How are the sense of presence and learning outcomes being investigated when using virtual reality? A 24 years systematic literature review

Article *in* Interactive Learning Environments · March 2023

DOI: 10.1080/10494820.2023.2184388

6 authors, including:

Aliane Loureiro Krassmann
Instituto Federal de Educação, Ciência e Tecnologia Farroupilha
58 PUBLICATIONS **230** CITATIONS
SEE PROFILE

Miguel Melo
Institute for Systems and Computer Engineering, Technology and Science (INESC …
120 PUBLICATIONS **1,062** CITATIONS
SEE PROFILE

Rafael Darque Pinto
10 PUBLICATIONS **134** CITATIONS
SEE PROFILE

Bruno Peixoto
Universidade de Trás-os-Montes e Alto Douro
11 PUBLICATIONS **136** CITATIONS
SEE PROFILE

Interactive Learning Environments

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/nile20

How are the sense of presence and learning outcomes being investigated when using virtual reality? A 24 years systematic literature review

Aliane Loureiro Krassmann, Miguel Melo, Darque Pinto, Bruno Peixoto, Maximino Bessa & Magda Bercht

To cite this article: Aliane Loureiro Krassmann, Miguel Melo, Darque Pinto, Bruno Peixoto, Maximino Bessa & Magda Bercht (2023): How are the sense of presence and learning outcomes being investigated when using virtual reality? A 24 years systematic literature review, Interactive Learning Environments, DOI: 10.1080/10494820.2023.2184388

To link to this article: https://doi.org/10.1080/10494820.2023.2184388

Published online: 21 Mar 2023.

INTERACTIVE LEARNING ENVIRONMENTS
https://doi.org/10.1080/10494820.2023.2184388

Routledge
Taylor & Francis Group

REVIEW ARTICLE

How are the sense of presence and learning outcomes being investigated when using virtual reality? A 24 years systematic literature review

Aliane Loureiro Krassmann [a], Miguel Melo [b], Darque Pinto [c], Bruno Peixoto [c*], Maximino Bessa [b] and Magda Bercht [d]

[a]Instituto Federal de Educação, Ciência e Tecnologia Farroupilha, Santa Maria, Brazil; [b]INESC TEC, Porto, Portugal; [c]Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal; [d]Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

ABSTRACT

The sense of presence is an important aspect of virtual reality experiences, being increasingly researched in educational contexts for its potential association with learning outcomes. A panorama of how these investigations have been conducted could help researchers and practitioners to harness this potential and find new directions. A systematic literature review was conducted to contribute to this perspective, with a comprehensive analysis of 140 primary studies recovered from five worldwide databases. The results show an overview of 24 years of research, with a summarization of areas, factors, and methodological approaches that have been the focus of investigation when these three variables of interest (VR, sense of presence, and learning) are together. We conclude with a list of research gaps that need to be addressed and a research agenda, identifying current and emerging challenges.

ARTICLE HISTORY
Received 8 June 2021
Accepted 17 February 2023

KEYWORDS
Virtual reality; sense of presence; learning; education; systematic literature review

Introduction

The emerging technology of Virtual Reality (VR) allows the creation of Virtual Environments (VE) in three-dimensional (3D) graphics systems that enable an immersive experience in which users can actively explore and interact. It capitalizes on resources that the traditional and online classrooms have not achieved yet, with the design of highly interactive and precise simulations (Girvan & Savage, 2019). These unique characteristics represent an enormous potential for education; for example, students can repeatedly practice a procedure in a safe environment whilst expending fewer resources (Hamilton et al., 2021).

However, for this dynamic to work, there is an assumption that the ability trained in VR can be effectively transferred to real-life performances or that the training outcomes are somehow similar or better compared to regular education and training techniques (Grassini et al., 2020). In this context, one construct that seems to influence these outcomes is the sense of presence, which is defined as the feeling of "being there" or the psychological state of experiencing the VE as if one is there rather than in the actual physical location: the computer world becomes the user's world (Witmer & Singer, 1998).

Research has shown that the sense of presence can offer the virtual experience the same value as a corresponding real one, posing as a critical feature to ensure the transfer of knowledge from the

CONTACT Aliane Loureiro Krassmann alkrassmann@gmail.com
*Present address: INESC TEC, Porto, Portugal.

virtual to the real world (Dengel & Mäzdefrau, 2018). This is because emotional and psychological responses, such as attention, involvement, and flow, can be associated with a user's sense of presence (Lessiter et al., 2001), given that our attention must be focused on the alternative world instead of the real world, creating a perceptual illusion of non-mediation (Lombard et al., 2009). It is worth highlighting the difference from the concept of immersion, which on the other hand, stands for what VR technology itself delivers (i.e. how capable of isolating the user from the real world, from an objective point of view).

