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Review

Design Recommendations for Immersive Virtual Reality Application for English Learning: A Systematic Review

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Abstract: The growing popularity of immersive virtual reality (iVR) technologies has opened up new possibilities for learning English. In the literature, it is possible to find several studies focused on the design, development, and evaluation of immersive virtual reality applications. However, there are no studies that systematize design recommendations for immersive virtual reality applications for English learning. To fill this gap, we present a systematic review that aims to identify design recommendations for immersive virtual reality English learning applications. We searched the ACM Digital Library, ERIC, IEEE Xplore, Scopus, and Web of Science (1 January 2010 to April 2023) and found that 24 out of 847 articles met the inclusion criteria. We identified 18 categories of design considerations related to design and learning and a design process used to create iVR applications. We also identified existing trends related to universities, publications, devices, human senses, and development platforms. Finally, we addressed study limitations and future directions for designing iVR applications for English learning.

Keywords: immersive virtual reality; English learning; education; learning

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1. Introduction

Technological development has given rise to various interface typologies that facilitate the use of immersive technologies, including augmented and virtual reality, tangible elements, wearable computing, etc. [1]. This expansion of interaction modes has enabled the design of digital interfaces to enhance user experiences, whether through immersive technologies or human senses. In this context, Virtual Reality (VR) has gained popularity and found application in diverse fields.

Traditionally, VR is defined as an interactive virtual environment composed of digital objects. In general, VR entails a three-dimensional computer-generated environment that users can interact with using a VR headset. Two key concepts in understanding immersive VR applications are immersion and presence. Slater [2] defines immersion as the objective level of sensory fidelity a VR system offers, while presence refers to a user's subjective psychological response to a VR system. Immersion is measurable and objective, whereas presence is an individual and context-dependent user response connected to the feeling of "being there" [2].

Immersive Virtual Reality (iVR) provides the highest level of immersion, where users engage fully with computer-generated simulations, exploring sensory experiences in a virtual world. iVR applications induce a sense of presence or "being there" in the user's perception [3]. In this way, iVR environments allow human and virtual agents to co-exist, which creates a mixed reality environment of the physical and virtual worlds [4].

In recent years, consumer Virtual Reality (VR) devices have become more affordable, introducing a consistent number of users to this technology [5]. Accordingly, VR has been applied to training and learning in many fields, as well as industrial processes [6,7], cultural heritage [8,9], military training [7], surgery [10], and geography [11], physics [12] and language learning [13–24].

In educational settings, VR and head-mounted displays (HMDs) can provide learners with exposure to demanding or instructional scenarios, enabling them to repeatedly hone new skills in an environment conducive to making corrections and experiencing non-harmful mistakes [10]. Within the context of language education, educators confront a formidable challenge: seamlessly integrating a range of technologies into their teaching methods, all the while catering to the diverse learning needs of their students. In this way, virtual reality can provide an innovative avenue for engaging learners in the educational process [25].

Virtual Reality (VR) has captured considerable interest within the realm of English language education, since it provides an immersive and interactive environment that enhances and enriches the language learning experience [15,17,21,23,24,26–28]. According to Pinto et al. [29], VR enhances language learning by boosting motivation and engagement, increasing student interest, and introducing gamified elements into the learning process. Additionally, VR technologies can support second language acquisition, and their integration with traditional learning methods is crucial for advancing knowledge and facilitating adaptation to various interaction methods and contexts, particularly in foreign language learning.

Huang et al. [30] reported that Augmented Reality (AR) and VR technologies enhance language learning by promoting immersive experiences, motivation, interaction, and reducing learning anxiety. However, the authors highlighted challenges such as student distraction caused by virtual content, which might divert their attention from the learning material. Moreover, the effectiveness of AR and VR in promoting language learning may hinge on factors like technology quality, activity design, and individual learner differences.

Peixoto et al. [31] concluded that the relationship between iVR and foreign language learning is largely positive, especially compared with conventional pedagogical methods. They noted that iVR was more enjoyable and significantly more effective than traditional teaching methods for language learning. Notably, participants who used VR exhibited significantly better vocabulary retention than those using traditional methods. Additionally, the kinesthetic aspect of VR played a substantial role in vocabulary retention.

In a systematic review encompassing 32 peer-reviewed studies published between 2015 and 2020, Dhimolea, Kaplan-Rakowski, & Lin [32] found that multiple exposures to VR are effective for learning. In addition, VR was advantageous for contextual vocabulary learning, and perceptions of VR-based language learning were positive.

Parmaxi [33] discovered that VR has the potential to offer dynamic learning experiences and enhance language learning performance, motivation, critical thinking, and higher-order cognitive skills. The use of VR in language education also led to increased student learning and the development of twenty-first century skills, such as communication and problem-solving. Furthermore, VR provides access to environments and situations that are challenging to replicate in traditional classrooms, facilitating the adoption of various instructional strategies.

Bahari [34] observed a research trend favoring the application of VR tools and affordances for improving listening and speaking skills in language learning compared with reading and writing skills. The VR environment provides affordances that foster language skill development through strategies like contextualized learning, immersive experiences, increased engagement, interactive learning, collaboration, and scaffolding. While listening and speaking skills have received more attention in VR-based research, reading and writing skills are less compatible with virtual environments.

The aforementioned articles collectively highlight the potential of VR for English language learning, addressing topics such as gamification [29], benefits of AR and VR for learning outcomes [32], features and educational methods [33], as well as affordances and challenges [34]. VR-assisted language learning has expanded in recent years, and proven to be beneficial in both the cognitive and affective aspects [30,33,35,36]. There were not found, however, studies that address guidelines or considerations to design iVR applications for English learning. To address this gap, we present a systematic review with the following objectives:

- Identify design recommendations for immersive Virtual Reality (iVR) applications focused on English language learning.
- Examine the process of developing iVR applications for English language learning.
- Analyze the utilization of human senses in iVR applications for English language learning.
- Provide directions for future research.

To achieve these objectives, this systematic review will address the following research questions:

RQ1: "Which human senses are most frequently employed in iVR applications for English language learning?"

RQ2: "Which iVR platforms are most commonly used for developing English language learning applications?"

RQ3: "What characterizes the design processes employed to create iVR applications tailored for English language learning?"

RQ4: "What design recommendations guide the design and development of iVR applications for English language learning?"

2. Method

A systematic evaluation of existing literature was conducted using a well-defined and methodical search approach, including criteria for inclusion and exclusion. In this process, the researchers have adhered to the guidance provided by the PRISMA Statement [37].

2.1. Eligibility Criteria

The inclusion and exclusion criteria were established to ensure that the selected studies were relevant and met the objectives of the review (Table 1). These criteria were applied independently by two reviewers to ensure objectivity and to minimize bias in the selection of studies. It was decided to limit the search to articles published from the year 2010 onwards, as this was the year in which relevant VR headsets were released.

Table 1. Inclusion and exclusion criteria.

