video. Regardless of this type of content, it was also essential to record if it was interactive or passive. Regarding the participants of the studies, we collected their educational stage according to the ISCED 1997 levels of education [24], and gender and number of participants. One of the most important variables collected consisted of identifying which factors are being evaluated (e.g. learning, cybersickness, immersions, among others) and which instruments were used to measure learning. Regarding the variables associated with learning comparisons, it was collected whether there were any comparison made with different VR conditions or not, if there was a comparison made with other forms of instruction, if there were other aspects

of multisensory immersion considered (besides visual) and if the user was introduced to VR previous to the activity.

1) QUANTITATIVE ANALYSIS

The manuscripts were analysed in order to extract information about the year of publication and type of publication. A visual representation of the most used words in the examined papers' titles (word cloud) was created using the Bibliometrix R Package, an open-source software package developed for bibliometric and scientometric analysis [25].

2) QUALITY ASSESSMENT

The assessment of the overall quality of the full-text papers was done employing a scoring system. In this system, the score of 1 is the lowest score and 3 to the highest score.

The quality rating was given according to three main factors. The first factor was related to the type of publication. For instance, a paper published in a journal was given 3 points; if it was published in a conference as a full paper it was awarded 2 points, and if the paper was published in a conference as a short paper it was given 1 point.

The sample size corresponded to another determinant that contributed to the quality rating. If the sample size exceeded the acceptable sample size a score of 3 was given; if the number of participants was acceptable a score of 2 was given; and if the sample size was less than the recommended 1 point was given.

III. RESULTS

A. STUDY SELECTION

In the first phase, 1042 records were identified in the databases mentioned earlier. After the duplicate articles were removed (n = 337), 705 unique papers were analysed. In a second phase, 593 records were rejected based on titles, keywords and abstract analysis, prompting 112 papers eligible for a comprehensive analysis. Later, 98 records were excluded based on an analysis of full-text, leaving a total of 14 full-text papers for examination in more detail. Lastly, a manual search was performed on different search engines and using citations identified manually in the selected articles that were not in the original query results. This step also included the use of Google Scholar that, although deemed inappropriate as a central search system [26], can be considered an additional resource to make sure that relevant papers that fit this SR's scope were also included.

After this process, the final number of full-text papers was 30.

Figure 1 presents a flow diagram with a report of the outcomes obtained in each phase and Table 1 presents all the articles that were selected and analyzed.

B. STUDY CHARACTERISTICS AND RESULTS

Next, we display a synthesis of results and characteristics extracted from the variables collected and introduced in

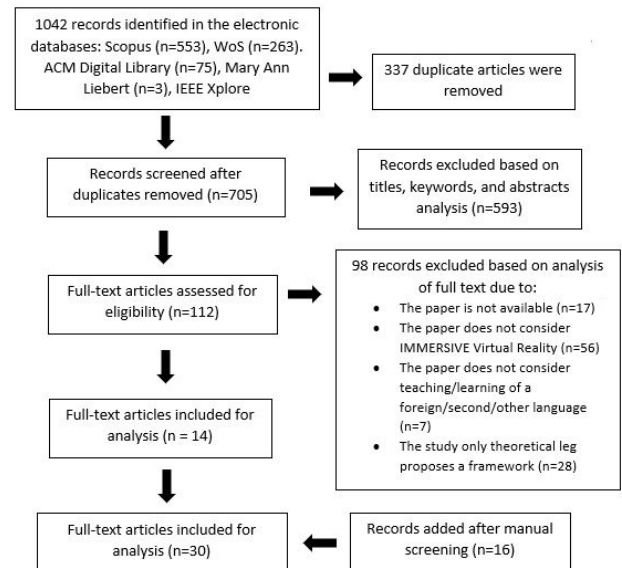


FIGURE 1. Flow diagram of the study selection.

TABLE 1. Selected articles.

Articles selected and analyzed
[13], [15], [27]–[54]

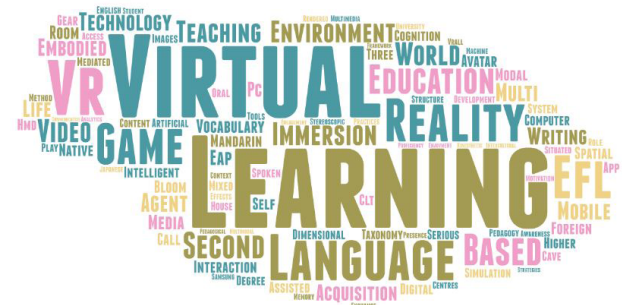


FIGURE 2. Word cloud representing the most used keywords.

the data collection process to address the questions initially stated.