According to Grassini et al. (2020), the scientific literature is still at the beginning of the investigation on the training effects of VR, and whether it may provide objective advantages in task performance should be further investigated. The sense of presence, by its turn, has been the subject of intense discussion both as regards its definition, causes, how to measure it, and the factors that may affect it (Bormann, 2006). To the best of our knowledge, there are still no Systematic Literature Reviews (SLR) that integrate the three aspects considered in this study (VR, sense of presence, and learning). Nash et al. (2000) published a non-systematic review of literature related to presence and performance within VE, summarizing the type of studies conducted and representative findings, indicating areas where additional efforts are needed. They conclude by stating that the question of how (or whether) these two relate remains. Although related in concept, their survey was non-systematic, had a different scope (e.g. VE instead of VR, performance instead of learning), and was conducted more than 20 years ago.

In this sense, we seek to contribute by presenting an SLR that aims at answering one main research question that directly reflects this paper's title: *how is the sense of presence and learning outcomes being investigated when using virtual reality?* The objective is to outline the state of the art regarding research on the sense of presence when VR is used for learning purposes, providing a panorama of the literature in this important interdisciplinary field.

Methods

The study follows the definition of SLR given by Kitchenham (2004). It is a means of evaluating and interpreting research relevant to an area or phenomenon of interest using a trustworthy, rigorous, and auditable methodology. The SLR execution was divided into three main stages: planning, conducting, and reporting the review, as described in the following subsections.

Planning the review

In the planning phase, three Research Questions (RQ) were established. To investigate them and outline a panorama on how the studies were conducted, we established a baseline common ground of inference, presented as follows.

RQ-1 how are the research about VR, sense of presence, and learning conducted?

In this RQ, we summarize the types of research adopted, the VR setting used (fully immersive or non-immersive), other aspects analyzed, the number of times before and during the VR activity, the comparisons of VR conditions or media, and if multisensory aspects were considered.

We define a fully immersive VR as a setting that provides an experience suppressing stimuli from the physical reality and increasing stimuli of the artificial environment. This is usually achieved with the use of specific devices (e.g. a headset or Head-Mounted Display – HMD), such as Oculus Rift, HTC's VIVE, Google Cardboard, or in specific controlled rooms as CAVE (Cave Automatic Virtual Environment), which have real-time user tracking and projecting to enable a realistic view. Studies were classified as fully immersive when the settings used HMD or CAVE. However, as a significant number of non-immersive (or partially immersive) applications are used for learning purposes, we include in the scope of research other 3D interfaces, like virtual worlds (e.g. Second Life, OpenSimulator), video games, and 360° videos, which were classified in the non-immersive

category. Despite that, web systems, 2D interfaces, and Augmented Reality applications were disregarded.

Regarding the analysis of the conditions, we identified if different variables or settings of the VR (e.g. devices or scenarios) were manipulated to perform a comparison. Concerning the media used, we analyzed if the same instruction or learning activity was compared to a different format (e.g. non-immersive VE, face-to-face instruction, video, or slides presentation, for instance).

RQ-2 how is the sense of presence investigated?

Seeking to comprehend how this construct is analyzed in the literature, the terminologies adopted to define it, and the methods and instruments to measure it objectively and subjectively were summarized.

To elaborate a report on the instruments used to measure or infer the sense of presence, we considered the main reference used to compose it, even if altered in some way or individual items were removed.

RQ-3 how is learning investigated?

Aiming to understand how this component is studied in the literature, we summarize the terminologies used to address it, the domains of learning covered, if the assessments were quantitative or qualitative (or both), the instruments used to infer or measure it, knowledge areas, forms of instruction, educational stages, and educational theories underlying the studies.

We understand as "learning" the definition given by The United Nations Educational, Scientific and Cultural Organization (UNESCO) that it is an individual acquisition or modification of information, knowledge, understanding, attitudes, values, skills, competencies or behaviors through experience, practice, study or instruction (UNESCO, 2011). As this component can be susceptible to multiple interpretations, the reviewers reached a consensus regarding the different terminologies that could be accepted to address it (besides "learning"): knowledge, transfer, performance, memory, retention, achievement, and recall.

A learning domains classification was performed following the taxonomy of Bloom (1956), which divides it into three. The Cognitive domain involves knowledge and the development of intellectual skills, such as remembering contents (knowledge), understanding concepts (comprehension), or the application of specific skills. The Affective domain includes how people deal with things emotionally, such as feelings, values, appreciation, motivations, and attitudes. The Psychomotor domain includes physical movement, coordination, and motor-skill areas. Finally, we considered the activities users had to perform in VR, and which types of data were collected in the studies to perform this analysis.

We also considered the International Standard Classification of Education by UNESCO (2011) to classify the studies regarding forms of instruction. Informal education (everyday life) is deliberate but not institutionalized (not following a specified curriculum). Formal education represents the institutionalized education system of a country (mainstream curriculum). Non-formal education (training) consists of formation in working and professional contexts.