	Inclusion Criteria	**Exclusion Criteria**
Publication period:	Published between January 2010 to May 2023.	Published before January 2010 or after May 2023.
Type of document:	Scientific article published in peer-reviewed journal or conference.	Not an article published in a peer-reviewed journal or conference.
Availability:	Accessible with Coimbra University's credentials	Behind a paywall
Type of study:	Applied research.	Other research (review, surveys, systematic literature review...).
Language:	English.	Not English.
Theme:	English learning.	Not English learning.
Research topic:	Immersive virtual reality.	Not immersive.
Number of pages:	Paper with 5 pages or more.	Paper with 4 pages or less.

2.2. Search Strategy

The ACM Digital Library, ERIC, IEEE Xplore, Scopus, and Web of Science were the databases chosen for this study. These databases are acknowledged as substantial and dependable sources of high-quality publications within the fields of Computer Science and

Engineering. In their initial search, the researchers employed a basic string to encapsulate the primary components of this systematic literature review (SLR): "Virtual reality" AND "English learning". In order to ensure a more all-encompassing exploration, synonyms and adjacent terms were incorporated. As a result, the ensuing search query was formulated as shown in Table 2.

Table 2. Search string.

Topic	Search Terms
Immersive virtual reality	("virtual reality" OR "immersive virtual reality" OR "immersive VR" OR "virtual environment" OR "immersive environment")
English learning	("English teaching" OR "English learning" OR "English teaching" OR "English as a second language" OR "English as a foreign language" OR "English as an additional language" OR "English training")

The search string was used to search these six global educational databases, specifically in the title, abstract, and/or keywords sections. The search was carried out in May 2023, resulting in the initial detection of 847 records.

As mentioned in the eligibility criteria subsection, the year 2010 was established as a limit due to the release of important VR headsets. These headsets played a crucial role in laying the groundwork for the subsequent surge in interest and development in VR technology. The gathered papers were brought into Mendeley using the BibTeX format, with the intention of removing duplicate papers, making necessary adjustments, and subsequently exporting them to a spreadsheet.

2.3. Study Selection

For each paper that was gathered, the title, abstract, and keywords were cross-referenced against the eligibility criteria. This stage involved both researchers independently and systematically reviewing the abstracts of the collected papers in an unbiased manner. When agreement was not reached, the articles were preserved for a more meticulous examination during the full-text analysis phase.

2.4. Data Collection Process

A data extraction form was generated to streamline the data collection process. This form was devised in accordance with the objectives of the systematic review, guaranteeing the comprehensive retrieval of pertinent information. Initially, the collected variables encompassed article data, including particulars such as publication type, year, keywords, abstract, journal name, and the country of the affiliated university. Also, it was registered with what type of VR headset the study was conducted, article main findings, and human senses used for the VR application. Regarding the design recommendations and process of developing iVR applications, it was registered in the sheets based on a text analysis.

The data were organized in spreadsheets for initial data processing. Subsequently, this document was imported into ATLAS.ti (Version 23.3.0) for content analysis.

Content analysis refers to a set of techniques for analyzing communications in order to obtain, through systematic and objective procedures for describing message content, indicators that allow for the inference of knowledge related to the conditions of these messages [38].

The process of content analysis is divided into four phases: (I) pre-analysis; (II) codification; (III) categorization, and (IV) analysis. The goal is to present the content and meaning of patterns in the data, which will give rise to codes. These codes, in turn, are identified by the researchers before, during, and after the analysis.

2.5. Quality Assessment

The full texts included for analysis were assessed for a quality assessment, based on three criteria:

- Criteria 1: Reports design or use of an application for teaching English; AND
- Criteria 2: Provides design considerations or guidelines; OR
- Criteria 3: Explain how VR applications are developed.

If the article matches the criteria 1 and one of the criteria 2 or 3, it was included in the review. Two researchers conducted a quality assessment of the full texts selected for analysis, using three criteria. The evaluation was performed to ensure that the chosen articles aligned with the review's objectives. Specifically, criterion 1 was obligatory, while criteria 2 and 3 were considered as optional. To clarify, for an article to be included in the review, it needed to meet criterion 1 and at least one of the other criteria. For instance, if an article satisfied criterion 1 and either criterion 2 or 3, it was deemed eligible for inclusion in the review.

3. Results

A total of 847 records were identified in the first phase of the study. Figure 1 offers a visual representation of the article identification, screening, and inclusion process, providing specific information about the criteria used.

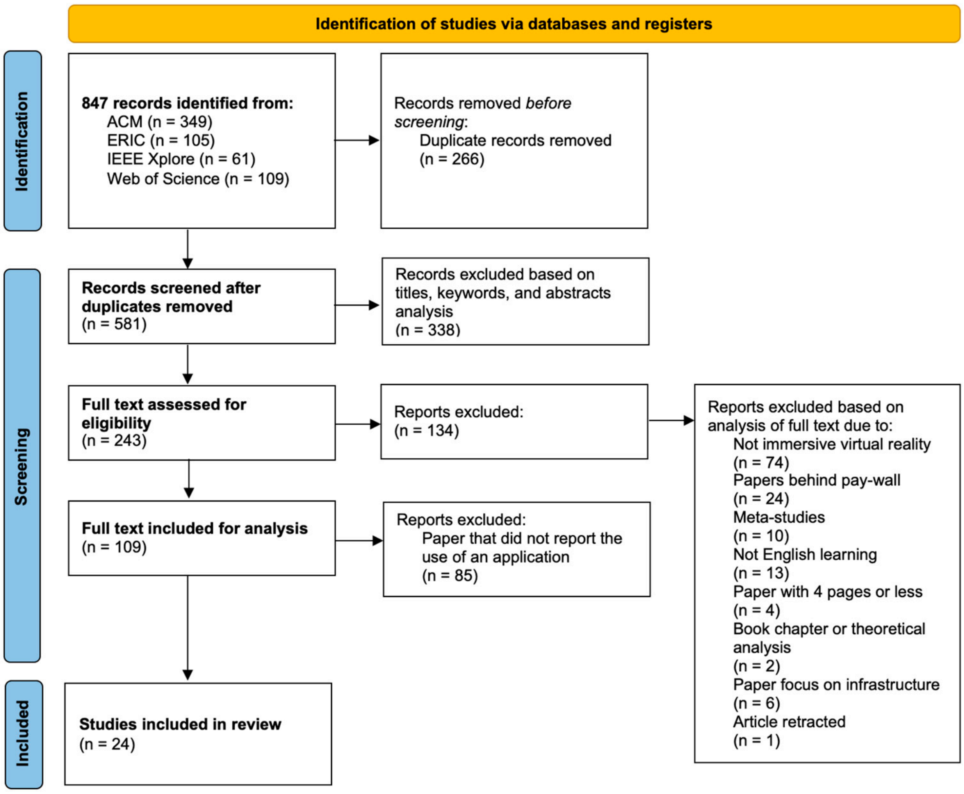

Figure 1. PRISMA flow diagram of the systematic literature review carried on. The diagram is divided three phase: identification, screening, and included.