1) QUALITY ASSESSMENT

The scoring of the 30 final papers for full-text analysis revealed an average score of 2,3 on the overall paper quality. Out of all the papers, 3.3% had the lowest scoring possible (1) while 33.3% had the highest possible rating (3).

A graphical representation using a word cloud (Fig. 2) has revealed that the keywords around the iVR and foreign language education theme of the researches examined are learning, virtual, language, reality, education, game and immersion.

2) WHICH LANGUAGE WAS THE SUBJECT OF STUDY

All the incorporated studies covered at least one foreign language. The most-reported language was English on 13 separate papers (40,6%), followed by Mandarin/Chinese with five occurrences (15.6%) and both Spanish and German in third



**TABLE 2.** Educational stages covered.

Educational stages	Percentage
Ist stage of tertiary education	40.5%
Post-secondary non-tertiary education	14.3%
Second stage of tertiary education	11.9%
Not informed	7.1%
Sum of others	26.2%

**TABLE 3.** Modes of instruction covered.

Modes of instruction	Percentage
Face-to-face	80%
Not informed	10%
Blended learning	6.7%
Gamification	3.3%

place with three occurrences each (9,4%). It is also important to note that one of the studies did not mention which foreign was being addressed. The remaining languages that were an object of study were: Arabic, Korean, Swedish, Amazigh, Japanese and Polish.

### 3) WHICH FORMS OF INSTRUCTION ARE COVERED?

Non-formal education was the most approached form of instruction (73.3.9%), followed by formal education (16.7%) and informal education (10%).

### 4) WHICH EDUCATIONAL STAGES ARE COVERED?

The first stage of tertiary education was the educational stage used in the majority of the studies - 40.5%, occurred during the start of a specific graduation / with undergraduate students. The post-secondary non-tertiary education (start of generic graduation in countries like the US) represented the second most covered stage with 14.3%, while the second stage of tertiary education (postgraduate, graduate students, PhD) represented 11.9%. Five of the studies did not provide information about the educational stage. Table 2 shows a synthesis of the factors identified and their percentage. Some papers analysed covered more than one educational stage.

### 5) WHICH MODES OF INSTRUCTION ARE COVERED?

Most studies analysed used face-to-face teaching as a mode of instruction (80%), while a tenth of the papers did not mention what mode of instruction they used. Table 3 shows a synthesis of the factors identified.

### 6) WHICH FACTORS ARE BEING EVALUATED?

All the factors analysed in the studies were examined, that is, the independent and dependent variables. Furthermore, all the studies investigated more than one factor, and learning was the most common one showing up in twenty studies (66.7%), followed by User perceptions showing up in fourteen papers (46.7%). In third place, Motivation, Satisfaction and Usability were considered factors to be evaluated in 26.7% of the

**TABLE 4.** Other evaluated factors.

Evaluated factors	Percentage
Learning	66.7%
User perceptions	46.7%
Usability	26.7%
Satisfaction	26.7%
Motivation	26.7%
Overall experience	23.3%
Cybersickness	23.3%
Interaction	16.6%
Immersion	16.6%
Sense of presence	13.3%
Engagement	13.3%
Gender	6.7%
Other	26.3%

papers. Eight of the papers assessed had some other unique factors.

Table 4 shows a synthesis of the factors identified in the remaining percentage.

### 7) DISPLAYS

The majority of the studies (51.6%) used a Head-Mounted Display setup, where 29% utilised Oculus Rift, 19.4% utilised HTC VIVE. Smartphone VR was the choice of 22.6% of the studies, while one paper took advantage of a CAVE system. Seven studies (22.6%) use some other setup or did not provide the necessary setup type information.

### 8) GAME ENGINE

The cross-platform game engine Unity was by far the most popular game engine (40%) while the rest were either not mentioned (23.3%), used an engine other than the top engines mentioned before (13.3%). The remaining studies, where the game engine question was not applicable, represented 23.3%.

