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Systematic Review of Educational Practices with Immersive Virtual Reality in Higher Education

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Abstract

The increased use of virtual learning platforms, intensified by the COVID-19 pandemic, underscores the importance of digital transformation in education. Research by the European Commission (2022) on the Extended Reality ecosystem, suggests that immersive technologies can be allied and integrated into the learning process. This study aims to analyse how learning occurs in immersive environments, their characteristics, benefits, and limitations. A systematic literature review methodology was adopted following the PRISMA protocol. The article selection process consisted of three stages, resulting in the analysis of 39 publications. After three stages of selection, 39 publications were analyzed, revealing that virtual reality enables the creation of virtual environments where students can actively interact and explore These simulated environments offer students the opportunity to experience authentic situations and apply their knowledge in a practical way. This review contributes to expanding discussions and considerations regarding the use of immersive technologies in an educational context.

Key concepts:

Educational practices, higher education, immersive environments, student learning, virtual reality.

Resumo

O aumento do uso de plataformas virtuais de aprendizagem, impulsionado pela pandemia da COVID-19, destaca a importância da transformação digital na educação. Pesquisas da *European Commission* (2022) sobre o ecossistema de Extended Reality sugerem que tecnologias imersivas podem ser aliadas e integradas ao processo de aprendizagem. Este estudo analisa como ocorre a aprendizagem em ambientes virtuais imersivos, suas características, benefícios e limitações. Foi utilizada a revisão sistemática da literatura em conformidade com o protocolo PRISMA. Após três etapas de seleção, 39 publicações foram analisadas, revelando que a Realidade Virtual possibilita a criação de ambientes virtuais nos quais os estudantes podem interagir e explorar ativamente . Esses ambientes simulados oferecem aos alunos a oportunidade de vivenciar situações autênticas e aplicar seu conhecimento de forma prática. Esta revisão amplia as discussões sobre o uso de tecnologias imersivas na educação.

Palavra-chaves:

Práticas educacionais, ensino superior, ambientes imersivos, aprendizagem, realidade virtual.

Introduction

The revitalization of pedagogy requires an intellectual investment identical to that made in science and research, it requires the construction of new practices, the search for new ways of teaching, and an effort to recover the lost enthusiasm of the educational gesture" (Nóvoa, 2018, p.20). This necessity is particularly pronounced in the current era of digitalization and connectivity, which are precipitating societal changes that extend to education. Consequently, there is a pressing need to develop new learning scenarios that offer multiple avenues for accessing information, leverage new applications and devices, expand the availability of quality digital content, and create realistic and interactive learning environments.

The growing attention to the eXtended Reality (XR) ecosystem in the media reflects the expectation that immersive technologies will be widely applied in different contexts in the coming years, including in education. This expectation is confirmed by the European Commission report, which describes the state of the art and assesses the strengths and weaknesses of existing research on the use of XR in health and education (European Commission, 2022).

Immersive technologies, encompassing virtual reality, augmented reality, and mixed reality, are discussed collectively under the term "Extended Reality (XR)" in the literature. The focus of this study is on Virtual Reality (VR), due to its potential contribution to education as presented in systematic reviews on the subject (Agbo et al., 2021; Di Natale et al., 2020; Radianti et al., 2020).

“Virtual reality technology is the integration of artificial intelligence technology, multimedia technology, computer graphics technology and computer network technology and developed into a new computer human-computer interaction technology, users can experience the three-dimensional virtual environment computer-generated , and naturally make a real-time interaction with virtual environment from visual, auditory and even tactile and taste, obtaining the similar operating experience with real-world” (F. Wu et al., 2015).

VR technology enables the creation of a simulated digital environment that allows for more dynamic interaction with content through immersion. There is still no consensus on the term immersion, and it is understood that “Immersion is a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and

experiences" (Witmer & Singer, 1998, pag 227). Makransky and Lilleholt (2018) indicate that VR is a way to simulate or replicate an environment. For the authors, there are several different VR systems, such as: (i) CAVE (Cave Automatic Virtual Environment), which uses projection technology to display 3D images within a large enclosed space; (ii) HMD (Head Mounted Display), which consists of an optical display in front of each eye, worn on the head or as part of a helmet, commonly referred to as VR goggles, that displays a virtual environment; and (iii) VR desktop, where the user interacts with a three-dimensional virtual environment displayed on a computer monitor using a keyboard, mouse, or joystick. Virtual environments that effectively exclude physical reality can be characterized as immersive VR (Makransky & Lilleholt, 2018). On the other hand, desktop VR systems that have little or no ability to exclude physical reality can be characterized as non-immersive VR. This article will focus specifically on immersive VR that uses mobile VR (e.g., Google Cardboard, Samsung Gear), high-end HMDs (e.g., Oculus Rift, HTC Vive), and enhanced VR (e.g., a combination of HMDs with data gloves or bodysuits) as devices.