After removing duplicate articles (n = 266), 581 papers were analyzed in the screening phase. In the second phase, 338 records were rejected based on titles, keywords, and abstract analysis. It is worth noting that a significant number of articles (n = 338) identified during the screening phase were excluded because they did not meet the inclusion criteria. Many of these studies focused on the use of virtual environments, such as online virtual worlds and three-dimensional virtual environments, rather than immersive virtual reality environments. Therefore, the exclusion of these studies does not affect the outcome of the conducted systematic review.

For a full-text assessment of eligibility, 243 papers were analyzed. Later, 134 reports were excluded based on eligibility criteria, and 85 were excluded because they did not report the use of an application. Lastly, 24 were included in the review.

3.1. Overview Analysis

The findings of the SLR revealed an observation: although we initially used the year 2010 as a research filter, the studies encompassed in the review were actually published from 2018 onwards, as indicated in Figure 2. Notably, the bulk of these studies emerged in 2021 (n = 9), followed by 2020 (n = 6). Since this SLR was conducted in May 2023, the researchers anticipate that more studies will likely be published by the end of the year.

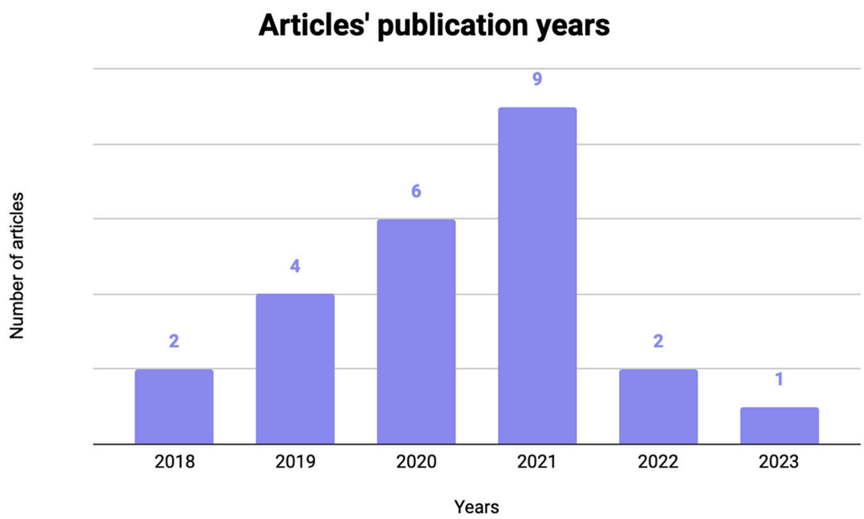

Figure 2. Graph of articles' publication years.

In terms of articles categorized by the affiliating university's country of the authors, Figure 3 shows China as the predominant contributor with the highest number of articles (n = 10). This was trailed by Taiwan (n = 6).

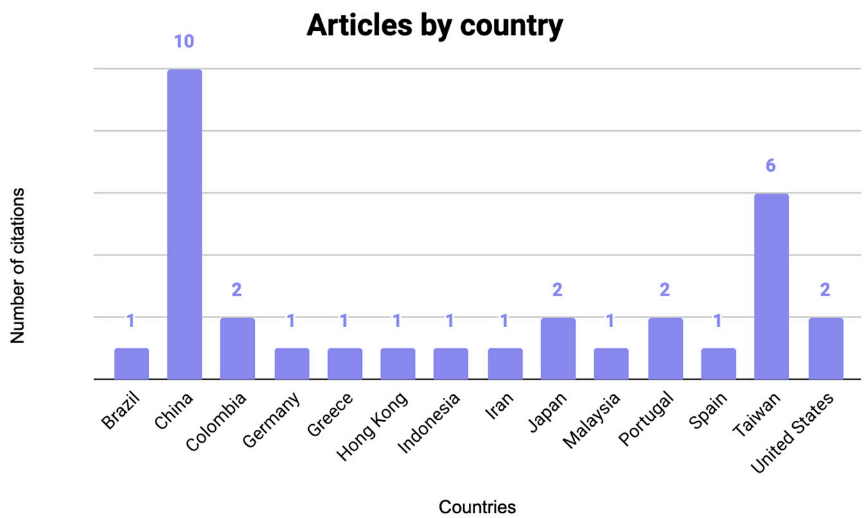

Figure 3. Graph of articles by country.

In order to represent the most used keywords, a word cloud was designed. Figure 4 reveals that the common keywords related with iVR and English learning are education, language, virtual, learning, reality, English, and environments.

Figure 4. Word cloud of most used keywords.

In relation to typical journals or conference proceedings, it was not possible to identify a pattern. However, an observation was made: half of the articles were published in conference proceedings, while the other half were published in journals (Figure 5).

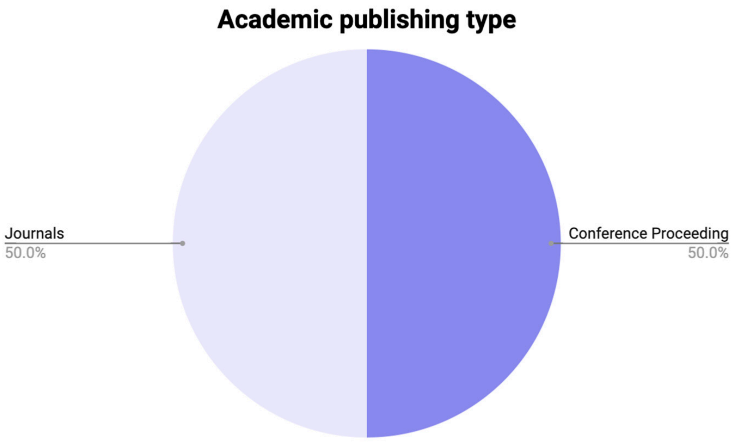

Figure 5. Graph of academic publishing type.

Figure 6 shows that the HTC Vive is the most common VR headset used in the analyzed articles; however, 8 papers did not report which VR headset was used in their studies. It is also important to highlight that many studies used low-cost VR headsets, such as Google Cardboard (n = 3), Samsung Gear VR (n = 2), and VR Box (n = 1).

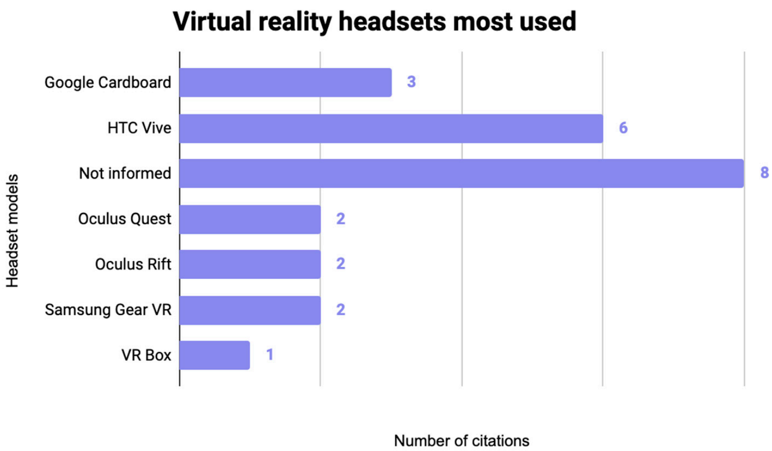

Figure 6. Graph of virtual reality headsets most used.