### 9) PLATFORM AND CONTENT-TYPE

Platform wise, 86.7% of the studies used a PC-VR application/software, while both mobile and online platforms tied with 6.7%. Concerning the content type, the majority (86.7%) used Virtual Environments in their studies, while the video was presented in 16.7% of the studies. Two studies explored both VE and video. Twenty-five of the studies (83.3%) used interactive content, 16.7% used passive content.

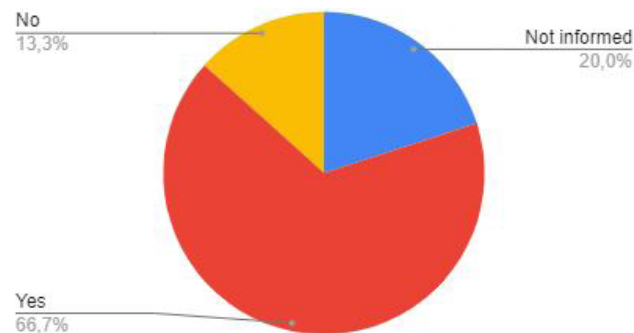
Table 5 shows a synthesis of the factors identified in the remaining percentage.

### 10) WHAT FORM OF THE ENVIRONMENT WAS USED?

The majority of the environments (75.9%) were used so that the user is taken to participate in the experience as if it was a real-world location. Three papers used the environments as a virtual exercises scenario; one paper used the environment in the form of a virtual classroom, while another study had a

**TABLE 5. Platform and content type.**

Platform and Content Type	Percentage
Virtual Environments	78.6%
Immersive 360 Video	14.3%
Stereoscopic 3D Images	7.1%
Interactive	83.3%
Passive	16.7%



**FIGURE 3. Was the user introduced to VR previous to the activity?**

real-world environment except it was cartooned. Two did not provide enough information on the matter. classes, exercises or

**11) WAS THE USER INTRODUCED TO VR PREVIOUS TO THE ACTIVITY?**

Most of the studies (66.7%) introduced the user to the VE before starting the experiment per se. Figure 3 shows that 13,3% did not, and 20% did not provide any information.

**12) IS A COMPARISON MADE WITH DIFFERENT VR CONDITIONS?**

Twenty-six of the full-text analysed studies made a comparison with different VR conditions (86.7%). Four studies (13.3%) compared different VR scenarios.

**13) IS A COMPARISON MADE WITH OTHER FORMS OF INSTRUCTION?**

Half of the studies did not make any comparison with other forms of instruction (50%). The investigations that did it (21.4%) compared VR with traditional learning (face-to-face / Printed text).

Table 6 shows a synthesis of the factors identified in the remaining percentage.

**14) ARE OTHER ASPECTS OF MULTI-SENSORY IMMERSION CONSIDERED (BESIDES VISUAL)?**

None of the examined papers considered Odor, Haptics, or any other kind of multisensory besides visual.

**15) HOW IS LEARNING ADDRESSED?**

Most papers addressed learning in multiple ways. Without any surprises, most of the papers addressed learning as Learning (96.7%). Some of the other terms used were Knowl-

**TABLE 6. Comparison made with other forms of instruction.**

Other type of instruction	Percentage
No	50%
Traditional learning	21.4%
Non-immersive VE	10.7%
Audio	7.1%
Video	7.1%
Non-Stereoscopic 3D Images	3.6%

edge (36.7%), Performance (23.3%), Retention (23.3%) and Recall (13.3%).

**16) WHAT INSTRUMENTS ARE USED TO MEASURE LEARNING?**

Most papers used more than one instrument to measure learning. The most utilised was “objective knowledge test” with 40%, “subjective knowledge test” with 30% and “perception questionnaire” with 26.7%. This was followed by “task performance” and “logs analysis” emerging in 23.3% of the studies each. “Observation” and “course performance (grade)” were the next two most used instruments, with 20% and 13.3% respectively. “Course performance (grade)” and “subjective knowledge test” appeared in 14.3% of the papers each.

**17) SAMPLE AND GENDER**

A total of 1979 participants participated in the thirty full-text papers analysed, and this gives an average of 65.96 participants per study. However, one study did not specify the sample size, and so, disregarding that one study, the average of the remaining twenty-nine studies changed to 68.24. This large number is boosted due to two studies that incorporated online surveys and accounted for 1098 (650 and 448) of the sample total (55.5%). Apart from the two papers, the remaining 27 studies had an average of 36 people per study, peaking at 110 and with a minimum of 3. Regarding gender, 46.7% of the studies documented the gender of the sample. More precisely, 46.6% were identified as males and 53.3% as females. None of the studies found meaningful discrepancies separating the genders.