It is plausible to see in immersive environments a great potential to contribute to education. "Virtual reality (VR) technology has been widely used to create situated and realistic learning contexts that learners cannot easily access" (B. Wu et al., 2020). Additionally, immersive VR systems "offer several learning affordances, that is, characteristics that can elicit learning behaviors promoting learning outcomes in educational contexts" (Di Natale et al., 2020). "Such experiences are illusions made available to us through human perception and our sensory systems (eg, visual, auditory, proprioceptive, tactile) and can support learning" (Lui et al., 2020).

It is also important to emphasize, as cited by Sanchez-Sepulveda et al. (2020), that students seek to learn in different formats, want to create, use tools of their time, make decisions, share opinions, are interested in relevant learning and connected to reality.

The systematic review of the literature was adopted as the research methodology to analyse the ways in which learning occurs in immersive virtual environments and to ascertain the potential of VR in learning experiences in a curricular context to answer the question: How does the use of virtual reality contribute to student learning in higher education?

The process of selecting academic publications commenced with an

initial set of 764 articles retrieved from the EBSCO database, covering the period between 2017 and 2022. Through a meticulous three-stage selection process, 39 publications were ultimately chosen for analysis. This article is structured to outline the methodology adopted, describe the eligibility criteria, provide general information about the 39 studies comprising the corpus of analysis, report educational experiences utilizing immersive VR in a curricular context, address limitations and challenges associated with the use of immersive VR in educational practice, and conclude with final remarks.

1. Methodology

The objective of this systematic review was to examine the utilization of VR technology in the educational domain and analyze how learning occurs within immersive virtual environments, including their characteristics, benefits, and limitations.

The focus of the review is on learning experiences that make use of immersive virtual reality technology and that are developed in a curricular context in higher education. And the guiding questions are as follows: How has the publication on the use of immersive virtual reality in educational practices evolved between 2017 and 2022? In which academic fields of higher education have empirical studies with immersive virtual reality been conducted? How can virtual reality contribute to student learning in higher education? What are the limitations and challenges associated with the use of immersive virtual reality in educational practice?

A systematic review provides an overview of pre-existing knowledge about a phenomenon, subject or topic using appropriate and explicit methods (Kerres & Bedenlier, 2020). The process of this systematic review was outlined by the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model (Page et al., 2021), which, through its systematic methods, helps to identify, select and critically appraise the scientific production related to a given theme.

While recognizing that the use of multiple databases in a systematic review broadens the scope of the research, we chose to use a single multidisciplinary search platform that aggregates a large collection of academic periodicals and covers various fields of knowledge, EBSCOHost. The choice of this database was based on its ease of use, familiarity with the platform, and economy of effort in combining different search strategies when using multiple databases, which contributed to the efficiency and consistency of the specific search criteria

used, which are described in detail throughout the text.

The starting point was a search for academic productions on the EBSCOhost platform, which includes the following databases: Education Source, Educational Resource Information Center (ERIC), PsycINFO, Psychology & Behavioral Sciences Collection, PsycARTICLES, Academic Search Complete, Library, Information Science & Technology Abstracts (LISTA), eBook Collection (EBSCOhost), and OpenDissertations.

The search equation was constructed by combining Boolean operators with the keywords "Virtual Reality," "Education," "Learning," and "Training" in the English language. The term "Virtual Reality" was enclosed in quotation marks to specifically identify the technology, and the use of the term "virtual" in isolation was excluded. Here is the search equation: [TI (("virtual reality" AND (education OR learning OR formation))) OR AB (("virtual reality" AND (education OR learning OR formation))) OR SU (("virtual reality" AND (education OR learning OR formation)))].

The following filters and restrictions are included in the search: search fields: title, keywords, and abstract; text: full-text, open access, and peer-reviewed; publication period from 2017/08/01 a 2022/07/31.