Visual and auditory stimulation are the most explored senses in the analyzed iVR applications (Figure 7). Touch was also mentioned ($n = 3$), and proprioception ($n = 1$) was noted as well. Unity was the most used platform to develop iVR applications (Figure 8).

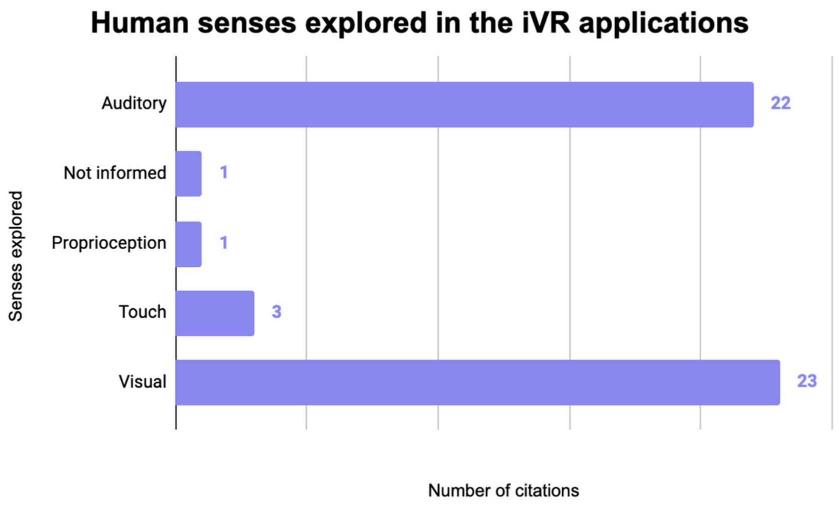

Figure 7. Graph of human senses explored in the iVR applications.

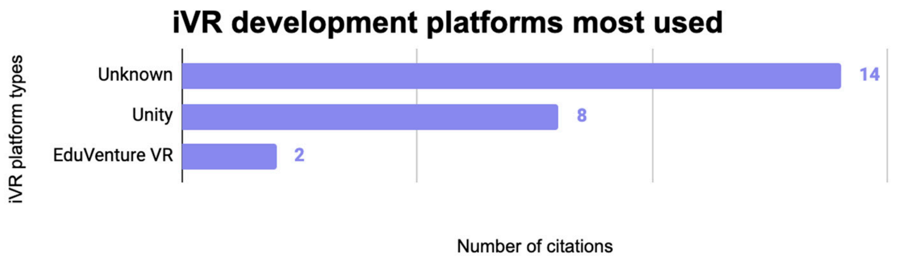

Figure 8. Graph of iVR development platforms most used.

To examine the approach employed in creating iVR applications, the researchers analyzed whether the article detailed the design of a novel application for English learning or reported the utilization of pre-existing ones. Figure 9 shows that most studies used a novel iVR app developed by themselves ($n = 9$). It is also important to notice that some studies used a pre-existing iVR app ($n = 8$) and pre-existing 360-degree video ($n = 3$). Additionally, some studies created a novel iVR app using EduVenture VR, a web-based authoring tool ($n = 2$).

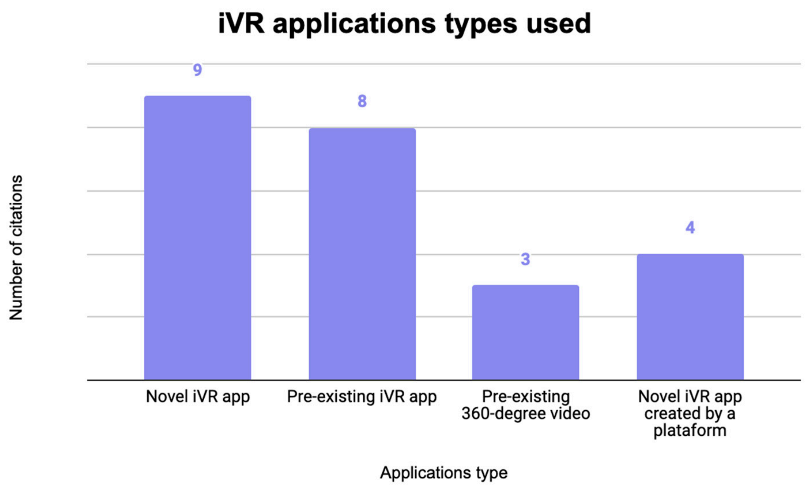

Figure 9. Graph of iVR applications types used.

3.2. Content Analysis

3.2.1. Design Process to Develop iVR Applications

Although most of the articles (Figure 9) propose novel iVR applications (n = 9), it was not possible to identify a clear and descriptive design process to develop iVR applications. Nevertheless, by analyzing articles that delve into iVR application development, we were able to distill common design process patterns. From this analysis, ten articles emerged that provide insights into the design of iVR applications. Based on similar terms and expressions, we identified patterns and group them into categories. Figure 10 shows a Sankey diagram illustrating the relationship between authors and categories identified in the content analysis. The Sankey diagram was generated by ATLAS.ti (Version 23.3.0).

