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A Systematic Review of Research for Design and Development in Immersive Virtual Reality Learning Environments*

Sürükleyici Sanal Gerçeklik Öğrenme Ortamlarındaki Araştırmaların Tasarım ve Geliştirme Açısından Sistematik İncelemesi

Fatih Aydın, Hasan Çakır

ABSTRACT

This study presents a systematic review of research studies conducted using immersive virtual reality learning environments in educational settings. The focus is on studies with measurable learning outcomes where participants interact through head mounted displays. The review draws on English-language, peer-reviewed scientific journals published between 2020 and 2024, and explores research design and representation of trend over the years, educational approach, learning goal, subject area, target audience, country, development tool of virtual environment, head-mounted displays utilization, and the indexing status of the journals. Different databases were searched according to the search strategies to access the relevant studies. These searches initially found 815 articles. Following the PRISMA 2020 guidelines and applying specific exclusion criteria, 38 studies were included in the analysis. The results reveal current trends in immersive virtual reality learning environments and provide researchers and designers with important suggestions for the development of future educational practices.

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ÖZ

Bu çalışma, eğitim ortamlarında sürükleyici sanal gerçeklik öğrenme ortamları kullanılarak yapılan araştırmaların sistematik bir incelemesini sunmaktadır. Katılımcıların kafaya takılan görüntüleyiciler aracılığıyla etkileşimde bulunduğu, ölçülebilir öğrenme çıktılarının olduğu çalışmalara odaklanılmaktadır. Araştırma, 2020 ve 2024 yılları arasında İngilizce yayımlanan hakemli bilimsel dergilerden yararlanmakta olup araştırma tasarımı ve yıllar içindeki eğilimi, eğitim yaklaşımı, öğrenme hedefi, konu alanları, hedef kitle, ülke, sanal ortam geliştirme aracı, kafaya takılan görüntüleyiciler ve dergilerin indeks bilgilerini araştırmaktadır. Belirlenen arama stratejileri doğrultusunda ilgili çalışmalara ulaşmak için çeşitli veri tabanlarında aramalar yapılmıştır. Bu aramalar sonucunda başlangıçta 815 makaleye ulaşılmıştır. PRISMA 2020 yönergeleri takip edilerek ve belirli dışlama kriterleri uygulanarak 38 çalışma analize dâhil edilmiştir. Sonuçlar sürükleyici sanal gerçeklik öğrenme ortamlarındaki mevcut eğilimleri ortaya koyarak, araştırmacılara ve tasarımcılara gelecekteki eğitim uygulamalarının geliştirilmesi için önemli öneriler sunmaktadır.

Makale Bilgileri

Keywords
Immersive virtual reality
Learning environments
Systematic review
Design
Development

Anahtar Kelimeler
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Ethical Statement: This article does not require an ethics committee decision as it is a review.

*This study is a preliminary investigation for a doctoral thesis.

Introduction

Recent years have seen a proliferation of Immersive Virtual Reality (IVR) based technologies. The advent of these technologies has engendered a range of opportunities, including the ability to experience realistic situations in 3D immersive media. These technologies hold considerable potential for innovation in educational environments. In contradistinction to other technologies, it brings learning affordances that can support learning outcomes by providing students with interactive experiences in a cognitive, affective, and physically immersive environment (Di Natale, Repetto, Riva, & Villani, 2020; Ferdig, Gandolfi, & Immel, 2018). Learning Envirionments (LEs) built on IVR have been found to support spatial understanding, promote hands-on learning experiences, increase learner motivation, and help with transferring knowledge to new situations (Dalgarno & Lee, 2010). Simply put, the 3D visual features of IVR make it easier to grasp abstract ideas, interact with digital objects, and feel a stronger sense of being presence in the learning space, all of which can make the teaching process more engaging and meaningful (Matovu et al., 2023).

Global sales of Head-Mounted Displays (HMDs) are expected to reach 6.73 million units by 2025 (Alsop, 2025). The production of low-cost, high-resolution HMDs has led to a significant increase in the use of IVR technology in educational settings. Compared to traditional screen-based Virtual Reliaty (VR) systems, HMDs allow users to experience the virtual world directly, increasing their interaction with the environment (Wu, Yu, & Gu, 2020). The elevated degree of interaction facilitated by virtual experiences has been shown to promote the conversion of theoretical knowledge into applied practice, thereby facilitating the development of procedural knowledge and the acquisition of relevant skills (Jensen & Konradsen, 2018; Jung & Park, 2022). In this context, HMD-based IVRs have the potential to provide more meaningful and lasting learning experiences than traditional teaching methods (Conrad, Kablitz, & Schumann, 2024; Wu et al., 2020). Therefore, in general, the use of IVRs in education has the potential to improve learning outcomes (Marougkas, Troussas, Krouska, & Sgouropoulou, 2023).

Nevertheless, in order for the opportunities offered by IVR to be of educational value, certain challenges in its integration must be overcome. In order to achieve the educational potential of IVR, it is essential to address the integration challenges that exist, and to ensure that the technology is aligned with pedagogical goals and teaching processes (Okojie, Olinzock, & Okojie-Boulder, 2006). A perusal of the literature reveals a paucity of reference to the pedagogical frameworks that underpin the development of IVR applications (Johnston, Olivas, Steele, Smith, & Bailey, 2018; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). It is evident that methodological approaches should be employed in order to investigate the competencies of IVR as a pedagogical tool in the field of education (Hamilton, McKechnie, Edgerton, & Wilson, 2021). It is therefore important to carry out research that focuses on IVR from a theoretical perspective and examines its pedagogical possibilities. It is worth mentioning these efforts, especially those taken into account in IVRLEs. Mayer (2022) states that meaningful learning involves the processes of selecting, organizing and integrating prior knowledge at the cognitive level. Makransky and Petersen (2021) provide a framework that explains the cognitive and affective aspects of IVR-based learning. The Cognitive Affective Model of Immersive Learning (CAMIL) addresses how psychological elements such as 'presence' and 'agency' provided by IVR shape the learning process. It also evaluates factors such as motivation, cognitive load and self-regulation that affect learning outcomes in a holistic approach. Another aspect of efforts to advance theory is research into the development of design. Radianti et al. (2020) state that very few studies have a learning theory that leads to development. Hamilton et al. (2021) also in agreement with the finding that the majority of studies do not have a theoretical basis for development.

A review of the results of the systematic analysis of IVRLEs highlights that research and design frameworks have not been sufficiently considered and that research efforts need to be expanded (Pellas, Mystakidis, & Kazanidis, 2021; Radianti et al., 2020). There is a significant gap in the existing literature on the research methods and instructional design features used in the process of developing the design of IVR applications specifically designed for LEs in studies using HMDs. By providing an up-to-date perspective on these critical areas, this review aims to fill a gap by providing researchers with strategic insights and recommendations for technological and instructional choices in the development of IVR-based LEs, ultimately supporting more effective and informed design decisions in IVR training applications.

Relevant Literature

Studies published in the last five years were taken into consideration in order to access the current research in the relevant literature. The existing literature covers different contexts and strategies and does not consider work related to a specific discipline or technique, but rather work within the context of general educational objectives. Details of the Systematic Review (SR) studies identified in the literature that are compatible with the objectives of this study are given in Table 1.