Once the studies have been collected, it is necessary, as suggested by Kerres and Bedenlier (2020), to develop rules about which studies will be selected for review. The selection criteria, which can be referred to as inclusion and exclusion criteria, are shaped by the research question. Thus, the inclusion criterion is defined as research with an empirical dimension on the use of virtual reality in higher education in a curricular context.

A total of 764 articles were identified and 218 duplicates were removed. The remaining 546 studies were catalogued by title, author, source, year, publication type, abstract, link, and database.

By reading the abstracts and, when necessary, consulting the methodological process, we attempted to identify studies with empirical evidence related to the use of virtual reality, as per criterion 1. We identified and excluded 14 duplicate publications, as well as 227 articles that did not utilize empirical data. Additionally, we found 68 empirical publications that did not involve the use of VR technology in their research.

Following the decision for the selection of articles, through the reading of the methodological process, we intend to verify the educational

experiences in higher education, defined as criterion 2. The application of criterion 2 excludes from the 237 studies: (i) 89 publications from outside educational institutions, (ii) 54 from non-formal educational institutions, (iii) 14 from primary education, and (iv) 16 from secondary education.

There are a total of 64 studies conducted in higher education that are subject to criterion 3. This criterion identifies experiences developed within a curricular context, where activities and practices are intentionally planned as part of an educational curriculum to enhance student learning. As a result, 17 studies that did not meet this criterion were excluded from consideration.

With 47 publications remaining to be assessed for eligibility, it was identified that 8 studies did not utilize immersive virtual reality and were subsequently excluded.

After applying the eligibility criteria, a set of 39 studies were selected to constitute the empirical material upon which the current systematic review presented in this paper is based. Figure 1 illustrates the process of identification and selection of eligible articles, according to the PRISMA model (Page et al., 2021). This methodological approach aims to ensure transparency in the selection process.

Figure 1

The process of identification and selection of eligible articles

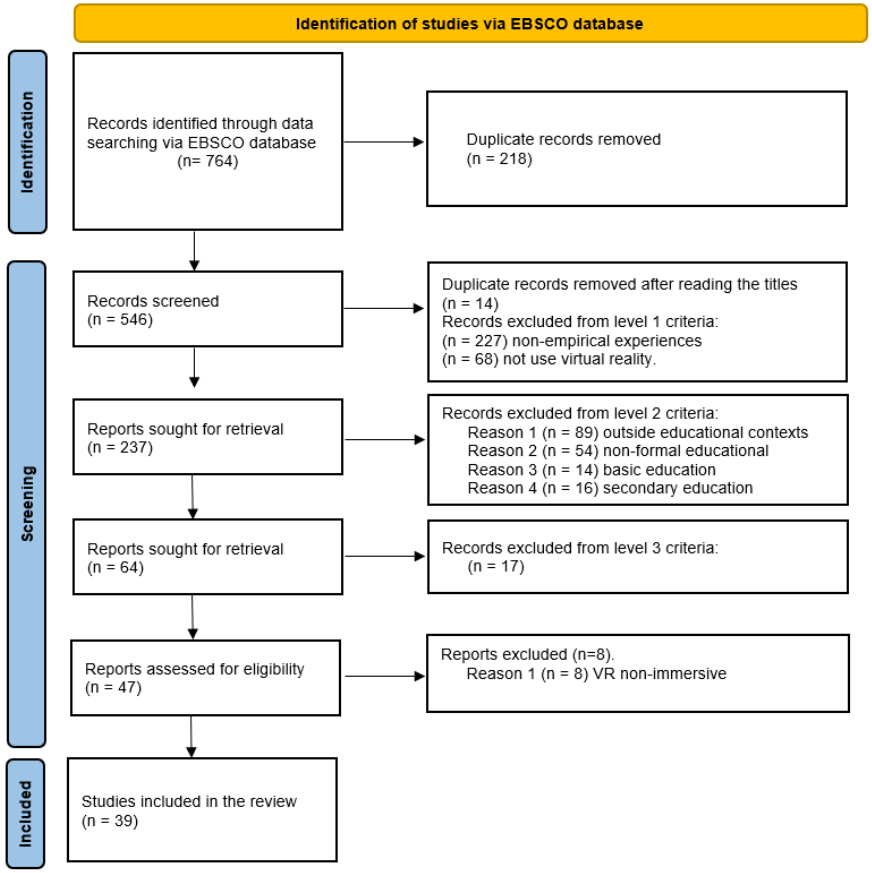


Figure. 1 PRISMA flow diagram of the systematic review process (adapted from Page et al. (2021))

The subsequent section offers an overview of the eligible studies included in the review. It provides general information about the selected studies, outlining their characteristics and pertinent findings. Additionally, it describes various educational practices, limitations, and challenges associated with the the use of immersive VR in educational settings, addressing the guiding questions of this review.