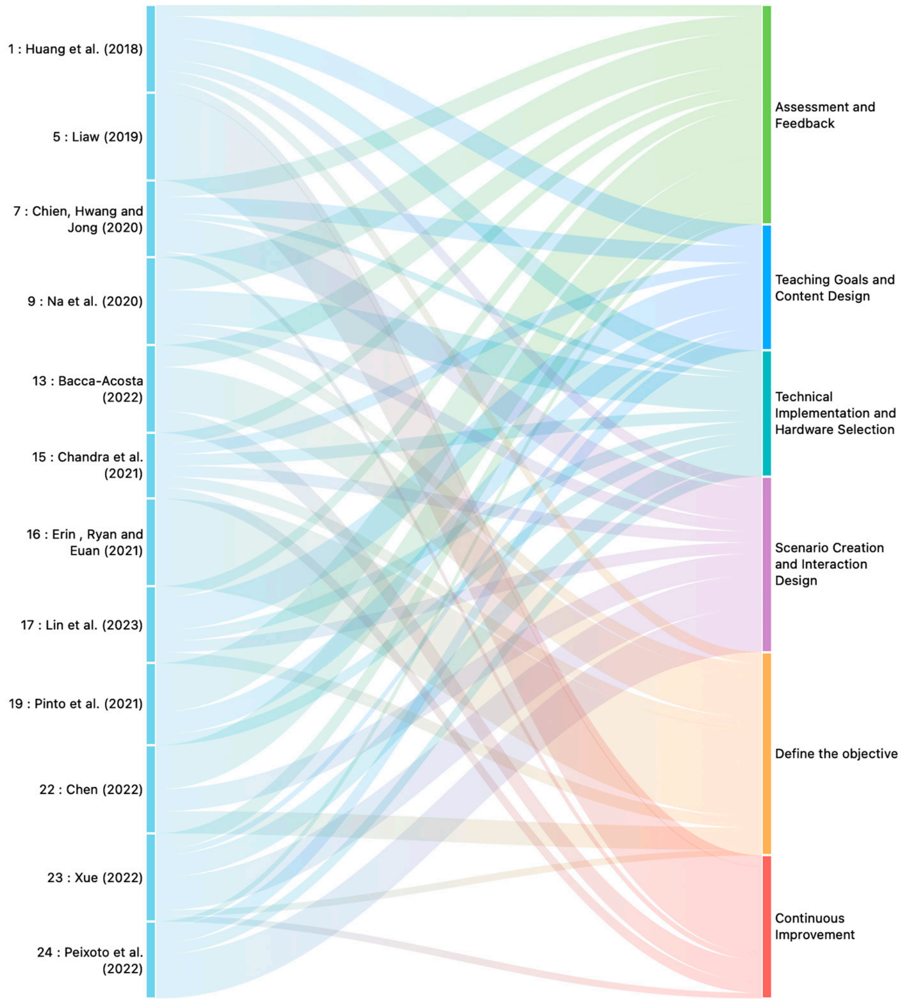

Figure 10. Sankey diagram depicting categories of the design process identified based on authors [15–19,21,23,24,26,27,39,40]. The left column presents references to articles extracted from the SLR, while the right column displays the identified categories. The connecting lines within the diagram illustrate the relationships between authors and categories. The width of these lines directly quantifies the volume of encoded text, with wider lines denoting greater content and narrower lines indicating smaller amounts of content.

The Sankey Diagram serves as a technique for visualizing the interrelation of data elements, showcasing data flows and connections across diverse fields. The line widths within Figure 10's diagram directly reflect the extent of content marked during the coding process. Consequently, categories featuring broader lines signify a greater volume of text, whereas narrower lines denote smaller amounts of coded content. In this way, all the connections to the left are directly related to right side.

Huang et al. [24] developed a VR English learning game based on the Assessment, Pedagogy, and Technology (APT) model. The design process emphasizes alignment with pedagogical goals, student engagement, real-time feedback, and collaboration between technology and education experts. The iterative nature of testing and refinement ensures that the final product effectively supports language learning while leveraging the potential of VR technology.

Chien, Hwang, and Jong [16] presented a VR application based on spherical video. To develop the application, the design process involved selecting the development environment, structuring the spherical video-based virtual reality (SVVR) system, creating authentic learning contexts, scripting interactions, integrating tags for guidance, and incorporating learning tasks. The design aimed to provide students with immersive experiences, allowing them to engage in authentic conversations and practice their English-speaking skills within a virtual environment.

Na et al. [26] developed a VR application that aims to leverage the immersive capabilities of VR technology. Regarding the design process, it encompasses various elements such as VR environment setup, practice scenarios, result assessment, and integration of speech recognition technology.

In Bacca-Acosta's [21] work, the design process involved collaborating with educators, adapting theoretical frameworks, designing scaffolds, implementing an experimental setup, and employing eye-tracking technology to evaluate the effectiveness of the designed scaffolds within the IVR learning environments. The specific topic chosen for the applications aimed to address a challenging area in English language learning and capitalize on the interactive nature of IVR technology.

Chandra et al. [15] utilized the Scrum methodology, involving stages such as requirement gathering, backlog creation, and sprint development. Four sprints were executed sequentially: the first encompassed storyboarding and asset preparation; the second focused on GUI design and data collection; the third involved game level development and testing; and the fourth centered on programming and testing using the C# language. Stakeholder evaluation and acceptance occurred after each sprint, with continuous improvement and risk management.

For Lin et al. [18], the design process involved selecting a pedagogical framework, defining learning goals, composing content and activities, creating interactive elements, and utilizing the EduVenture VR platform to develop an immersive and engaging language learning experience focused on English for Tourism Purposes.

Pinto et al. [29] developed an application featuring seven scenarios, using the Unity game engine. The initial tutorial introduced game mechanics, while subsequent scenarios presented context-based evaluation exercises in tourism-related contexts. Players' progression depended on correct answers, facilitated by interaction with a virtual TV that provided feedback through videos and indicators. In Chen's [23] study, the design process entails meticulous deliberation of gameplay mechanics, educational objectives, technical implementation, and user experience, resulting in the development of a mobile VR English learning game enriched with captivating and interactive features.

Xue [27] designed a realistic simulation, offering flexibility and immediate feedback. It offers a multi-modal learning experience with sound, 3D images, animations, and videos. Cartoon-style scenes and situational dialogues create an engaging atmosphere. Students can personalize their learning, fostering creativity and innovative thinking. The application includes functional modules for exercise guidance, International English Language Testing System (IELTS) training, stage tests, and online interaction. A training evaluation system records progress and provides feedback. Peixoto et al.'s [40] process involved script creation, audio recording, VE creation, avatar placement, user interaction design, and hardware setup, resulting in an iVR experiment for English learning assessment.

As mentioned in the studies outlined, the creation of iVR applications for English learning involves distinct steps, as can be observed in Table 3. After defining the objective, it is necessary to establish teaching goals and content design, which need to be in alignment.

Defining the technology and hardware is important to specify the application's particularities and limitations, which in turn will impact the creation of scenarios and interaction design. During this phase, the type of scenario to be created and the interaction metaphors of the platform will be determined. Assessment and feedback emphasizes the need to implement feedback mechanisms and integrated exercises to motivate student learning. Finally, in continuous improvement, it is emphasized that applications need to undergo constant development.

Table 3. iVR design process based on RSL.

Steps	Authors	Description
Define the objective:	[15,17,21,23,24,26–28]	Identify the application's purpose, target audience, collect data, understand business processes, roles, and user requirements for the application.
Teaching goals and content design:	[15,16,18,24,27,29,40]	Define teaching objectives such as learning topic, activities, and storyline.
Technology	[15,16,24,26,27,29,31]	Describe the technology to be used in the application and specify the device for development.
Scenario creation and interaction design:	[15,16,18,23,24,26,27,40]	Illustrative scenarios should incorporate contextual objects that enhance user interaction. Avatars and dialogue scripts can be employed to foster an immersive experience.
Assessment and feedback:	[15,16,18,21,23,24,26,27,29,31]	Implement feedback mechanisms, integrate assessments, and display motivating feedback for learners.
Continuous improvement:	[15,16,21,24,27,39]	Create iVR environment that promotes continuous improvement, ensuring it remains engaging and effective for learners. Continuously update and revise based on users' feedback and changing technology.