To elaborate the report on the types of methodological approaches and instruments used to assess learning outcomes, the inference was based on the data collection instruments and the data analysis methods adopted in the studies. Regarding educational theories, we focused on identifying the explicitly mentioned main theories used to underpin the studies, being faithful to what the authors express. For example, when authors only stated that students were "learning by doing", with no further precision, it was coded that no explicit theory was used.

Conducting the review

We opted for a simple search string that could directly reflect the three main aspects investigated in this study, which should appear together (in the same document) but in any field: "virtual reality" AND "sense of presence" AND "learning". The term "sense of presence" was chosen because it

does not specify any technological domain, unlike telepresence and virtual presence. In agreement with Lee (2004), "telepresence" emphasizes the possibility of being physically transported to a remote workspace via teleoperating systems, and "virtual presence" was coined to refer to the presence caused by VR technologies. In addition, a preliminary search revealed that the word "presence" solely resulted in numerous papers referring to physical presence and unrelated to the sense of presence, which were impracticable to survey.

Also, despite including a number of 3D interfaces in the scope of research, we opted for using only the term "virtual reality", aiming to retrieve papers with that had other characteristics specific to VR, such as active exploration and interaction. According to Fuchs (1996), VR differs from real computer-generated photographs and films due to the possibility of interaction it offers, changing users from being mere spectators to become the "actors" of the virtual world.

A start-year limit of publications was not defined, and the end-year limit was set to 2020. The data retrieval occurred in January 2021. Five well-established renowned databases were selected as sources to search for peer-reviewed primary studies, as they are recognized as significant reliable sources that high-quality index publications from the areas of Computer Science, Engineering and Education: Web of Science, Scopus, ACM Digital Library (ACM DL), IEEE Xplorer, and Elsevier (Science Direct).

Each paper had to include an actual user study where participants take part in some learning experience in a VR environment, with analysis of presence rating measurements, such as questionnaires or observation of behavior. Table 1 shows the Inclusion Criteria (IC), and Exclusion Criteria (EC) defined to evaluate the papers.

The SLR was conducted in three main phases, described as follows.

Phase 1, Search: The first phase consisted of data retrieval, which was conducted by inserting the search string directly on the space destined for search in the websites of the databases. The retrieved papers were imported to the Parsifal online free tool (https://parsif.al/), using the BibTex format, which allowed the cleaning of the duplicated papers, organization by database, and exportation to a spreadsheet, that was then used in the following phases.

Phase 2, Selection: This phase consisted of reading the title, abstract, and keywords of each retrieved paper, confronting it with the IC and EC. It was conducted in pairs (peer review); each paper was analyzed by two reviewers individually. In case of disagreement, a third senior researcher would perform the review and make their own decision, reaching the tiebreaker without knowing the previous ones.

Phase 3, Extraction: The final phase consisted of reading in full each paper accepted from the previous phase, confronting it again with the IC and EC. Papers were randomly and equally divided into four reviewers; each reviewer read each paper individually.

Reporting the review

In Phase 1, the search in the selected databases returned 3.503 papers. From this set, 1.083 were duplicates, that is, returned from the search in more than one database. After removing them, a

Table 1. Inclusion and Exclusion criteria.

Inclusion Criteria (IC)	
IC-1	The study presents a practical implementation of VR.
IC-2	The study presents an investigation of the sense of presence in VR.
IC-3	The study assesses learning in VR.
	Exclusion Criteria (EC)
EC-1	The study is gray literature or not peer-reviewed research.
EC-2	The study is secondary, that is, review, survey or philosophical.
EC-3	The study is not written in English.
EC-4	The full text of the study is not available.
EC-5	The study does not address the practical use of VR.
EC-6	The study does not investigate the sense of presence.
EC-7	The study does not assess learning.

total of 2.420 unique papers remained. In Phase 2, the peer review indicated a draw with the decision for 68 papers. After the tiebreaker of these 68, 2.167 papers were rejected, and 253 were accepted to the following phase. In Phase 3, 113 papers were rejected, and 140 were accepted, consisting of the dataset analyzed in this SLR (see Appendix I – https://cutt.ly/pgbkRLy). Figure 1 presents a summary of the papers analyzed in each research phase.

Figure 2 exhibits the EC selected to reject each one of the 2.280 excluded papers, allowing to observe that EC-2, which refers to secondary studies or just proposals without implementation, application, or conduction of tests, and EC-6, which refers to studies that did not measure or infer the sense of presence, were the most used criteria. Together, they were responsible for 62% of rejection cases. On the other hand, the least used criteria were EC-3 and EC-4, for studies not written in the English language or not available for reading, respectively, with 1% each.

Results and discussion

The eligible publications were published between 1996 and 2020. Figure 3 shows the publications' distribution throughout the years, revealing an exponential growth tendency in the last year: it reached the highest number of papers (32), three times more than the year before (2019, 10 papers).