Table 1. Systematic Reviews Related to Research

Article	Research Dimensions	Years
Radianti et al. (2020)	Research method, research design, data analysis method, learning theory, learning outcome, application domain, learning content, design element	2016-2018
Di Natale et al. (2020)	Educational context, learning outcome, motivational outcomes	2010-2019
Hamilton et al. (2021)	Subject area, learning domain, HMDs, theoretical framework, learning outcome	2013-2020
Pellas et al. (2021)	Instructional design approach, design strategy, design techniques, research design method, data collection method, development tool	2009-2020
Luo et al. (2021)	Disciplinary field, instructional design, technological feature, research designs and procedure, data collection method, data analysis method	2000-2019
Marougkas et al. (2023)	Learning theory or educational approach	2012-2022
Conrad et al. (2024)	Comparative media characteristics, learning outcome	2010-2020
Santilli et al. (2024)	Research design, disciplinary field, teaching methodologies	2018-2023

Radianti et al. (2020) conducted a comprehensive review of research gaps that are not usually focused on, such as learning theories, learning content, research methods, design elements for the development of IVR technologies in Higher Education (HE). Usability, user testing and conference papers were also included in the study. In the same year, Di Natale et al. (2020) highlight aspects of IVR that facilitate learning in their ten-year review. The study examines how IVR technology enhances the learning process by engaging students' cognitive and affective domains. It demonstrates that IVR serves as a powerful tool to improve academic performance and ignite intrinsic motivation by transforming classroom instruction into immersive experiences. It also provides educators and researchers with evidence-based, practical recommendations for seamlessly integrating this innovative technology into educational settings. Through a SR of experimental studies conducted between 2013 and 2020, Hamilton et al. (2021) examine the pedagogical impact of IVR in education. They state that IVR provides a learning advantage in science and engineering and is effective in supporting the development of cognitive and procedural skills, but there is a paucity of studies investigating its impact on affective learning domains. Pellas et al. (2021) conducted a study to evaluate the state of IVR in both K-12 and HE. Their research explores how VR impacts the way lessons are designed and the resulting effects on students. The study also compares different VR technologies and teaching approaches to see how they affect student learning. Ultimately, the goal of their review is to pinpoint the specific conditions and design elements that make VR most effective as a learning tool. The application of IVR in K–12 and HE settings between 2000 and 2019 was systematically explored by Luo, Li, Feng, Yang, and Zuo (2021). The role of VR in the classroom is explored through an analysis of 149 articles. The research dimension includes contextual factors, design elements, technological possibilities and research findings. Their findings, while highlighting the evolution of pedagogical approaches over time, suggest that VR makes a moderate contribution to learning performance. Marougkas et al. (2023) carry out a SR of the applications of IVR in education, interpreted through the lens of learning theories and pedagogical approaches. The findings vividly demonstrate the dominance of constructivism, the seamless alignment of experiential learning with VR, and the promising future potential of gamification, while underscoring VR's transformative capacity to reshape learning processes and the indispensable role of theoretical underpinnings in educational design. Conrad et al. (2024) examined the comparative effectiveness of IVR using HMDs according to media characteristics and different types of information. The study shows the benefits of HMD use in terms of knowledge acquisition compared to other media, based on the results of studies reviewed between 2010 and 2020. Santilli et al. (2024) examines the comparative effects of VR and traditional teaching methods in HE. The study examines key factors such as the impact of VR on learning outcomes and its technological features such as immersion and interactivity. Would like to mention some recent studies with specific aspects in addition to the general studies presented in Table 1. Marougkas et al. (2024) with their study on personalization strategies and Huang and Hu (2025) with their study on geography education are the most prominent of these studies.

Rationale for Review

It can be seen that SRs in the relevant literature mainly review studies prior to 2020. This study provides an up-to-date assessment and only includes studies on immersive technologies. In particular, Hamilton et al. (2021) and Conrad et al. (2024) conducted studies based on HMDs only. The last year covered by these two studies was 2020. The widespread use of HMDs has led to differences not only in technical terms, but also in design and development processes and pedagogical approaches. Therefore, it is important to understand how IVR environments are designed, what pedagogical approaches are used and how these changes are reflected in learning processes in the light of recent studies. In addition, existing SRs generally focus on the effects of IVRLEs. It is clear that there is a gap in the literature in terms of reviewing only those studies that have developed an application for IVRLEs. In contrast to other studies, the examination of the index information of the publications included in this study also provides information on academic visibility and prestige.

The aim of this research is to systematically document research designs, educational approaches and design features in the design and development process of IVRLEs in the literature and to guide educational researchers in line with learning objectives. The research questions identified to achieve this objective are asfollows:

1. What are the trends and distribution of research designs used in the development of immersive virtual reality learning environments?
2. What educational approaches inform the design of immersive virtual reality learning environments?
3. What is the distribution of the main findings from the literature review?
    a. Learning objective
    b. Subject area
    c. Target audience
    d. Country
    e. IVR development tool
    f. HMD utilization
    g. Index information of journals

Method

Research Design

This study uses a SR methodology to dig into the nitty-gritty of how IVRLEs are designed and developed. By identifying both the consistent findings and the variations across similar studies, SRs help researchers build a solid understanding of a topic and accumulate reliable knowledge. This approach allows for the integration of knowledge in the field, helps to identify gaps in the research, and can even lead to advancements in theory (Davies, 2000; Gough & Thomas, 2016).

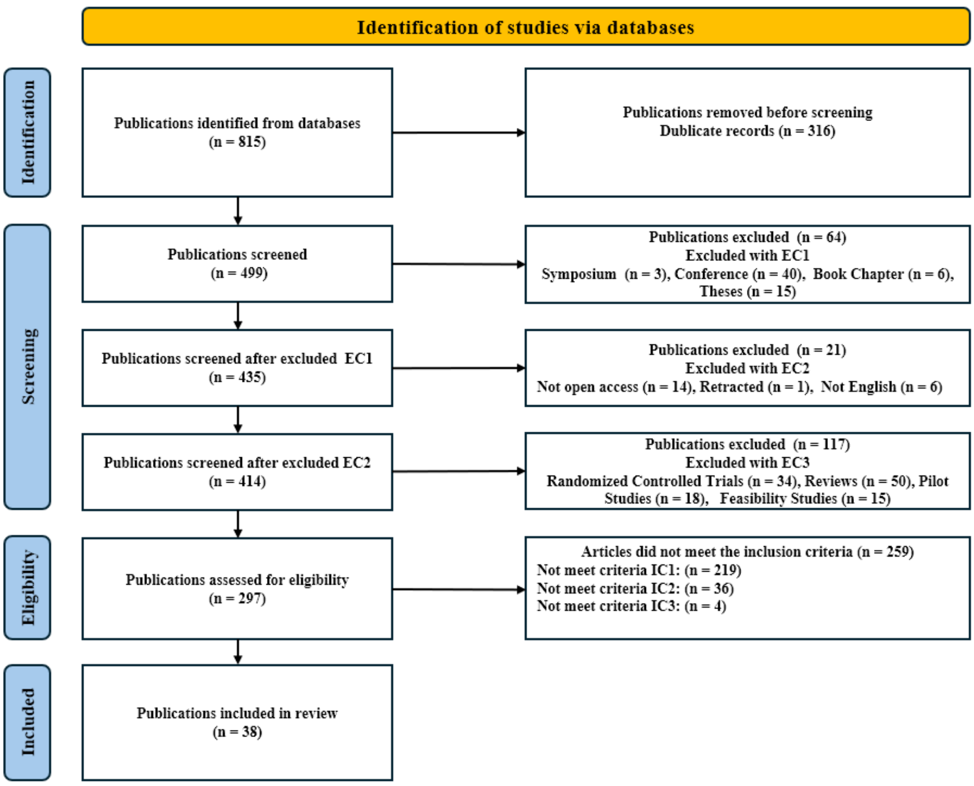

Figure 1. Flow diagram of studies selection process.