3.2.2. Design Recommendations for iVR

Based on content analysis, it was possible to divide the design recommendations for iVR applications for English learning into two main categories: design and learning, as explained below.

Design

Fifteen papers offer design recommendations for iVR applications aimed at English learning. Figure 11 presents these recommendations in a Sankey diagram, illustrating the contributions of each paper regarding each aspect. Among the aspects, interaction design and realism and learning context garnered a substantial number of citations per article.

In cognitive experience, it was categorized recommendations that cover aspects such as cognitive load [18,21,41], diversity of cognitive styles [14], and potential of cognitive experiences in iVR environments [27]. iVR applications should offer fresh cognitive experiences for effective content acquisition within iVR environments [27]. While immersive experiences enhance engagement, designers should be cautious about overwhelming learners' working memory with excessive immersive elements, as it may hinder cognitive processing [18,21,41]. To reduce cognitive load, designers can implement scaffolds that gradually provide information [21] and incorporate verbatim on-screen text to enhance comprehension by reducing cognitive load during listening exercises [18].

Comfort plays a crucial role in the design of iVR language learning applications. Designing an effective iVR language learning environment involves ensuring a safe and supportive atmosphere that minimizes anxiety and encourages active participation [39]. By incorporating avatar-based interactions and anonymity, learners can feel more comfortable practicing and making mistakes in the virtual space [39]. To further reduce anxiety and enhance confidence, the iVR application should provide opportunities for learners to interact with characters, receive feedback, and create a non-threatening learning environment [22]. This involves designing the platform to boost students' self-esteem, risk-taking abilities, and motivation, especially beneficial for those who may feel uneasy speaking in front of others [13]. Additionally, iVR can be leveraged to build students' confidence in expressing themselves in English and foster an error-tolerant environment where learners can practice and improve without fear of judgment [13].

Figure 11. Sankey diagram depicting categories of the design process identified based on authors [13,14,16,18,21,22,24,27,29,39–44]. The left column presents references to articles extracted from the SLR, while the right column displays the identified categories. The connecting lines within the diagram illustrate the relationships between authors and categories. The width of these lines directly quantifies the volume of encoded text, with wider lines denoting greater content and narrower lines indicating smaller amounts of content.

A well-planned content design can ensure effective language learning within iVR applications that is easily comprehensible by users [24]. Immersive experiences can simplify the visualization of abstract and complex concepts [42]. Striking a balance between engagement and learning outcomes, designers should consider a combination of adapted and selected authentic materials, carefully choosing and modifying them as needed [41]. Furthermore, promoting comprehensive language learning requires incorporating a diverse range of content, spanning different topics, vocabulary, and language structures [22]. The validity of content design is paramount, aligning VR content with the intended language use and context [18].

In interaction design, recommendations were incorporated to address user flow [30], interactivity [42], visual and textual cues [21,40], as well as strategies to reduce distractions and prevent cybersickness. Related to user flow, it is crucial to prioritize clear, well-structured learning content while ensuring a seamless flow and logical organization of activities within the application [30]. Interactivity allows users to modify objects, manipulate elements, and have personal experiences within virtual worlds [42]. Other recommendations include emphasizing intuitive user interactions, offering clear tutorials for users unfamiliar with VR, and minimizing distractions caused by novelty in interaction design [29,40]. Employing a variety of cues, including text, images, and on-site indicators, such as scaffolds, and providing multiple representations of information to accommodate different learning preferences ultimately enhances engagement and improving learning performance [21,40]

Finally, it is crucial to address potential cybersickness issues, especially for VR newcomers. This involves minimizing dynamic content that can induce cybersickness symptoms and ensuring a comfortable, nausea-free VR environment, as these directly impact the quality of the learning experience [29]. Additionally, it is important to consider the potential impact of cybersickness on user preferences and learning outcomes, and proactively design interventions to reduce the risk of cybersickness and its influence on user attitudes [40].

Creating environments based on realism and applying 3D visualization can form effective language learning, increase engagement, and facilitate the collaborative learning process [13,29,30,43]. Furthermore, iVR applications should facilitate experiential learning through practical scenarios [21] while ensuring cultural relevance and relatability [27]. Additionally, interactions should be intuitive and meaningful, avoiding unrealistic actions to foster an effective learning process [40]. Finally, achieving a high degree of immersion through advanced technologies is crucial for enhancing learning experiences [42].

The sense of presence is a crucial characteristic to design iVR applications. Designers should focus on creating immersive and engaging virtual environments that facilitate both physical and social affordances, allowing users to feel fully present in the virtual space and fostering co-presence among participants [39]. Encouraging learners to interact with the virtual environment from a first-person perspective enhances their engagement and participation [14]. Maintaining a strong sense of presence within the application, considering factors like audio quality, is essential for user immersion and engagement [29]. Leveraging the mobility and interactivity features of iVR promotes active participation and a sense of "being there" [44]. Designers should strike a balance between creating presence and avoiding cognitive overload to prevent distractions [44]. Prioritizing fidelity of representation and interactivity contributes to immersion and user satisfaction [44], enhancing comprehension and language learning outcomes [40].

The synergy between sensory experiences and the sense of presence and immersion has the potential to significantly enhance user engagement, resulting in improved language learning outcomes [27]. For the optimization of iVR applications in the context of language learning, designers should incorporate audio elements, including character voices and captivating sound effects [30]. Additionally, the incorporation of multimodal inputs, encompassing audio, visual, and textual elements integrated within the VR environment can further enhance the language learning experience by exposing users to diverse sensory modalities [18]. Finally, to ensure a positive sensory experience for users, it is essential to align aspects such as sound design, scenario composition, and interactivity [29].

Regarding user-centered design, designers should prioritize user-friendly interactions, ensuring that the application is intuitive, easy to understand, and responsive to users' actions [30,39]. Collaborating with educators or subject matter experts to create a user-centered design that considers learners' needs, preferences, and cognitive styles is essential [21]. Furthermore, a focus on user satisfaction by developing captivating scenarios, interactions, and visual/audio elements contributes to the application's effectiveness and appeal [29].

Learning

In total, 16 papers describe general recommendation related to learning aspects of iVR applications for English purposed. Figure 12 visually conveys these recommendations, delineating the contributions of each paper in relation to each aspect. Adaptive learning and feedback emerge as focal points, garnering a substantial number of citations per article.