Next, the presentation of results and discussion is structured to present a clear logic flow and specify themes/patterns related to the SLR, following the sequence of RQ. To illustrate research answers, we extract some examples from the dataset of papers analyzed in the SLR, prioritizing the more recent publications. We categorized studies to allow more objective, consistent, and trustworthy comparisons. Agreeing with Hein et al. (2018), comparing the results of studies that used inconsistent measurement methods give limited insight since researchers might, for example, measure different aspects of presence or entirely different qualities of a VR experience.

RQ-1 how are the research about VR, sense of presence, and learning conducted?

The analysis of this RQ was divided into research methods, VR settings, evaluation of other aspects (besides the sense of presence and learning), VR acclimatization, duration of VR activity, comparison of VR conditions and media, and the use of multisensory immersion.

Research methods

Most studies were experiments (65.71% of the papers), which according to Kitchenham (2004), are the most reliable scientific empirical approach. One example is the work of Cooper et al. (2018), which conducted a within-subjects factorial design to compare multisensory feedback cues in a

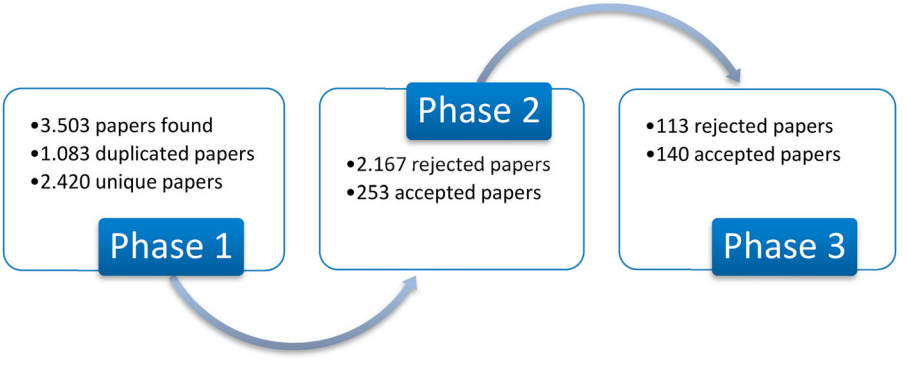

Figure 1. Papers analyzed in each research phase.

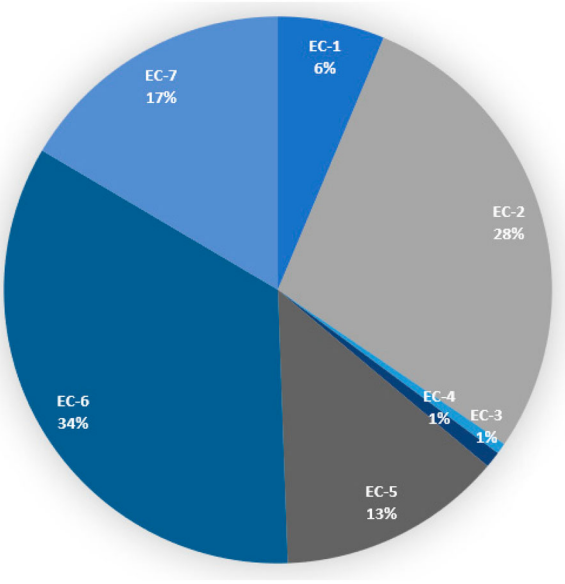

Figure 2. Summary of the EC selected to reject the papers.

car wheel change simulation. However, almost a fifth of the papers (18.57%) did not explicitly inform the type of research adopted. In the sequence, corresponding to 4.29% of papers each, there were case studies, quasi-experiments, and papers that used specific/particular or multiple research methods. The exploratory research method was the less conducted, present in the remaining 2.85% of the dataset.

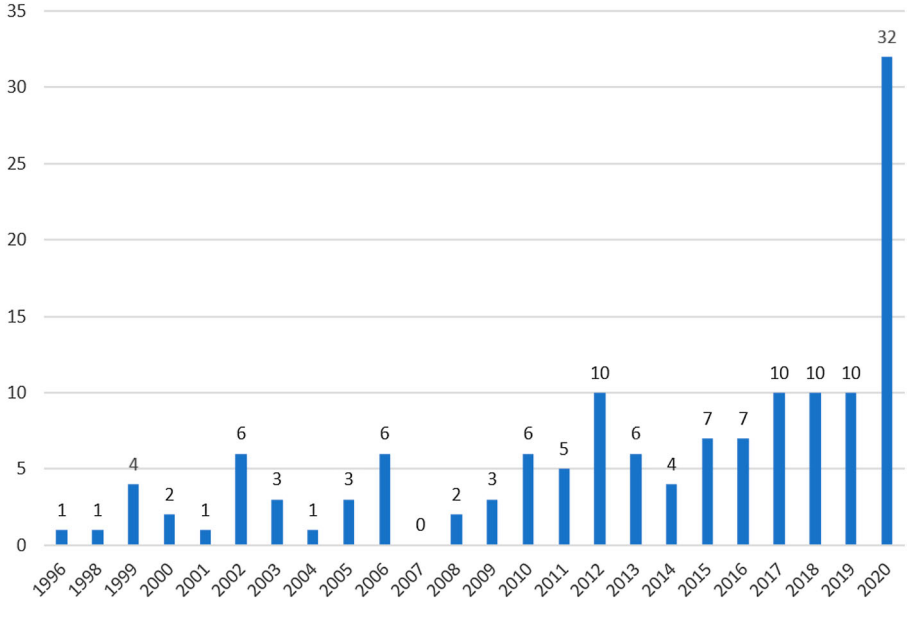

Figure 3. Papers' distribution over the years.