To ensure transparency and replicability, followed the updated PRISMA 2020 guidelines (Page et al., 2021). Data collection was guided by a flow diagram adapted from these guidelines. Using this approach helps ensure the research process is clear and can be easily followed by others. The presence of design and development elements in the titles, abstracts, or keywords of studies constituted the core search strategy. On this basis, excluded research studies that examined outcomes not directly related to students or the context of academic education, to ensure consistency with the scope and objectives of this review. The literature search was carried out using the widely recognized databases Google Scholar, Academic Search Complete, ERIC, PubMed, Scopus and ProQuest, which were selected for their comprehensive indexing of the results of educational research. To ensure the reproducibility and validity of the SR, the process, aligned with the PRISMA flow diagram and supported by quantitative data, is presented in Figure 1.

Data Collection

This SR analyzed studies published between 2020 and 2024, with data retrieved from selected databases on 21 January 2025. Details of the search strategies, including specified keywords, Boolean operators are shown in Table 2. Search results were limited to free, full-text, peer-reviewed journal articles in English. The terms 'design' and 'development' were preferred to approximate the focus of the study.

Table 2. Search Strategies and Strings in Databases

Databases	Search strategy
Academic Search Ultimate	TI ("Immersive virtual reality" OR "Immersive VR") AND AB ("design" OR "development")
ERIC	TI ("Immersive virtual reality" OR "Immersive VR") AND AB ("design" OR "development")
Pubmed	"Immersive virtual reality"[Title] OR "Immersive VR"[Title] AND (("design"[Title/Abstract] OR "development"[Title/Abstract]) AND ("learn*"[Title/Abstract] OR "teach*"[Title/Abstract] OR "educat*"[Title/Abstract] OR "train*"[Title/Abstract]))
Scopus	(TITLE ("Immersive virtual reality" OR "Immersive VR") AND TITLE-ABS-KEY ("design" OR "development"))
Proquest	Title ("Immersive virtual reality" OR "Immersive VR") AND abstract ("design" OR "development")
Google Scholar	allintitle: ("design" OR "development") AND ("Immersive virtual reality" OR "Immersive VR") 2020-2024 limit

Study boundaries were established by configuring parameters within the database interfaces to match the research objectives. In the PubMed database, a search strategy was used to retrieve studies relevant to the educational focus, using the terms 'learn*', 'teach*', 'educat*' and 'train*' linked by the logical operator OR to maximize inclusion of relevant literature. However, Google Scholar's limited search interface for data extraction prevented effective restriction of the search scope. As a result of the screening, a total of 815 articles were found (Academic Search Complete= 135, ERIC= 43, Pubmed= 66, Scopus= 286, Proquest= 122, Google Scholar= 163).

The three exclusion and three inclusion criteria outlined in Table 3 were generally applied in the publication selection process shown in Figure 1. Initially, all publications retrieved from the databases were compiled in an Excel document and duplicate results were removed. In the second stage, the EC1 criterion was applied and, due to the limitations of the Google Scholar search, studies such as symposia, book chapters, dissertations and conference proceedings were excluded. This allowed a focus on empirical, peer-reviewed research. In the third stage, according to the EC2 criterion, title and abstract data were reviewed, and publications that were not open access, non-English language and retracted articles were excluded from the results. In the fourth stage, the EC3 criterion was applied, and a full-text review of the results determined that randomized controlled trials, feasibility studies, pilot studies, or reviews were considered beyond the scope of this review. This approach allowed for a focused review of scholarship directly related to the development and implementation of IVR technologies in educational contexts, ensuring alignment with the educational objectives of the study. In the fifth stage, the full texts of suitable publications were assessed and 38 studies that met the IC1, IC2 and IC3 criteria were included in the SR. At all stages of the process, data collection was carried out by two researchers and then checked by another independent reviewer.

Table 3. Selection Criteria for Inclusion and Exclusion

Exclusion Criteria	Inclusion Criteria
EC1: Those without peer-reviewed scientific journal publications	**IC1**: A teaching approach producing measurable educational participant outcomes should exist
EC2: It should exclude non-English language, not open access and retracted articles	**IC2:** It should have a unique HMD-based application shaped by researchers' contributions in design and development
EC3: Interventionist or controlled studies not focusing on participants' educational outcomes should be excluded	**IC3:** The developed environment should be an immersive setting

Coding and Analysis

At this stage, the articles included in the review were coded in the Excel document using the coding sheet shown in Table 4.

Table 4. Coding Sheet

	Research design	Educational approach	Main items
Sub items	Quantitative	Experiential learning	Learning objective
	Qualitative	Problem-based learning	Subject area
	Mixed	Game-based learning	Target audience
	Conceptual	Design-based learning	Country
	Design-based	Constructivist learning	Development tool
	No method	CTML	HMD utilization
	Others	CAMIL	Index information
		Gamification	
		No approach	
		Others	

In this coding sheet, the 'research design' domain was coded in classified such as quantitative, qualitative, mixed, conceptual, design-based, no method, others. The "educational approach" domain is categorized based on the learning approaches encountered in the studies on IVR. These are experiential learning, problem-based learning, game-based learning, design-based learning, constructivist learning, Cognitive Theory of Multimedia Learning (CTML), CAMIL, gamification, no approach and others. The methods and learning approaches marked in the others section were further reclassified after the coding was completed. Due to the diversity of the data for the "main items" sub-items, no classification was made beforehand, and classification procedures were performed during the coding of the data. In the "learning objective" domain, if there is more than one learning objective in an article, they are coded separately. In the "HMD utilization" domain, the brand and model of the device mentioned in the article is directly indicated. In the "index information" field, if the journal is indexed in more than one index catalog, this is coded separately.

The analysis of the data was carried out by determining the frequency values in the Excel program. The structure of the examined domain and the graph type suitable for the result to be emphasized were selected and displayed.

Findings

Research Design Trends in Immersive Virtual Reality Learning Environments

What are the trends and distribution of research designs used in the development of IVRLEs? Figure 2 shows the distribution and trends of research designs used in the development of IVRLEs between 2020 and 2024.

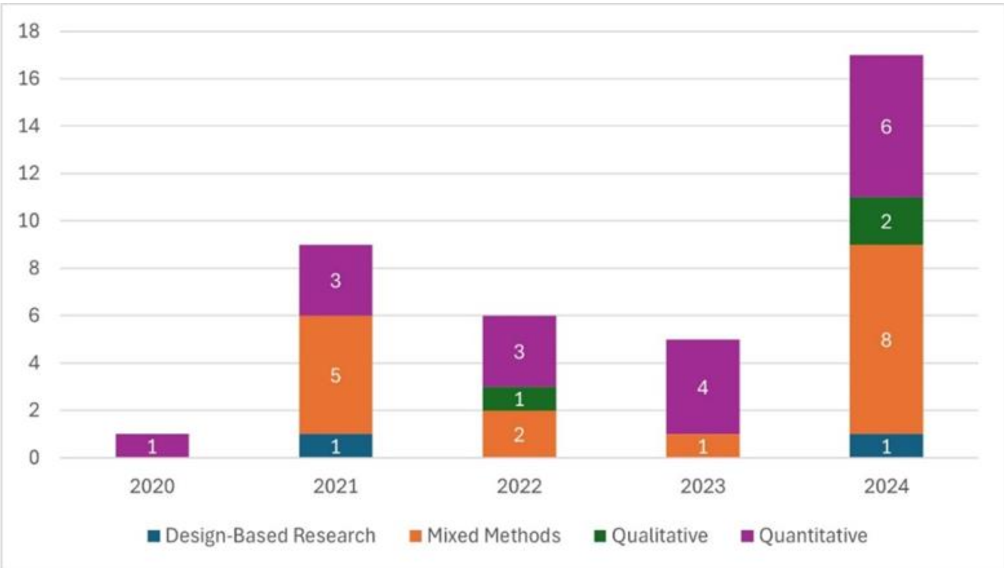

Figure 2. Research design trends by year.