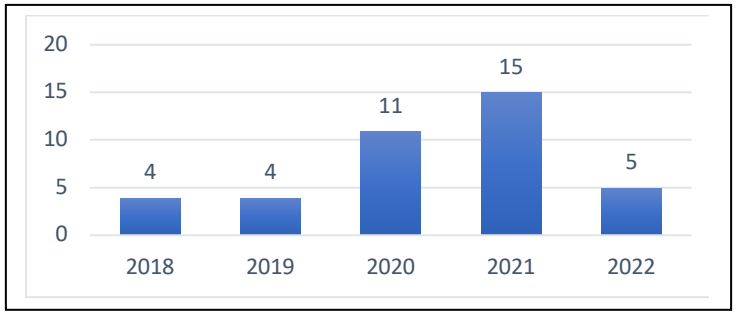
2. Descriptive Results

As descriptive results about the corpus of analysis (n=39), the general information elaborated refers to the year of publication of the selected studies, the type of methodology adopted in each research, the country in which each study was developed, and the academic journals in which these studies were published. These details provide an overview of the characteristics of the eligible studies.

The increase in publications in 2020 and 2021 is highlighted in Figure 2, which depicts the number of publications between 2018 and 2022 according to the eligibility criteria of this review. The decrease in the year 2022 may be attributed to the search period for articles (up to 31/07/2022). It is anticipated that the empirical discourse on the subject will continue to expand.

Figure 2

Number of eligible articles published per year.



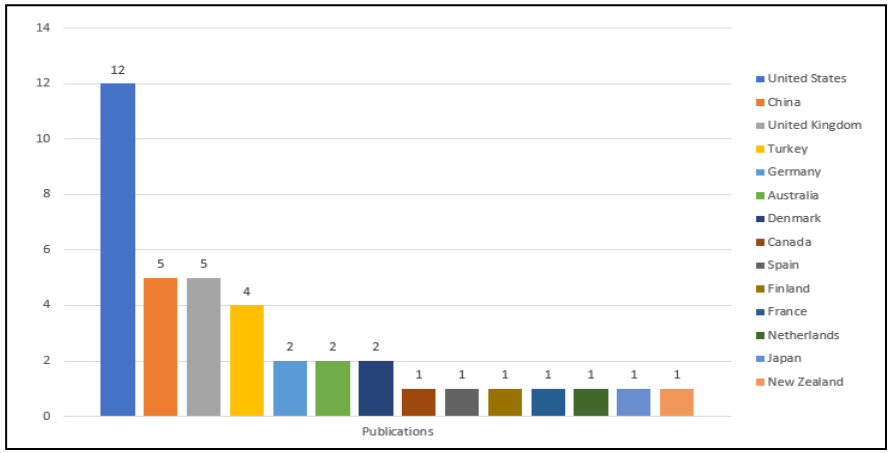
In terms of methodology, it's understandable that a significant portion of studies decide for quantitative methods, given the exclusion of theoretical experiences and those lacking empirical investigation. Among the eligible studies, 74% (n=29) employ quantitative methods, 13% (n=5) utilize mixed methods, and another 13% (n=5) rely on qualitative approaches.

The studies were conducted in 14 countries. It is notable that 30% (n=12) of these studies were conducted across various regions of the United States, followed by China and the United Kingdom, each with 13% (n=5). Together, these three countries accounted for 56% of the publications analysed. Please refer to Figure 3, which illustrates the

countries in which educational practices occur according to the eligibility criteria for articles included in this review.

Figure 3

Number of eligible articles published by country.



The academic journals with the highest number of publications meeting the criteria of this review are the British Journal of Educational Technology and Educational Technology Research & Development, which together account for 30% of the eligible publications, with 20% (n=8) and 10% (n=4), respectively.

In the educational practices reported in the selected articles, it is evident that immersive virtual reality "offer a novel virtual learning experience, where the virtual world provide personal viewing inside VR, thereby offering a sense of immersion during learning" (B. Wu et al., 2020). VR offers the possibility to create simulations, that is, "interactive digital learning environments that mimic a real-life process or situation" (Merchant et al., 2014).