VR settings

Most studies were developed in fully immersive VR settings (60.71%), such as Kwon (2019), in which HTC's VIVE was the HMD used to access a moon exploration simulation. This result may be related to the expansion and accessibility of this interface technology in the last years. On the other hand, the non-immersive setting that corresponds to another parcel of papers (39.29%) can be exemplified with the work of Fokides and Atsikpasi (2018), in which users accessed the Second Life platform from a default desktop interface. Therefore, it can be said that the findings of this SLR are overall covering these two main interfaces of VR technology.

Evaluation of other aspects

It was identified that 15.71% of the studies did not evaluate other aspects besides learning and the sense of presence. However, most papers included a third factor or more to increase their scope of research in their analysis. Table 2 summarizes the factors identified in the remaining 84.29% of the papers. Aspects that appeared in just one study were grouped into "Other". This was the case of half the studies (50%), which evaluated particular (exclusive) aspects. Within these, Roettl and Terlutter (2018) study can be mentioned, which included the assessment of attitude towards a game and the brands that appeared in it, besides arousal, scepticism towards advertising, and general attitude towards it video games.

Cybersickness, a form of motion sickness that occurs due to VR exposure, ranging from a slight headache to an emetic response, was the most recurrent third aspect evaluated, appearing in around one-third of the papers (31.36%). Among other benefits, studying cybersickness allows identifying which factors influence it to eliminate or reduce them, enhancing the system usability posteriorly.

Subsequently, user perceptions and usability were aspects analyzed by around a fifth of the studies each (20.34% and 18.64%, respectively). For instance, Yang et al. (2020) analyzed learner perceptions about their VR system developed towards facilitating communicative abilities, and Schild et al. (2018) identified several usability issues that helped improve their VE for paramedic training. Immersion (11.86%), motivation (11.02%), and engagement (11.02%) were factors analyzed in at least 10% of the publications each. In the sequence are the aspects of cognitive load and enjoyment (8.47% each), followed by realism and immersive tendencies (5.93% each), and flow (5.08%). Factors such as gender, satisfaction, emotion, and involvement, were analyzed by less than 5% of the papers each.

VR acclimatization

Almost half of the studies (47.14%) introduced their users to a VR acclimatization environment previously to the main activity. This result is not consonant with the systematic review of Hamilton et al.

Table 2. Other aspects evaluated in the studies.

Aspect	%	Aspect	%
Other	50.00%	Flow	5.08%
Cybersickness	31.36%	Gender	4.24%
User perceptions	20.34%	Satisfaction	4.24%
Usability	18.64%	Emotion	3.39%
Immersion	11.86%	Involvement	3.39%
Motivation	11.02%	Gaming experience	2.54%
Engagement	11.02%	Task difficulty	2.54%
Cognitive load	8.47%	Spatial Ability	2.54%
Enjoyment	8.47%	Attention	2.54%
Realism	5.93%	Ease of navigation	1.69%
Immersive tendencies	5.93%	Perceived ease of use	1.69%

(2021). Most studies (72%) featured only a direct intervention with the VR experience, meaning that the student was exposed to the technology just once. Nash et al. (2000) argue that a previous exposure allows the navigator to iteratively refine their knowledge of that environment, being important not only for the users to get familiarized with the VR environment but also with the controls needed to interact with it.

In contrast, 31.43% did not provide a moment of VR introduction, and in the remaining 21.43% of the papers, this information was not given. More than half (59.09%) did not inform how long this exposure was from the parcel that exposed users to a VR acclimatization environment. In 15.15% of the papers, it took 1–5 min, and 7.58% between 6–15 min. The remaining parcel of 13.64% of studies reported a period of longer than 15 min for VR acclimatization. One example is in the work of Schild et al. (2018), where the familiarization took up to 30 min for the paramedic trainees to try interaction possibilities, spatial navigation, and communication channels in immersive VR. According to Hamilton et al. (2021), the novelty of HMDs may hinder learning outcomes and classroom application, and it is therefore prudent to ensure that the degree of familiarity with the technology is factored, which means familiarization trials or free navigation before the start of experimental studies to mitigate potential problems caused by technological novelty.