In 2020, only one study using a quantitative research approach was identified. In 2021, mixed methods were predominantly used (n=5) followed by quantitative (n=3) and design-based research (n=1). In 2021, mixed methods were predominantly employed (n=5), supported by quantitative (n=3) and design-based research (n=1). In 2022, a more balanced distribution was observed among mixed methods (n=2), quantitative (n=3), and qualitative (n=1) approaches. In 2023, mixed methods (n=1) and quantitative research (n=4) were prominent, while qualitative research was absent. In 2024, mixed methods (n=8) and quantitative approaches (n=6) demonstrated a notable increase, whereas qualitative (n=2) and design-based research (n=1) remained limited. These findings indicate a progressive shift towards mixed methods and quantitative research in IVR studies, while the use of qualitative approaches has remained relatively limited**.** These findings largely align with the studies of Pellas et al. (2021) and Luo et al. (2021). According to Pellas et al. (2021) while experimental studies are often preferred to measure IVR effectiveness, HE uses mixed methods to understand more complex learning processes. Luo et al. (2021), on the other hand, take a broader perspective on experimental research design and include quantitative, qualitative and mixed methods within this category. Meanwhile, the study by Radianti et al. (2020) presents an alternative classification of research designs, categorizing them as design-oriented, conceptual, empirical qualitative, and empirical quantitative. Similarly, Santilli et al. (2024) report that mixed methods play an important role alongside quantitative research approaches.

Distribution of Educational Approaches in Immersive Virtual Reality Learning Environments

What educational approaches inform the design of IVR learning environments? Figure 3 shows the distribution of learning theories or educational approaches. The findings show that experiential learning (n=12) was the most frequently adopted approach. Researchers seem to have a strong interest in the potential of IVR to support interactive and experience-oriented learning. Gamification (n=6) and constructivist learning (n=4) also reflect the integration of participatory, student-centered methodologies. Hybrid design (n=3) represents the category that brings together multiple theoretical approaches. Furthermore, CTML (n=2), collaborative learning (n=2) and flow theory (n=2) are seen as more limited approaches. Task-based learning, situated learning theory, problem-based learning, game-based learning, design-based learning, embodied learning and action learning (n=1 each) have not been adequately studied in IVR environments. Overall, the findings reveal a strong preference for experiential and gamification-based strategies in the design of IVRLEs.

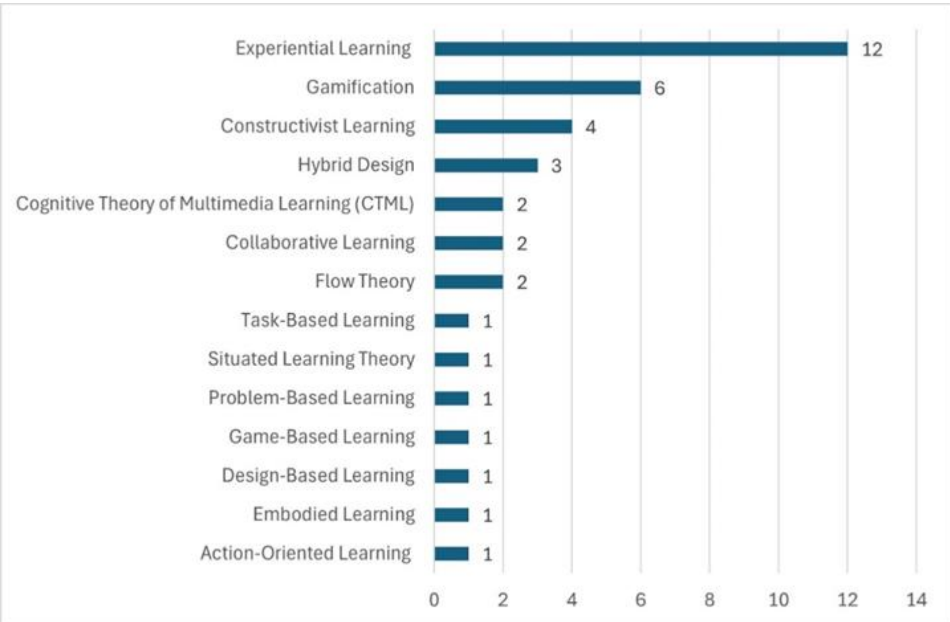

Figure 3. Distribution of educational approaches.

Previous research on IVRLEs reveals gaps in the explicit use of learning theories. Studies by Radianti et al. (2020) and Hamilton et al. (2021) state that with the exceptions of experiential learning, generative learning, CTML and situated learning, the majority of studies do not specify a clear pedagogical framework. In K-12 contexts, Pellas et al. (2021) report on the prevalence of student-centered approaches such as virtual field trips, project-based learning, game-based learning and problem-based learning. Luo et al. (2021) identify a shift from inquiry-based methods to direct instruction in IVR applications, which they attribute to new immersive features. Marougkas et al. (2023) identify several frameworks, including constructivism, experiential learning, gamification and flow theory, but report their limited coverage.

Table 5. Educational Approaches and Application Subjects

Educational approach	Application subjects
Experiential learning	Filmmaking, architectural history, fire safety, nursing simulation, empathy, briefing safety, suicide risk, language learning, architectural spaces, police training, classroom management
Gamification	Fire safety, neonatal resuscitation, aircraft maintenance, learning topology, animal handling, hazard perception
Constructivist learning	Physical theory, designing gardens, physics classroom simulation, teaching architecture
Hybrid design	Epistemic curiosity, geo-contextualgame, climate change
CTML	Service robot animation, microbiology
Collaborative learning	Chemistry tasks, geography training
Flow theory	Plants and environments
Task-based learning	Virtual garage
Situated learning	Indwelling urinary catheter
Problem-based learning	Virtual anatomy laboratory
Game-based learning	Lab safety
Design-based learning	Geometrical tools
Embodied learning	Electricity concepts
Action-oriented learning	Virtual salesroom

As detailed in Table 5, the educational approaches in IVRLE cover a wide range of subjects. For instance, experiential learning (n = 12) is employed in areas such as filmmaking, architectural spaces, history, fire safety, empathy, safety briefings, suicide risk assessment, police training, nursing simulations, and language learning. Gamification (n = 6) is used in subjects such as fire safety, neonatal resuscitation, aircraft maintenance, topology, animal handling and hazard perception. Constructivist learning (n = 4) is used in subjects such as physics, garden design and physics classroom simulations. Hybrid designs (n = 3) are used in contexts such as epistemic curiosity, geo-contextualised games and climate change. Less frequently used approaches include CTML (n = 2), collaborative learning (n = 2), flow theory (n = 2), task-based learning (n = 1), situational learning (n = 1), problem-based learning (n = 1), game-based learning (n = 1), design-based learning (n = 1), embodied learning (n = 1) and action-oriented learning (n = 1). These approaches are applied to specific topics such as microbiology, chemistry tasks, virtual anatomy labs and virtual salesrooms.