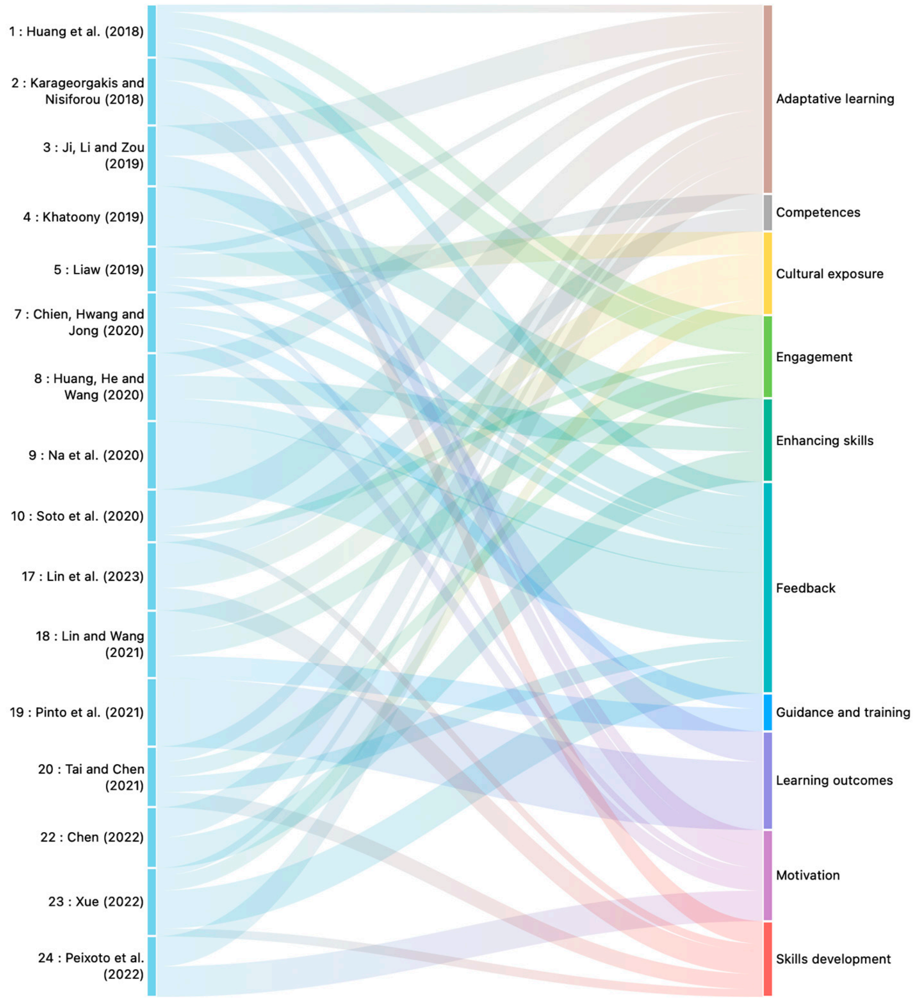

Figure 12. Sankey diagram depicting categories of the design process identified based on authors [13,16,18,20,23,24,26–29,39–44]. The left column presents references to articles extracted from the SLR, while the right column displays the identified categories. The connecting lines within the diagram illustrate the relationships between authors and categories. The width of these lines directly quantifies the volume of encoded text, with wider lines denoting greater content and narrower lines indicating smaller amounts of content.

Most of the papers (n = 9) report that it is necessary to guarantee that iVR applications are highly adaptable, and responsive to individual differences, enabling effective and inclusive learning experiences for a wide range of users with varying needs and preferences [13,23,24,28,39,41–44]. In the context of learning evaluation, emphasizing the promotion of language competence is crucial [18]. This involves crafting scenarios that nurture fluency, comprehension, and formulaic competence, motivating students to articulate ideas cohesively, comprehend spoken language, and recall fundamental language elements to facilitate effective communication.

Several papers ($n = 5$) underscore the significance of engagement in iVR applications, highlighting its role in capturing users' attention and sustaining their interest during the learning process [13,24,28,42,44]. Furthermore, these papers emphasize that engagement not only enhances comprehension and motivation [44], but also underscores the need to design language learning activities capable of creating authentic contexts that fully immerse learners [28,42].

In the context of enhancing language skills, three papers emphasize the importance of incorporating specific elements into iVR applications. These elements include facilitating interactions with native speakers [20], promoting collaborative strategies and effective verbal communication [20,43], and creating immersive learning environments that replicate real-world business scenarios [23]. Researchers also emphasize the significance of learning outcomes [29,41], contending that the design of iVR applications should prioritize the attainment of positive learning outcomes, substantiating their educational value through pre- and post-game assessments, and proficiently aiding language learning objectives.

Incorporating feedback mechanisms within the iVR application is essential to enhance user engagement and learning. These mechanisms encompass various aspects, such as allowing users to express their opinions and feelings [30], providing real-time feedback on user performance [30], utilizing automatic speech recognition for pronunciation feedback [20], enabling reflective feedback processes [39], implementing peer evaluation features [22], and gathering user perceptions through questionnaires [26] and interviews [44]. Detailed feedback, including pronunciation and grammar errors, fosters autonomous learning [27], and an evaluation system that tracks progress objectively is crucial [27]. Regularly collecting feedback from users helps identify strengths and weaknesses [27], and a comprehensive evaluation system should assess sensory, interactive, and cognitive experiences [27]. These feedback mechanisms collectively contribute to an effective iVR language learning environment.

To enhance the effectiveness of iVR language learning, it is crucial to integrate guidance and training [22]. Teachers can contribute by designing scenarios, offering initial feedback, and steering students toward effective language learning strategies. Additionally, the successful implementation of innovative technologies like VR in the classroom necessitates proper training [28]. Diverse teaching approaches, comprehensive guidance, and adequate training are essential to bolster students' self-efficacy across various dimensions of language learning.

When designing iVR applications for language learning, it is imperative to prioritize learning outcomes [41]. The focus should be on evaluating whether increased engagement and immersive experiences translate into positive learning outcomes and improved language skills. To achieve this, designers must ensure that the iVR application substantially contributes to users' learning outcomes and effectively supports language learning goals, as validated through pre- and post-game assessments [29]. The application should demonstrate a significant enhancement in learning outcomes to justify its educational value.

Incorporating motivation is essential for designing effective iVR-based language learning experiences [13,22,24,28,39,40,42]. Creating enjoyable activities and challenges not only makes the learning process engaging and memorable but also encourages active participation. Motivational factors play a crucial role in iVR language learning, with the immersive nature of VR applications enhancing learner motivation and fostering a positive attitude toward learning [22,24,28,39]. Emphasizing the convenience of VR, the novelty of avatars, and global interactions can make language practice enjoyable and motivating [39]. Overcoming initial skepticism by ensuring positive and enjoyable experiences within the virtual environment is vital for dispelling doubts [39]. Incorporating interactive and engaging activities within the VR environment can further boost learning motivation [22]. Fostering a positive and constructive learning atmosphere, where students support each other and collaborate in language improvement, contributes to motivation and enjoyment [22]. Finally, enhancing creative self-efficacy can reduce anxiety and enhance intrinsic motivation, particularly in projects using VR technology for learning [28].