Duration of VR activity

Half the papers (50%) did not specify or inform the VR activity duration. In 27.71% of the studies, users spent more than 30 min in total. For instance, in Yang et al. (2020), each student experienced a VE developed to facilitate the communicative ability, using HTC's VIVE as HMD, for around one hour in total, within a four-week window. In the sequence, 14.29% of the studies applied activity in VR with 11–30 min of duration. The remaining 10% of the papers were divided between 1–5 min (5.71%) and 6–10 min (4.29%).

Comparison of VR conditions

Most studies (60.71%) did not perform a comparison of VR conditions, which means that the intervention was usually composed of a single VE accessed by a single device, with no manipulation of variables. In the sequence, 15% of the papers compared other (particular/exclusive) aspects. The work of Cooper et al. (2018), for example, compared multisensory feedback cues (auditory, haptic, and visual), in a VE for car wheel change simulation. A comparison of different VR devices was performed by 11.43% of the studies. This was the case of Rupp et al. (2019), which analyzed a space-themed 360°educational video delivered through four different devices: smartphone, Google Cardboard, Oculus Rift DK2, and Oculus CV1. Few studies (7.86%) compared different scenarios (2.86%), and different user controls (5%).

Comparison of media

Most papers (56.43%) did not perform a comparison of media. This result corroborates Hamilton et al. (2021). Most studies (62%) utilized immersive VR as the sole learning method and did not combine the technology with additional pedagogical practices or materials to encourage learning. On the other hand, in 15.71% of the papers, a comparison was performed with the same instruction delivered through a non-immersive VE. For instance, Kim et al. (2018) compared a radial arm maze to assess spatial learning and memory with an HMD and a flat monitor. In agreement with Dengel and Mäzdefrau (2018), research on the effect of different immersive settings on learning outcomes usually refers to the comparison of different levels of immersion, such as a desktop computer and HMD. Studies in this scope commonly try to analyze the effects of immersion on learning.

Around 10% of the studies (10.71%) performed multiple media comparisons, such as Sutcliffe and Alrayes (2012), which compared the Second Life (3D) with the Blackboard (web) platform and the

face-to-face instruction. On the other hand, few studies (7.86%) compared the VR with the face-to-face or the "real" instruction; this was the case of Tao and Archambault (2016), in which 12 powered wheelchair users performed three navigation-reaching tasks in the real world and VR. A smaller parcel (6.43%) performed a comparison with a video or a slides presentation, as in the case of Dubovi et al. (2017), which compared the OpenSimulator platform with the PowerPoint traditional slides presentation, towards the learning of medication administration. The remaining 2.86% of papers conducted a comparison with other (particular/exclusive) types of media.

Multisensory immersion

Most papers (83.57%) did not include multisensory immersion aspects in their scope of research (besides visual). Although the multisensory research is not something new, and studies have shown that using multisensory feedback (e.g. haptic) can augment or enhance task performance in a VE (e.g. Nash et al. (2000)), the immersive multisensory technology relies on the use of specific, complex, and often expensive apparatus, requiring technical knowledge to implement or use it, which can explain this result. The remaining 16.43% of the studies analyzed Auditory (5.71%), Haptic (6.43%), Olfactory (0.71%), and the combination of more than one sensory immersion stimuli (Multisensory, 3.57%). For example, this was the case of Cooper et al. (2018); they used multisensory cues (Haptic and Auditory) to signal critical events in the simulation, which were manipulated in a factorial design.

RQ-2 how is the sense of presence investigated?

The analysis of this RQ was divided into the sense of presence terminology, measurement approach and measurement instrument.

Sense of presence terminology

To comprehend how this construct is studied, the terminologies adopted to define it in the studies were summarized. Almost 40% (37.86%) addressed the sense of presence as just "presence". Other 32.14% used multiple terms to address it (a combination of different terminologies) or other terms, such as "virtual presence" and "collaborative virtual presence", which was the specific case of Massey et al. (2013); they tested a model to examine the relationships among organizational participants' perceptions of collaborative virtual presence and teamwork quality towards corporate learning. The term "sense of presence" was used in 27.14% of the papers, and the remaining 2.86% of studies consistently used the term "spatial presence", such as the work of Natsis et al. (2012); they investigated the impact of viewing condition and didactic strategy on attention allocation, suspension of disbelief, and spatial presence, in a VE for the learning of Greek history.

Sense of presence measurement approach

The measurement of the sense of presence was subjective in almost all papers (97.86%). The remaining 2.14% of the studies went for subjective and objective ways, using log analysis and physiologic sensing (heartbeat) as objective measures. From the 140 papers, not one used an objective approach exclusively. According to Bormann (2006), the sense of presence is a subjective measure, and (Dengel & Mäzdefrau, 2018) corroborate, stating that it is an individual psychological, situational variable that is difficult to analyze objectively. Given that presence is a mental state, it is no surprise that subjective reports are the most common measurement method (Nash et al., 2000). This statement continues to be valid nowadays, considering the current stage of neurological inferring systems. However, it is still not easy to access the necessary equipment from multiple perspectives, such as technical and financial.