In summary, experiential learning and gamification stand out as consistently popular approaches in IVRLEs. Moreover, the combination of learning theories under the category of hybrid approaches reflects an innovative trend. Although different contexts were examined, it is worth noting that there are important similarities between the study by Marougkas et al. (2023) and the present study in terms of the outcomes of the different educational approaches.

Distribution of Learning Objectives

What is the distribution of the learning objectives from the SR? Table 6 shows the learning objectives stated in the articles analyzed, with some articles having more than one learning objective.

Table 6. List of Learning Objectives in Reviewed Studies

Learning objective theme	Number of articles including
Knowledge acquisition	11
Social behavioral skills	10
Applied skills	10
Decision making skills	9
Spatial reasoning and perception	9
Problem solving skills	8
Technical skills	6
Conceptual understanding	5
Clinical reasoning skills	4
Transfer and integration skills	3
Knowledge management	3
Critical thinking	2
Reflective thinking	2

The results show that different skill areas have different levels of importance in IVRLEs. Knowledge acquisition is one of the most emphasized skills. Subsequently, social behavioural skills, in addition to applied skills, are addressed. Social behavioural skills encompass elements such as communication, collaboration, and social interaction. Applied skills are categorized as competencies that support learning through practical applications, ranging from mathematical reasoning to classroom management, going beyond theoretical knowledge to effective use in real-world contexts. Other skill areas include decision making, spatial reasoning and perception, problem solving, technical skills, conceptual understanding, clinical reasoning, transfer and integration skills, knowledge management, critical and reflective thinking.

Distribution of Subject Area Findings

What is the distribution of subject areas studied? The domains shown in Figure 4 are categorized based on the content taught and the purpose of the studies reviewed. Medical and nursing education are defined as separate categories as they focus on specific professional competencies such as surgical skills or patient care. When analyzing the results, science, education and vocational education had the highest representation with seven studies each, followed by engineering and architecture and safety education with five studies each. Nursing education was represented by four studies, while medical education, health education and arts education were represented by one study each.

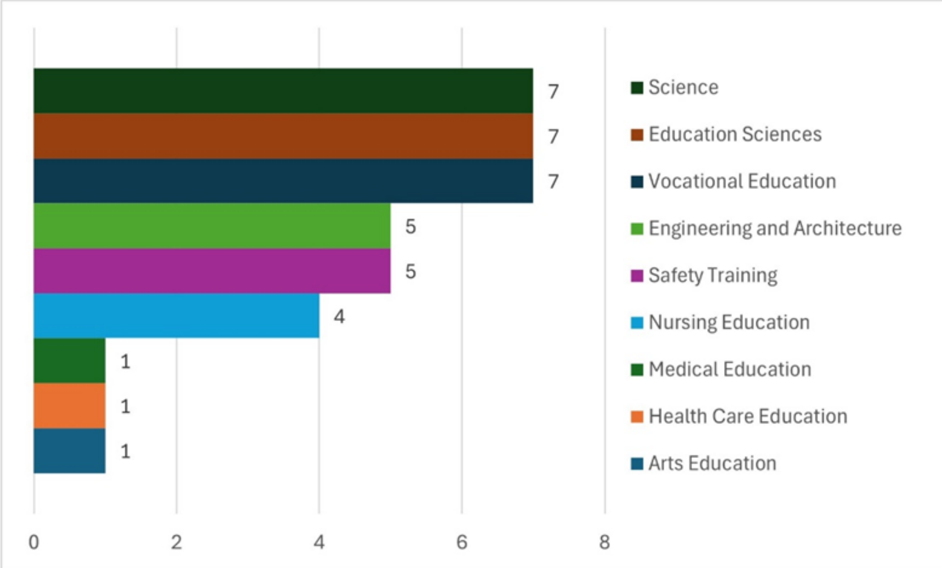

Figure 4. Distribution of subject area.

To evaluate these results with the subject areas in other reviews, Radianti et al. (2020) report the dominance of engineering and computer science, Hamilton et al. (2021) report the dominance of science, engineering-architecture. This demonstrates the strong application of IVR in technical and science disciplines. Luo et al. (2021) found health, medicine and basic sciences, while Santilli et al. (2024) reported health sciences and science as the leading fields.

Distribution of Target Audience

What is the distribution of the target audience from the SR? A graph of the target audience of the scanned studies is shown in Figure 5.

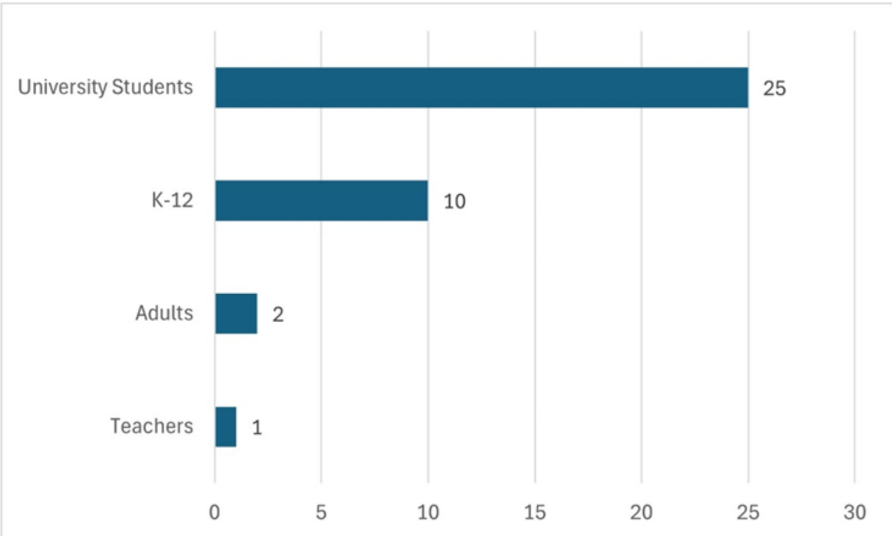

Figure 5. Distribution of target audience.

The majority of studies in the SR on IVR focused on university students (n=25), with a smaller number focusing on K-12 students (n=10), adults (n=2), and teachers (n=1). Consistent with these data, Matovu et al. (2023) report that 58% of studies are concentrated in HE. Similarly, Conrad et al. (2024) find that studies on university students predominate.

Figure 6 shows the distribution of target audiences according to subject area, revealing the diversity and limitations of IVRLE use cases. For example, university students are involved in a wide range of subject areas, such as educational sciences (n = 5), engineering and architecture (n = 4), nursing education (n = 4), and vocational education (n = 4). This indicates the versatile use of IVRLEs in HE. In contrast, K-12 students are concentrated in the sciences (n = 5) and underrepresented in fields such as engineering and architecture (n = 1) and educational sciences (n = 1). By contrast, adults are only marginally represented in safety education (n = 1) and vocational education (n = 1), while teachers are only represented in educational sciences (n = 1). This distribution shows that IVRLEs are primarily used in academic settings, particularly by university students, but are less developed for other target groups.