**18) iVR IMPACT**

According to 73.3% of the papers, iVR had a positive impact on foreign language education. A fair portion of the investigations (20%) stated that iVR had a neutral impact. Negative impact is represented in 3.3% of the papers, the same percentage as studies that did not mention what sort of influence it had.

**IV. DISCUSSION**

The discussion of results is organised by the main objectives investigated in this systematic review.

## A. THE FEATURES OF IVR FOR FOREIGN LANGUAGE EDUCATION

One of the central characteristics of the analysed papers was the use of immersive Virtual Environments. This may be due to VE's numerous advantages in the language learning area [55]. Features such as active participation, high interactivity and individualisation are key for positive learning outcomes [46], [56]. This technology also allows a comprehensive level of freedom in the development of the experiment. An example of this occurs in the study of Garcia *et al.* [35] where, due to potential dizziness / motion sickness and consequently a chance of injury, there is the possibility to explore the same virtual environment, either sitting down or standing. Cho [50] even had all participants, including non-VR, stand while experimenting. Even though culture teaching is an essential feature in acquiring a foreign language, this did not receive as much recognition as the linguistic element [57]–[59]. These virtual environments also allow the freedom and opportunity to recreate real world circumstances and places of cultural importance for the user to be immersed without the expense needed for an educational trip [48]. Unlike other forms of multimedia that may be used in the classroom to teach languages, this allows students to physically experience the culture by hearing the sounds, coming into contact with the language in use, exploring the environment, and interacting with the culture [15]. In the case of Cheng *et al.* [30], in addition to the cultural characteristics of the VE, a physical interaction was further formulated where players had to bow - a typical characteristic in Japanese greetings. Meanwhile, in Mohammed Alfadils study [48], the students can interact, learn and enjoy 12 different locations such as the zoo, coffee shop, airport, cinema, and museum through immersion in a virtual environment without the need of travelling thousands of kilometres. Some of the analysed studies took advantage of the fact that navigation and interaction with avatars increase the level of Presence [30], [49], [60] by using NPCs in their experiments. For example, in Chung [27], Cheng *et al.* [30] and Jia and Liu [42] work, the learner engage with NPCs in the conversation to learn new vocabulary. In the study of Pinto *et al.* [44] the user would be placed at a table surrounded by the NPCs engaged in a narrative fitting each scenario. Other studies had the distinction of using objects as a teaching method. In one of the papers [34], the user was given commands (both in text and audio) and explored the virtual environment looking for the mentioned object. That was a reliable option as the search-and-find method as an active learning technique has shown various benefits in the learning process [42], [43], [61]. Correlated with this characteristic, some principles of gamification were used in the experiment (and on Tazouti's study [36]), where a scoring/point system was used. Another technique using objects was to allow the user to see and hear the objects with the corresponding foreign words [42], [46]. The Ebert et Al. study [28] took it one step forward and added a second phase, where the words were presented and pronounced so that the participant had to point to the corresponding object. In the study of O'Brien

and Levy [15] if the participant approached an object, Korean cue cards would be popped up above the object. Soothing music was employed as a feature in the background during the experiments to add to the immersiveness and increase focus [28], [36], and students tend to enjoy it [15]. Agitate music was used to give guidance and information during exploration.

The better part of the studies introduced the user to the VE previous to the activity. The users would freely roam the virtual environment [34], [35] for a while in an environment with no defined gameplay goals so that they could familiarise themselves with their surroundings [13], [42] and controller navigation [34], [43], [44], [46], [48] and therefore, enabling them to focus on the task at hand [38] when starting the exercise, preventing the users from feeling overwhelmed and confused due to the novelty effect [50].

Some other features include coloring sentences in a VE according to its respective function [38], the possibility for educators to produce learning scenarios and monitor students' interaction and their learning process [32], the use of immersive video [32], [37] and even the use of stereoscopic three-dimensional images [40]. In one of the studies [43] the teacher and student could use a virtual whiteboard and voice chat to communicate in the virtual world. The teacher uses it to emphasise important information, also asking the student to write or highlight particular points of interest.