Szczurowski and Smith (2017) argue that the lack of isolation of presence as an independent variable is the main reason why it is so challenging to capture it through quantitative means. In addition, this might be related to the fact that, although objective measurements allow a more precise assessment, they require a baseline comparison for each participant, which means a considerable effort in some study designs. Finally, they are mostly associated with situations of fear or excitement, which are not common to be provoked during learning activities. To Grassini and Laumann (2020, p. 16), "at the current state of research, no physiological measure has collected enough evidence to be considered "good enough" to be reliably used alone".

However, quantitative methods for measuring the sense of presence are needed to prove any correlation or influence better that it might have on knowledge transfer or retention. "Quantitative metric of presence can also reveal what type of variable presence is and provide more clarity on the taxonomy of presence" (Szczurowski & Smith, 2017, p. 04). According to Grassini and Laumann (2020), with the proliferation of technologies that simulate interactions between people and environments, we need to evaluate users' sense of presence consistently, and quantitative measures will provide a more accurate analysis than questionnaires or bare behavior.

Sense of presence measurement instrument

Table 3 summarizes the primary references used to compose the instruments applied to measure the sense of presence, allowing us to observe that the Presence Questionnaire (PQ) by Witmer and Singer (1998) was the most prominent one, referenced in approximately one-third of the studies (30.71%).

This result corroborates Grassini and Laumann (2020), which also found the PQ the most frequently used reference, indicating this as a reliable scientific source.

In the sequence, the Igroup Presence Questionnaire (IPQ) by Schubert et al. (2001) was referenced by 14.29% of studies. Papers that mentioned more than one instrument (or reference) were grouped in the category "Multiple"; they represent 13.57% of the dataset, and one example is seen in Massey et al. (2013), which adapted items from three different references, including the PQ (Witmer & Singer, 1998). This was the same proportion of papers in which the reference selected to compose the instrument was not identified, being categorized as "Not informed". In this category were also included the cases when the instrument was proposed by the authors (without external references).

In the category "Other" were grouped papers with exclusive instruments or references (that appeared just once). They represent 9.29% of the studies, and one example is seen in Roettl and Terlutter (2018); they used only one statement "I was totally absorbed in what I was doing", referenced in Rheinberg et al. (2003), to investigate the impact of technology in a game evaluation and brand placements. Subsequently, 6.43% of the papers mentioned the Independent Television Commission-Sense of Presence Inventory (ITC-SOPI), from Lessiter et al. (2001), which was the same proportion that selected the Slater-Usoh-Steed Questionnaire by Usoh et al. (2000). Smaller parcels referenced their instruments on the Temple Presence Inventory (TPI) by Lombard et al. (2009) or on the

Table 3. References for the instruments used to measure the sense of presence subjectively.

References	%
Presence Questionnaire by Witmer and Singer (1998)	30.71%
Igroup Presence Questionnaire (IPQ) by Schubert et al. (2001)	14.29%
Multiple	13.57%
Not informed or proposed by the authors	13.57%
Other	9.29%
Independent Television Commission-Sense of Presence Inventory (ITC-SOPI) by Lessiter et al. (2001)	6.43%
Slater-Usoh-Steed Questionnaire by and Usoh et al. (2000)	6.43%
Temple Presence Inventory (TPI) by Lombard et al. (2009)	2.14%
Presence-Involvement-Flow Framework (PIFF) by Takatalo et al. (2010)	2.14%
MEC Spatial Presence Questionnaire (MECSPQ) by Vorderer et al. (2004)	1.43%
Total	**100.00%**

Presence-Involvement-Flow Framework (PIFF) by Takatalo et al. (2011) (2.43% each). Finally, 1.43% of the studies used the MEC Spatial Presence Questionnaire (MECSPQ) by Vorderer et al. (2004) as the main reference to construct their sense of presence inferring instrument.

RQ-3 How is learning investigated?

The analysis of this RQ was divided into learning terminologies, learning domains, learning assessment approaches and instruments, knowledge areas, forms of instruction, educational stages, and learning theories.

Learning terminology

Aiming to understand how this component was analyzed in the literature, we summarize the terminologies, considering the main term consistently used to address the learning construct in each paper.

As a result, over one-third of the studies (35%) used multiple terms. For example, in the work of Lee et al. (2010), the words ''performance'', ''achievement'', and ''learning'' were simultaneously used. In the second place, the word ''performance'' alone was adopted by 28.57% of the papers (e.g. Cooper et al. (2018)), followed by ''learning'', used in 20.71% of the studies (e.g. Kwon (2019)). The terms ''knowledge'' or ''knowledge transfer'' were used by 7.14% of the papers, and the words ''memory'' and ''recall'' were referred to in 4.29% of studies each.

Learning domain

This analysis allows distinguishing more clearly which types of learning outcomes were most pursued when the sense of presence was added to the investigation of VR as instructional media.