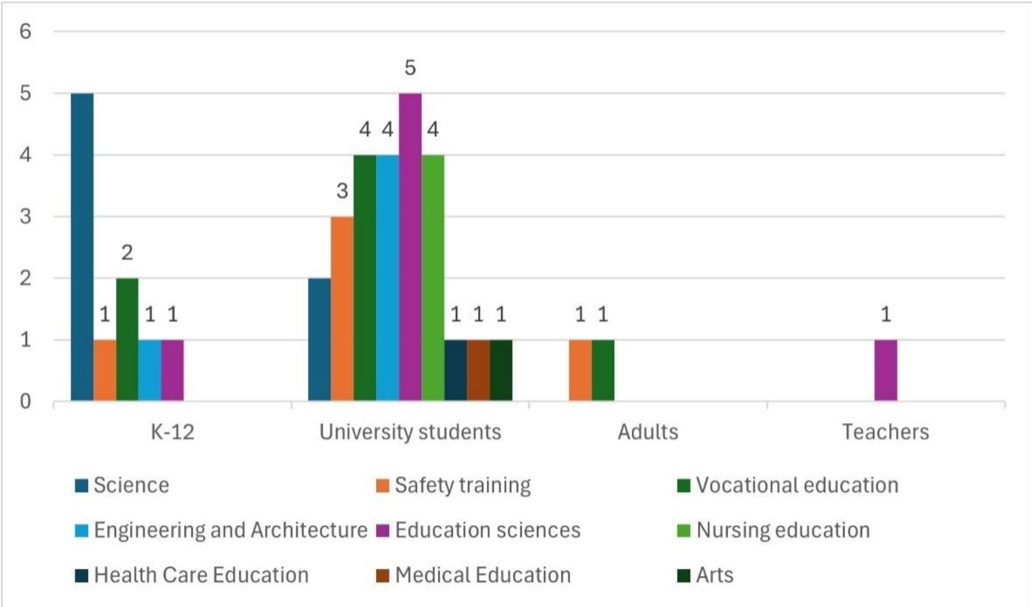

Figure 6. Analysis of IVRLEs distribution by target audience and subject area.

Distribution of Countries Where Studies are Conducted

What is the distribution of countries where the studies are conducted? As shown in Figure 7, the data presented, derived from an analysis of the universities affiliated to the first authors, reveal a notable concentration of IVR research activity in certain geographical regions.

China has a particularly strong presence (n=7) and leads in terms of the number of studies. The United States (n=4) and Taiwan (n=4) also show a significant commitment to the field. In addition, the presence of studies from Belgium, Spain, Finland, Germany and South Cyprus underlines the trend towards IVR research in the European context. Close to these findings, Luo et al. (2021) provide valuable context. Their analysis of VR in K–12 and HE demonstrate that the majority of studies have been conducted in three primary regions: North America, Asia, and Europe, with the United States, the United Kingdom, and Taiwan being the most frequently represented countries.

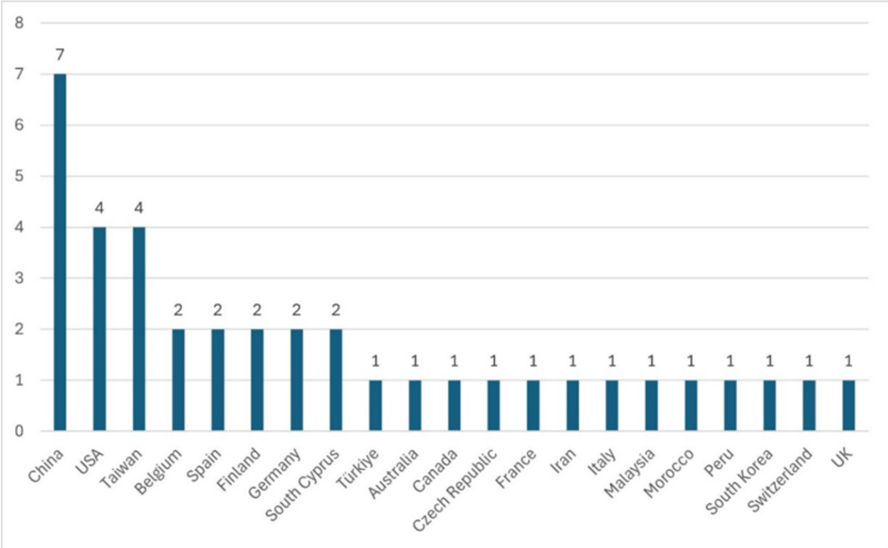

Figure 7. Distribution of countries.

Distribution of IVR Development Tool

What is the distribution of the development tools used in the studies? An analysis of the development tools in use in IVRLEs as shown in Figure 8, reveals several key platforms adopted by researchers, with Unity emerging as the most frequently reported tool (n=27), followed by 'not specified' (n=6), Unreal Engine 4 (n=2), OpenGL/OpenVR (n=2), and a combination of Tilt Brush, SketchUp Pro 2019, and VR Enscape 3D (n=1). This predominance of Unity is consistent with its established leadership in the IVR development landscape, where it powers over 60% of VR experiences on platforms such as Meta Quest and SteamVR, which is attributed to its accessibility and robust community support (Unity, 2025). Conversely, the limited use of Unreal Engine is seen as an important finding.

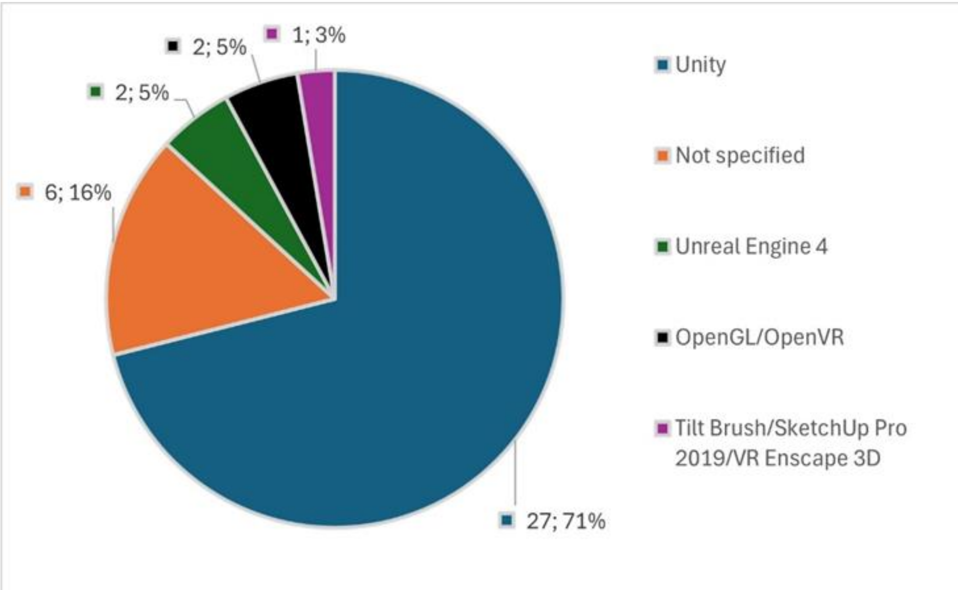

Figure 8. Distribution of IVR development tool.

Distribution of HMD Utilization

What is the distribution of HMDs used in studies? Analysis of the HMDs, as shown in Figure 9, reveals a diverse landscape of devices used in the included studies.