Recommendations about skills development were also noticed by researchers. iVR technology holds significant promise for language learning, as noted by researchers [42]. Its built-in translation capabilities can enhance students' comprehension and expedite educational progress. Moreover, a well-designed iVR platform has the potential to foster not only speaking skills, but also reading proficiency and vocabulary acquisition through immersive, self-paced, and engaging learning experiences [13]. Lin et al. [18] highlighted the immersive nature of VR for improving language accuracy and knowledge retention, while fluency and pronunciation may require additional explicit instruction and practice. Additionally, Tai and Chen [44] stressed the importance of contextual interpretation within iVR experiences to enhance learners' comprehension of spoken content by leveraging the "here-and-now" orientation. Finally, Xue [27] advised a balanced approach to foreign language skill development, encompassing listening, speaking, reading, and writing, combining teaching with practical exercises to enhance overall language proficiency.

4. Discussion

In this systematic literature review, we identified 18 categories of iVR design recommendations for English learning and a design process used to create iVR applications. Additionally, we investigated existing trends related to universities, publications, devices, human senses, and development platforms. In this section, we reflect on our findings and discuss the study limitations. The first section provides an overview analysis to address RQ1 and RQ2, followed by a section on the design process to tackle RQ3, and finally a section on design recommendations to address RQ4.

In general, overview analysis provides information about the current state of iVR applications for English learning. Regarding usual VR headsets, we highlighted that although the HTC Vive is the most common device, most articles reported the use of low-cost VR headsets (Google Cardboard, Samsung Gear, and VR Box), which demonstrates a preference for cost-effective solutions in the development of English learning applications in the iVR domain. In terms of human senses, the findings indicate that visual and auditory perception predominates, underscoring their fundamental importance in engaging users within iVR applications for English language learning.

In the realm of designing innovative iVR applications, we identified that nine articles delved into the intricacies of creating entirely new applications, while another eight papers zeroed in on the utilization of pre-existing applications (Figure 9). Furthermore, other articles featured the incorporation of pre-existing 360-degree videos (n = 3) or the utilization of novel iVR applications generated through a platform (n = 4). This analysis highlights the fact that the majority of articles did not engage in the development of entirely new iVR applications, a trend evident in Figure 8. Given the inherent complexity and cost associated with crafting iVR applications, it is conceivable that researchers may choose a more accessible and cost-effective path by harnessing pre-existing applications or platforms. Table 4 shows the platforms used to design iVR applications.

Table 4. iVR platform used to design applications.

iVR Platform Used	Articles
EduVenture VR	[16,18,28]
Experience Colorblindness	[45]
Google Expedition	[42]
Google Tour Creator	[28]
ImmerMe	[13]
MindShow	[14,22]
Mondly	[44]
Pre-existing 360-degree video	[27,30,41,43]
Tilt Brush	[17]
vTime	[39]

Regarding the design process, it was possible to identify six stages: define the objective, teaching goals, content design, technology, scenario, interaction design, assessment and feedback, and continuous improvement. This process elucidates the need for applications to include assessment and feedback components and concerns related to scenario and interaction design. The importance of implementing exercises and automatic feedback, allowing students to test and measure their learning in real-time, becomes evident. Additionally, the significance of the aesthetic quality of virtual simulations is emphasized, as they should incorporate contextual interactions to ensure a seamless navigation experience.

Issues related to technology, such as technical implementations and hardware definition, also received significant attention in terms of the number of mentions. Given that the development of immersive reality applications demands substantial investments, it becomes essential to predefine the technical aspects to be incorporated into the platform and specify the hardware for which it will be developed. The definition of the device is crucial for addressing interaction-related issues.

Design recommendations for iVR applications in English learning serve as an initial guiding framework, assisting designers and developers in carefully considering crucial factors prior to initiating a project. These recommendations have been derived from a systematic literature review and organized into two categories: design and learning. The design category encompasses topics such as cognitive experience, comfort, content design, interaction design, realism, and learning context, as well as the sense of presence, sensory experience, and user-centered design. These topics integrate subjects aimed at improving the user experience in iVR environments. The learning category includes recommendations related to adaptive learning, competences, cultural exposure, engagement, skill enhancement, feedback, guidance and training, learning outcomes, motivation, and skills development. In this way, the learning category encompasses aspects related to improving the user's learning experience. We purposefully omit language teaching/learning strategies as these would fall outside the scope of this work, and have been well-addressed by other works [22,30,33,35,36,46]

Under the design category, we integrated user experience design recommendations that will exert a substantial influence on the application's development. Notably, interaction design and realism in learning content emerged as prominent themes by their substantial citation count in the literature, highlighting their significance in the referenced papers. The identification of eight themes underscores the intricate nature of designing iVR applications for English learning, encompassing various aspects and challenges.

The design of iVR applications for language learning is a multifaceted endeavor, with several critical considerations. Managing cognitive load while offering fresh cognitive experiences is essential to ensure learners can engage effectively without feeling overwhelmed. Moreover, fostering user confidence and reducing anxiety through features like avatar-based interactions and anonymity plays a pivotal role in creating a safe and supportive learning atmosphere. Content design must balance realism, 3D visualization, and cultural relevance to enhance engagement and comprehension. Interaction design recommendations, including user flow, interactivity, and the use of cues, are vital for improving user engagement and performance. Additionally, addressing cybersickness challenges and finding ways to mitigate its impact on user attitudes is crucial for a positive learning experience. Achieving a high degree of immersion through advanced technologies and striking the right balance between engagement and learning outcomes are overarching goals. These discussions offer insights into the intricate world of iVR language learning applications, where technology, psychology, and pedagogy converge to create immersive and effective learning experiences.

5. Conclusions

This article had as objective to identify design recommendations for iVR English learning applications. Our research was motivated by the existing gap in the research literature, which led us to seek guidelines or considerations for designing iVR applications for English learning. To fulfil this objective, we considered four research questions: RQ1: "Which human senses are most frequently employed in iVR applications for English language learning?"; RQ2: "Which iVR platforms are most commonly used for developing English language learning applications?"; RQ3: "What characterizes the design processes employed to create iVR applications tailored for English language learning?"; and RQ4: "What design recommendations guide the design and development of iVR applications for English language learning?". With the obtained results of the investigation, we were able to answer each one of them.

Visual and auditory are the most used senses in iVR applications for English language learning, answering the research question (RQ1). Some papers also reported the use of proprioception [17] and touch [14,23,27].

The design process to design iVR applications can be characterized by six steps: (1) define the objective, (2) teaching goals and content design, (3) technology and hardware selection, (4) scenario creation and interaction design, (5) assessment and feedback, and (6) continuous improvement. Regarding design recommendations, we identified two main categories, design and learning, that bring together 18 recommendations.

These diverse approaches in VR-based English language learning offer valuable insights into the evolving landscape of technology-assisted education. Discussing the design processes and pedagogical considerations can help educators, researchers, and developers explore new avenues for enhancing language learning through VR technology.

The results of this research are based on systematic literature review. Future studies will delve deeper into recommendations based on interviews with virtual reality experts. Based on the interviews, the recommendations will be evaluated and subsequently reissued.

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