## B. USED TECHNOLOGIES AND THEIR IMPLEMENTATION

The literature analysis revealed that PC-VR applications or software are used over mobile apps and online platforms significantly. This was presumably the right approach as some studies [62] show that participants encounter significantly lower rates of illness and blurred vision when using desktop-VR compared with smartphone-VR. Desktop-VR content is delivered by HMD, such as the Oculus Rift or the HTC Vive [38]. These two HMDs are readily available off-the-shelf [43] and possess high fidelity displays [28], and represented 51.6% usage of the HMDs setups on the SR.

Smartphone-VR was the choice of 22.6%. Even though these technologies' performance and graphical fidelity cannot compete with more expensive VR solutions [63], this type of setup presents some unique advantages. The Gear VR and Google Cardboard are mobile-rendered head-mounted devices [49] that can be easily attached [47] to smartphone turning them into head-mounted virtual reality viewer [13], [52]. These can be made out of cardboard or plastic, allowing them to be priced from US\$3 to US\$30 [64], significantly less expensive than higher-end desktop VR where prices range from US\$350 to US\$1,500 [64]. Not only that, these devices are lightweight, portable and work with almost any phone [63], allowing experiments with multiple users at the same time. For example, Xie *et al.* [54] used fifteen Google Cardboards and 15 smartphones simultaneously running Google Expeditions and the presenters, with using an iPad, had complete control, directing the other students

(on their smartphone-VR devices) to look toward the specific areas where they were presenting.

Unity was by far the most popular game engine found in the analysed papers. This game engine is well-established in the gaming industry [50] and features multi-platform porting, rich assets store and supports two of the most popular programming languages (JavaScript, C#), which may explain why it is considered to be the most cost-effective, flexible and sustainable solution to develop VR application [65], [66]. It also allows for optimised VR functionality software like VRChat, an online chat platform created with the Unity engine with features that include voice chat using the HMD microphones and object manipulation with HMD controllers [43].

One of the studies [33] decided not to have any intrusive devices that would need to be worn nor hand-held devices that required to be used to interact with the room. Thus, they used five projectors to create a 360 panoramic display that would still allow building environments that can visually immerse users. This system appeared as a circular and seamless screen to the users.

One paper [53] that used multiscreen projection system that provides users with a high level of immersion denominated CAVE. These characteristics of this system include virtual tracking of the subject and surround sound. Even though the CAVE technology is perhaps the most exciting and immersive medium, O'Brien *et al.* concluded that its exorbitant cost and large scale make it an unfeasible prospect for most schools.

Some analysed papers [32], [33], [43], [49] have already started to focus on voice detection technologies and, although they cannot wholly replace human-human [67], [68], several studies [32], [69], [70] have shown that technologies with dialogue exercises can be used to improve language learning. These exercises allow students to practice their pronunciation, which is crucial for beginners and can enhance students motivation and performance [33], [49], [71]. In Divekar's study [33], an AI waiter starts a Mandarin dialogue with the user through a text-to-speech engine and has relevant features such as accepting a range of inputs that map to an intent. In the example presented by the paper, both "I want water" and "Can I get some water" map to the "ordering" intent. The same concept is applied to the output step where the system has multiple sentence variations for a given purpose and outputs one randomly as they all have identical meaning. Similarly, Tai *et al.* study [49] also takes advantage of an app that listens to the learners' words and, via automatic speech recognition, the app analyses the accuracy of their pronunciation and gives positive feedback if they speak clearly and correctly.

Most studies adopted the controls that come by default with their chosen VR system concerning navigation and interaction. However, it is interesting to highlight a Myo armband's employment for locomotion [28], where the user points their arm forward to move. About interaction, Chiu's research [31]

adopted a laser beam between the eyes as a mechanism to interact with the environment.

### C. EDUCATIONAL METHODS, TARGET AND LANGUAGE LEVEL

The most-reported language was English, followed by Mandarin / Chinese, while Spanish and German tie in third place. This is an expected outcome considering English is not only the most spoken language in the world, but it is also at the top of the global language network [72], [73]. We can also highlight that Mandarin Chinese is a very close second. Hindi and Spanish finish the top four of most spoken languages globally [73], meaning that the top three languages on our foreign language education review match with the most spoken languages in the planet.