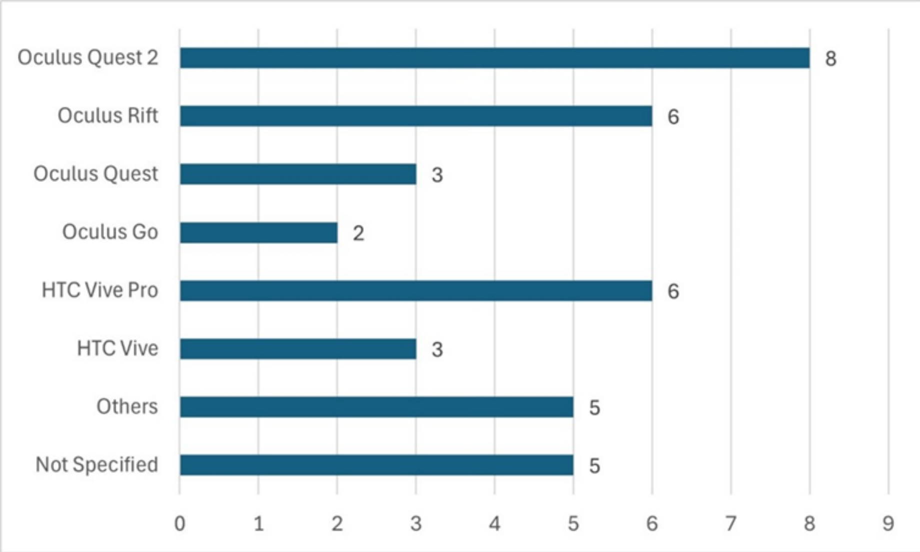

Figure 9. HMD utilization.

The most commonly reported HMD was Oculus Quest 2 (n=8), followed by Oculus Rift (n=6) and HTC Vive Pro (n=6). Other HMDs included HTC Vive (n=3), Oculus Quest (n=3) and Oculus Go (n=2). A significant proportion of studies did not report the HMD utilization (n=5), while another segment reported 'other' (n=5).

The findings reflect the adoption trends of technology with immersive features. The popularity of the Oculus Quest 2 suggests that it is related to its standalone capabilities, ease of use and relatively inexpensive price. While the review by Hamilton et al. (2021) reported that the Oculus Rift and the HTC Vive were the most popular HMDs at the time, these results suggest that the Oculus Quest 2 is more preferred at the present time. This development likely reflects the growing demand for user-friendly and accessible VR experiences.

Index Information of The Reviewed Journals

What is the index information of the journals in which the research is published? The journals analyzed in this study were classified according to different types of indexes included in the Web of Science Core Collection. The index coverage of journals is an important indicator of both scientific visibility and publication quality. The data presented in Table 7 show the scientific level and the multidisciplinary structure of the referenced sources. In order to show this structure as it is, the cases indexed in different core collections are shown together.

In this context, a total of 26 different journals were defined under five index classes, and the journals were coded and presented. Social Sciences Citation Index (SSCI) & Science Citation Index Expanded (SCI-E) are the journals indexed together (n=9). The journals in this group demonstrate that research has a strong literature base in both the social sciences and the natural sciences, appealing to a broad academic audience with the advantage of this dual indexing. Journals indexed solely in SSCI (n=6) and solely in SCI-E (n=4) also belong to highly prestigious index groups, reflecting the scientific quality and interdisciplinary impact of IVR research. The number of journals indexed in both SSCI & AHCI is (n=1), reflecting the intersection of social sciences with arts and humanities. The journals in the Emerging Sources Citation Index (ESCI) (n=6) are innovative and emerging academic journals that make significant contributions to current issues and new areas of research. This distribution, particularly the prominence of highly prestigious indexes such as SSCI and SCI-E, highlights the enhanced scientific visibility and academic impact of IVR studies.

Table 7. Distribution of Journals by Index Information

Index category	Journal codes	Number of journals
SSCI & SCI-E	J3, J4, J7, J10, J12, J13, J14, J17, J22	9
SSCI	J1, J2, J5, J6, J9, J11	6
SSCI & AHCI	J24	1
SCI-E	J8, J23, J25, J26	4
ESCI	J15, J16, J18, J19, J20, J21	6

Discussion and Conclusion

When IVR technology is incorporated into LEs, students learn by experiencing the subjects, unlike traditional methods. This increases interest in the training and contributes to the retention of information (Crogman, Cano, Pacheco, Sonawane, & Boroon, 2025). But for these IVRLEs to be useful, many factors need to be carefully considered, such as the design of pedagogical approaches and instruction, as well as technological capabilities (Bizami, Tasir, & Kew, 2023; Hamilton et al., 2021). This chapter presents the theoretical and pedagogical underpinnings of IVRLEs, discusses the findings that reflect current trends, and draws conclusions.

When analyzing the results in terms of the research methods of the included studies, although Radianti et al. (2020) state that design-oriented, empirical qualitative and quantitative research is dominant in IVR studies, there is a clear shift towards mixed methods and quantitative research in studies between 2020-2024. As can be seen, the use of qualitative approaches is limited. Although IVR research has traditionally been more exploratory and design-oriented, over time there has been a trend towards quantitative methods aimed at measuring IVR effectiveness and mixed methods that combine different types of data. The limited qualitative research suggests that the potential for better understanding the IVR experience and enriching the user experience has not yet been fully realized. As a result, although previous literature has highlighted the lack of rigorous methodological designs in IVR research (Makransky & Mayer, 2022). The results of this study point to a methodological shift, especially in recent years, with the increasing use of mixed methods and quantitative approaches. However, the under-examination of qualitative and design-based research in recent years raises concerns about the advancement of theoretical knowledge.

Based on the findings on educational approaches, there is a predominance of studies on experiential learning, which highlights the importance researchers attach to the potential of IVR to support interactive and experiential learning (Tacgin & Dalgarno, 2021). This is undoubtedly due to the fact that IVR environments offer students the opportunity to safely understand abstract concepts through concrete experiences (Matovu et al., 2023). Gamification and constructivist learning are also prominent, reflecting the integration of interactive and learner-centered methodologies. Gamification is known to increase student engagement by making learning more fun and motivating (Yang et al., 2023). Constructivist learning encourages students to construct their own knowledge; IVR support this process through exploration and experimentation (Matovu et al., 2022). Another striking aspect of the results is the hybrid design found. Hybrid design approaches are becoming increasingly important in the design of IVRLEs. These approaches allow IVR designers to create a sense of reality in virtual environments by combining different pedagogical strategies to make the learning experience richer and more diverse (Cheng, 2023; Porte, Boucheix, Rapet, Drai-Zerbib, & Martinez, 2024). This development may lead to the emergence of features designed with learning objectives and student needs in mind (Tacgin & Dalgarno, 2021), providing interactive and meaningful experiences. In general, experiential, gamification-based and constructivist approaches to learning are strongly prioritized to increase interaction and participation, with the impact of technological developments driving learning theory preferences. Therefore, it can be said that there is an increasing need for more studies on how these approaches are applied and what results they produce in different student characteristics and different subject areas. The diverse applications of educational approaches in IVRLEs demonstrate their alignment with theoretical frameworks and their positive impact on learning outcomes. For example, experiential learning is prevalent in contexts such as filmmaking and nursing simulation. It leverages the immersive properties of IVR to facilitate hands-on experiences (Tacgin & Dalgarno, 2021), and aligns with the CAMIL. This model emphasises presence and agency (Makransky & Petersen, 2021; Matovu et al., 2023), which increases conceptual understanding and motivation (Yang et al., 2023). Gamification, when applied to areas such as neonatal resuscitation and hazard perception, increases engagement through task-based scenarios and reward systems. Constructivist learning, employed in subjects such as physics and garden design, fosters student agency and critical thinking, drawing on the theories of Piaget and Vygotsky (Matovu et al., 2022). Hybrid designs, seen in innovative contexts such as epistemic curiosity and geo-contextualised games, combine multiple theories to create rich learning experiences that address the needs of different learners (Cheng, 2023).