Some studies have examined the development of public presentation skills through the use of simulations of real virtual worlds. McFaul and FitzGerald (2020) used a virtual environment in a legal education program in which students interact with avatars representing audience members. These avatars respond to students' presentations with recorded questions, simulating a realistic interaction. This approach allows students to practice answering questions, dealing with challenges, and honing their communication skills in front of a virtual audience (McFaul & FitzGerald, 2020).

In the study by McGovern et al. (2020), a group of marketing students had the opportunity to practice body expression, eye contact, and use of gestures during their presentations and to receive feedback from the activity, allowing the students to make adjustments and improve their communication skills.

In the field of teacher education, VR has proven useful in the transition to teaching practice through classroom simulations that help future educators cope with anxiety and the initial challenge of managing a classroom (Theelen et al., 2022). It can also help manage student behavior, as in Chen's study (Chen, 2022), where participants interacted in an immersive learning environment with avatars representing students who exhibited challenging behaviors such as sleeping in the classroom, disrupting others, and using cell phones. Participants were instructed to teach the prepared material when dealing with these challenging behaviors. This experience allowed for the application of behavior management strategies, decision making, and problem solving (Chen, 2022).

There are also references that describe simulations of care in clinical practice in psychology (Rogers et al., 2022) and social work (Roberson & Baker, 2021) that provide students with access to experiences that may be difficult, dangerous, or costly in real life.

Another relevant aspect is the capability of VR technology to promote virtual visits to historical sites, museums, exhibitions, and cultural environments in an immersive way. A group of students from China and Uzbekistan learned about the cultures and traditions of their foreign partners through 360-degree videos and were able to summarize, explain, compare, and contrast the information they learned (Shadiev et al., 2021).

VR applications have also been used for architectural visualization in educational settings. This has been described in some studies (Erkan, 2020; Huang et al., 2021; Nisha, 2019; Özgen et al., 2021; Sanchez-Sepulveda et al., 2020). For example, VR technology can be used as a design tool to promote students' differentiated spatial perception. It can improve the functional organization and aesthetics of space, and it can also improve the quality of interior lighting in the projects developed (Erkan, 2020).

In addition, "the use of VR can encourage students to improve their analytical skills, such as collecting and analyzing data, writing computer programs, or making complex decisions" (Radianti et al., 2020). Through hands-on applications and conducting experiments, the technology has been used to teach and enable students to identify, analyze, and solve problems in various fields such as: robotics (Vogt et al., 2021), electrical circuits (B. Wu et al., 2020), biology (Lui et al., 2020), and chemistry (Klingenberg et al., 2020; Miller et al., 2021).

For example, Miller et al. (2021) study was designed to teach students

about basic molecular compounds and their three-dimensional assembly in an Organic Chemistry Structures and Conformations course. The activity took place in a VR environment where participants manipulated molecular structures with handheld controllers. During the activity, students were given written instructions and problems to solve, with a visual background that changed as they solved different levels of problems and environmental conditions, providing an immersive and interactive experience of learning about chemical structures. For the authors VR in the classroom extends learning technologies into immersive and visual experiences. They accelerate learning and clarify complex concepts, especially in fields like chemistry and physics where learners tend to struggle. “The power of VR technologies comes from the ability to demonstrate: abstract concepts, the visualisation of understood phenomena, and the dynamic relationships in a multi-view representation of the virtual environment” (Tacgin, 2020).

VR provides a controlled simulation environment where students can make mistakes without aversive consequences or safety concerns. In addition, they can progress through the exercises at their own pace, with the ability to receive immediate, individualized feedback from a virtual agent during the experience, which is a significant advantage that is difficult to achieve in traditional classroom environments where a teacher is working with multiple students at the same time. VR's characteristics are associated with a number of learning opportunities, including better spatial representation, contextualized learning, and experiential learning opportunities (Klingenberg et al., 2020). The literature addresses the existence of common problems for users related to physical symptoms, such as nausea and dizziness (Makransky & Lilleholt, 2018; Radianti et al., 2020).And also difficulties related to the technology itself, such as the quality and resolution of the screen, computational problems that occur during the experiments, and the cost of the equipment (Radianti et al., 2020).