Different literature reviews related to language learning and technology reveal that most of the studies are conducted in a university context [74], [75]. A significant number of our reviewed papers' sample, were in the first stage of tertiary education, this is, the start of a specific graduation / undergraduate students. This result corroborates Solak's [16] findings in their meta-analysis on VR and foreign languages education from 2015. Considering various studies implied that they managed to get participants as volunteers around the university campus, and not as part of a course linked with the experiment, this may explain why non-formal education, any organised educational activity outside the established formal system, was the most approached form of instruction. This may also explain why none of the studies used an international language level standard, such as the popular Common European Framework of Reference for Languages [76], for describing the user's language ability.

Concerning the modes of instruction covered, we hypothesise that the reason most studies determined face-to-face learning as their mode of instruction is linked with the large use of HMDs. This needs an in-person instructor to set up the equipment and in case of any problem with the computer emerged [29].

### D. IMPACT OF iVR IN FOREIGN LANGUAGE EDUCATION

Results show that the vast majority of foreign language education studies had a positive impact and improved students' learning [29], [41]. Based on the findings, the iVR method reported significantly higher perceived enjoyability and effectiveness [28] and not only on the student's linguistic abilities but also on their cognitive abilities as well [29]. Likewise, the users registered better focus on the assignment without external distractions [38]; the integration of avatars in the learning materials can improve English learning efficacy [27]; increase in motivation [27], [33] or willingness to learn was displayed and the enjoyment that stems from the feelings of presence and immersion afforded by the novel technology [38]. Additionally, weaker learners have the freedom to revise and upskill themselves at their own pace [37], as long as they have access to the system.



When rivalling iVR with conventional teaching practices, the participants stated that VR is more enjoyable [34], it was proven to be significantly better than using solely conventional teaching methods [27], [39]. Even in Ebert's work [28] where it recorded higher initial test scores using the traditional method, recalling the words a week later was significantly higher using the VR. Not only that, according to Vázquez *et al.* [45] paper, the kinesthetic component also plays a substantial role in the retention of vocabulary. The rate at which participants from the VR kinesthetic group forgot the words after a week was significantly lower compared to the text-only and VR non-kinesthetic conditions.

Nevertheless, studies like Cheng's [30] show that iVR does not always claim better learning. Thus, even though the participants showed a significant improvement in the sense of cultural involvement, there is no conclusive evidence that the language learning outcomes improved.

## V. CONCLUSION

In this SR it has been found that virtual environments are widely used as indeed truly potential didactic territories for foreign languages learning and teaching. Furthermore, these highly valuable didactic environments comprehend an important number of learning-related strategies and realities, provides freedom in the development process and several valuable and applicable features for foreign language education, namely the very active participation, high interactivity, navigation and interaction with avatars and even recreation of circumstances and places of cultural importance.

We also came across the fact that, regarding the VE implementation, Unity was by far the most prevalent game engine found in the examined papers as it allows rich assets store, popular programming languages and also easy porting to PC-VR HMDs, which according to this investigation are the most used iVR technology by a significant margin.

Based on the findings, iVR for foreign language education is an excellent strategy. One should take advantage of this as it had a positive impact and improved students' learning, especially when rivalling iVR with conventional teaching practices was proven to be significantly better. Also, participants stated that iVR is more enjoyable.

This made it possible to summarise the findings in two key main conclusions:

- The relation between iVR and foreign language learning is quite positive, particularly compared with conventional pedagogy practices.
- The relation between iVR and the users' motivation and satisfaction is also quite positive.

Therefore, these findings present the iVR as a highly rich and potential didactic tool for foreign language learning and teaching, which may well surpass the efficiency levels of learning and teaching a foreign language as produced by conventional and traditional methodologies. Also, the high levels of motivation and satisfaction shown by users when using iVR certainly contribute to a significant increase in the

very levels of learning efficacy and success a student may attain as he or she will be more committed to the activities exercises suggested. Therefore; these two aspects are of great importance and provide relevant conclusions that educators and language researchers may want to consider.

Nevertheless, even with this positive evidence of iVR setups, there are important points that deserve to be addressed. Regarding the sample of studies, several more studies should be conducted in virtual reality and foreign language education. Concerning the gaps in the literature, future research should explore much more comparisons between VR and other forms of instruction, including, but not limited to, other types of conventional teaching techniques, video, photos, different setup types, et cetera. Additionally, one thing that all the analysed studies lacked was the consideration of other aspects of multisensory immersion. Studies with these features should be conducted to check for better results considering the incorporation of all multisensory stimuli increases users' involvement, thus leading to more attention devoted to the VR environment [77].

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