Another point presented in the findings is the examination of the learning objectives expected of the participants. It is known that the effectiveness of IVRs in LEs depends on the advancement of conceptual frameworks that include cognitive, affective factors and pedagogical strategies (Makransky & Petersen, 2021). The results highlight cognitive skills, particularly knowledge acquisition and conceptual understanding, are most emphasized in IVR environments, reflecting their central role in educational contexts. After that, social behavioral skills and applied skills are seen to come to the fore and this result points to interactive learning experiences. In addition, spatial reasoning and perception (Wang, Yaqin, & Lan, 2024), which are crucial in immersive environments, emerge as key areas of focus, illustrating the importance of spatial awareness in IVR. The prominence of these skills suggests that IVRLEs not only support cognitive development, but also develop students' spatial perception and awareness skills and comprehension skills, as well as their social and applied skills. It is reported that IVRs may be more effective in teaching both cognitive and psychomotor skills (Hamilton et al., 2020) and in supporting declarative knowledge acquisition (Conrad et al., 2024) compared to traditional teaching methods. This is in line with the prevalence of cognitively oriented studies in the results of this review. Accordingly, it demonstrates the potential power of IVRs in teaching knowledge, concepts and theories and that, when carefully designed, they enable deep learning by engaging students in meaningful cognitive processing (Mayer, Makransky, & Parong, 2023).

Radianti et al. (2020), Hamilton et al. (2021), Luo et al. (2021) and Santilli et al. (2024) report that studies in the science, health and technical fields are the prominent subject areas. Unlike these studies, in this research, studies within the scope of education sciences and vocational education were defined as separate subject areas. It is not surprising to find more science, educational and vocational studies in the subject area results, as the studies analyzed should include a training. Engineering and architecture, safety training and nursing education also stand out as subject areas with high representation. However, as the Covid-19 pandemic period and post-pandemic studies were reviewed, it would have been expected that there would have been more studies in this period due to the role of immersive technologies in overcoming the challenges (Khan, Ali, Khan, & Al-Antari, 2024) caused by the pandemic in health disciplines. The main reason for this may be that studies such as randomized controlled trials, which are commonly used in health and medical sciences, were not included in this study.

It can be seen that the majority of the studies reviewed focus on university students. One of the main reasons for the widespread use of IVR technology in HE is that complex and abstract concepts, especially in STEM fields, can be visualized in a 3D environment. This feature facilitates students' deeper conceptual learning in disciplines that require spatial understanding, such as biology and physics (Acevedo, Magana, Benes, & Mousas, 2024). This intense interest in HE may be closely related to the potential of IVR to provide hands-on and intuitive learning experiences and the direct pedagogical contribution of the technology (Craig & Kay, 2023; Matovu et al., 2023). K-12 students are predominantly represented in science but show limited presence in areas like engineering and architecture and education sciences. Limited representation of adults and teachers, and the absence of groups such as students with special educational needs, suggests that various demographic groups are under-examined. This is due to the fact that the IVRLE development process is complex and often prioritises educational settings. Recent studies demonstrate the potential of IVRLEs for inclusive education. Applications providing support for children with autism spectrum disorders, for example, are noteworthy in this regard (Soltiyeva et al., 2023). Future research should focus on developing IVRLE applications for underrepresented groups, such as those in special needs education and teaching the elderly. This would extend the educational impact of this technology to a wider audience.

The distribution of the countries in which the studies examined were carried out, mainly China, The United States and Taiwan, as well as European countries, contains some important indicators. The first could be China's Smart Education (Wang, 2023; Zhang, 2025), the USA's EdTech plans, Taiwan's DIGI+, the European Union's Horizon Europe funding and national policies supporting innovative technologies such as IVR technologies, artificial intelligence. The expected outcomes are that this support will increase innovation in education, encourage collaboration with different sectors, guide cultural development and educational research. Another factor is that these countries are developing ecosystem software (e.g. development tools such as Unity, Unreal Engine) with their technological infrastructure to produce hardware (e.g. HMDs such as Meta Quest and HTC Vive). Therefore, IVR development tools and HMDs mentioned in the findings seem to have taken the lion's share of the pie due to their widespread and academic acceptance. This dominance is not accidental, but rather reflects the critical importance of selecting appropriate authoring tools when designing IVRLEs. The choice of such tools plays a critical role in creating effective, engaging virtual experiences with pedagogical underpinnings. The new technical capabilities offered by IVR development platforms are thought to significantly reduce design and development barriers, accelerating the adoption of immersive technologies in LEs. Another non-coincidence was that the results coincided with the market share of HMDs used by the research participants. In educational environments, the ability of the Meta Quest 2 and HTC Vive brands to work with computer-independent installation, the sense of presence in the virtual environment and the immersive innovations it brings to interaction have created a milestone effect on the user experience. On the other hand, merely providing a sense of presence will not be enough to ensure effective learning. Well-designed IVR experiences positively affect the learning process by reducing factors that cause cognitive overload (Liu, Wang, Koszalka, & Wan, 2022). Therefore, in order to maximize the educational benefits of these tools, it is important to apply appropriate instructional design principles during the development of IVRLEs (Makransky, Terkildsen, & Mayer, 2019; Tacgin & Dalgarno, 2021).

The journals in which the analyzed studies are published are largely included in indexes with high impact levels. In particular, it shows that the studies published in journals covered by both SSCI and SCI-E are strongly examined on scientific grounds between social sciences and natural sciences. The presence of journals indexed only by SSCI shows that IVR studies maintain their increasing importance in the fields of education and social sciences, while an innovative and developing direction is seen with the journals covered by ESCI. In this context, the index structure of the journals shows that the treatment of IVR in the context of education is not limited to social sciences, but also that the search for collaboration with different disciplines such as engineering, health and science is strong.

This paper presents an up-to-date SR of the trends, theoretical foundations and methodological approaches in the field of IVR design and development in education. A general flow perspective is thus provided for researchers and designers interested in developing both educational and technologically effective LEs. The findings not only fill gaps in existing research, but also provide a useful framework for future research on how to design IVR systems. In particular, future studies are recommended that develop applications for underrepresented groups to better understand the inclusive education potential of IVRLEs (Soltiyeva et al., 2023). Furthermore, due to the absence of qualitative and design-oriented research, it is suggested that the theoretical and pedagogical foundations of the IVR experience be enriched through in-depth studies exploring user experiences (Makransky & Mayer, 2022). Investigating the applicability of IVRLEs in different disciplines (e.g. the arts or the social sciences) and informal learning environments (e.g. museums) would allow us to assess the impact of this technology on learning in a broader context. Finally, examining the integration of IVR development tools and HMDs with pedagogical design principles could contribute to the design of more effective and accessible learning environments.

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Conflict of Interest

There is no conflict of interest

Ethical Statement

This article does not require an ethics committee decision as it is a review.