The study by McFaul and FitzGerald (2020) portrays a low adherence of distance legal education students to carry out the immersive experience. The highlighted barriers are: (i) students did not realize that the software had enough value to invest time in using it; (ii) lack of student engagement, which underscores the importance of carefully integrating technology into learning objectives; (iii) lack of confidence or anxiety in dealing with new technologies; (iv) problems with the functionalities and quality of the application, which indicate the

need for investment in developing technologies suitable for the purpose of the activity (McFaul & FitzGerald, 2020).

It is also important to note that the study carried out by Parong and Mayer (2021) suggests that although immersive environments can stimulate more intense affective processing, they tend to result in lower levels of cognitive processing and, consequently, less effective learning outcomes. This is because the intense emotional arousal caused by immersion can act as a captivating element but can distract attention from the essential cognitive aspects of learning. For the authors, educators should weigh up the potential costs of using immersive VR in terms of the potential for additional distraction against the potential benefits in terms of motivation and interest, over and above those provided by less immersive media. Alternatively, they should consider how to mitigate the distracting potential of immersive environments, for example through pre-training in other immersive experiences.

Limitations of the experiments reported in some studies include: (i) the short duration (Rogers et al., 2022); (ii) the small sample size (Makransky & Lilleholt, 2018; Valenti et al., 2020); (iii) the reduced number of interactions with participants (Rogers et al., 2022); the difficulty of solving technical problems of access and use (Valenti et al., 2020). These facts corroborate the study conducted by Radianti et al. (2020a), which shows that the technologies discussed in most of the articles analyzed are still at an experimental stage. Their implementation is not systematic or based on best practices.

Despite the existing barriers, it is recognized that virtual reality technology contributes to the learning process by providing authentic and realistic simulated experiences that allow students to apply their knowledge in practice.

Conclusions

By incorporating technology into educational contexts, as demonstrated in these practical experiences, traditional teaching and learning activities can be transformed, as indicated by Lampropoulos and Kinshuk (2024), enriching the educational experience to improve effectiveness and promote interactivity.

Several systematic reviews (Agbo et al., 2021; Di Natale et al., 2020; Koolivand et al., 2024; Oyelere et al., 2020; Radianti et al., 2020; B. Wu et al., 2020) address immersive Virtual Reality in an educational context, highlighting the importance of understanding the use of this

technology in educational practice. This study contributes to the debate on the use of Virtual Reality in Education, bringing information on a set of practical experiences in a curricular context in higher education.

It is possible to observe that the use of immersive virtual reality in practical experiences has demonstrated the technology's ability to create three-dimensional virtual environments that promote enriching learning experiences for students. For Holly et al. (2021) the use of immersive and interactive technologies such as virtual reality opens new possibilities for creating engaging learning experiences.

The findings of the review suggest that:

(i) there is an increase in the number of publications investigating empirical experiences using VR technology in recent years, indicating the growing interest of universities in using immersive environments in educational practices;

(ii) universities and academic institutions in the United States stand out in educational practices utilizing virtual reality within the curriculum;

(iii) Virtual reality technology proves to be versatile and promising for education, aiding in competency development, enhancing understanding of academic content across diverse fields, improving presentation skills, and simulating complex practical scenarios. This enables students to involve in authentic experiences and apply their knowledge practically.

(iv) Challenges to technology implementation in education include equipment costs, software quality issues, and apprehension among students and teachers about technology use. Furthermore, limitations of experiments demonstrate the immaturity of the use of technology in an educational context.

Regarding the third point above (iii), and also based on the classification by Radianti et al. (2020), four types of knowledge were identified after analyzing immersive experiences in higher education within educational practices:

- Analysis and problem-solving;
- Communication, collaboration, and interpersonal skills;
- Practical-procedural knowledge; and
- Declarative knowledge.

It is concluded that most experiences can be categorized into these four proposed types of knowledge.

The study highlights that the integration of VR technology in education still faces significant challenges. It is important to reiterate that, as pointed out by Slater and Sanchez-Vives (2016), "More affordable systems will facilitate not only the reach to final consumers but also to more developers and research groups, resulting in a much wider range of applications and generation of content for VR that will emerge in the near future." This will facilitate the utilization of the technology in an educational context, through applications with higher quality and lower cost.

Although a fair amount of research needs to be done, notably on cost-effectiveness, student satisfaction, and other potentially adverse effects, virtual reality is a growing phenomenon with immense potential (Koolivand et al., 2024).

Note

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Curriculum note

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