Figure 4 summarizes the results, allowing observing that most studies (60%) focused on the Cognitive learning domain. According to Anderson and Lawton (2009), it focuses on adapting what we have learned in one situation to another. One example is in the work of Kwon (2019), which analyzed a moon exploration learning game based on the Earth and Moon unit of an elementary school science class. In the systematic review of Hamilton et al. (2021), most studies also utilized immersive VR to teach cognitive skills, with only a handful examining the procedural or affective applications.

The Psychomotor learning domain was the second most approached, present in 25% of the papers. For instance, in the study of Cooper et al. (2018) the activity users had to perform was a car wheel change in VR, with the time taken to complete the task as a performance measure. The Affective learning domain was the focus of the remaining 15% of studies. One example is seen in the paper of McGinn and Arnedillo-Sánchez (2015), in which juvenile students performed role-playing activities to enhance their ability to resist sexual coercion.

Learning assessment approach

Most studies assessed learning in just quantitative ways (79.29%). One example is in the work of Dubovi et al. (2017), which analyzed objective post-tests and task performance (time and errors) in a VE for learning medication administration procedures in nursing education. Other 17.14% of the papers used both approaches (quantitative and qualitative) in a mixed way, and only 3.57% of the studies used just a qualitative assessment of learning.

Anderson and Lawton (2009) underline that if we are interested in knowing whether students are performing well at a higher level of learning, then quantitative approaches alone are inadequate, explaining the need of using measures of learning that require analysis, synthesis, and evaluation. In addition, to Hamilton et al. (2021), qualitative analysis such as interviews or focus groups could help explore the phenomenology or direct experience of using VR, highlighting concerns relating to unfamiliarity or technological anxiety.

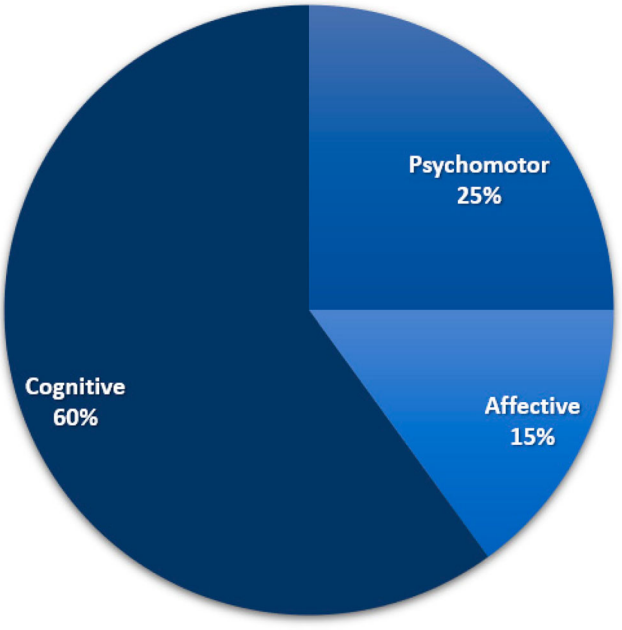

Figure 4. Summary of studies' learning domains.

Learning assessment instrument

As for the practical ways to evaluate learning, a small parcel of the papers did not inform the instruments used to assess the learning component (2.86%), but a more significant proportion (37.86%) was composed of studies that adopted knowledge tests. More specifically, 21.43% used an objective knowledge test, and 16.43% a subjective knowledge test. This result corroborates the survey of Hamilton et al. (2021), in which most papers used test scores to infer learning outcomes. However, they highlight that the restrictive nature of the assessment instrumentation may impede an appropriate demonstration of learning outcomes; it may not reveal more subtle forms of learning that extend beyond mere recall of information. Therefore, they suggest that long-form essay questions, oral examinations, or group discussions could be used to facilitate students' ability to present their in-depth understanding and applied knowledge.

In the second place, 32.86% of the papers used exclusive (particular) or multiple (a combination of more than one) instruments to assess learning, such as time, course grade, mental maps, and observation. An example is seen in Grassini et al. (2020), which used product quality, errors made during assembly, and speed of assembly to analyze the performance of participants building an aeroplane model for the training of procedural skills. Thus, the recommendations of Hamilton et al. (2021) were somewhat reflected in the results of this SLR, with this category having almost an equivalent proportion of knowledge tests as instruments to assess learning.

Subsequently, task performance was the instrument used in 11.43% of the papers. Furthermore, learning perception questionnaires were adopted in 5.71% of the studies, almost the same proportion that used memory tests (5%). Finally, course performance (grade) and time were used in only 2.14% of the papers.

Knowledge area

Regarding knowledge areas, Figure 5 presents a summary that shows that more than forty per cent of the studies (43.57%) were developed towards general purposes, not specifically linked to a

determined knowledge area. One example is seen in Cooper et al. (2018); they evaluated how substituting cues among different modalities of stimulus affected performance in a car wheel change simulation.

The Health area corresponds to 9.29% of the papers and can be exemplified with the work of Schild et al. (2018), which focused on paramedic training for anaphylactic shock. This was the same proportion of the category "Other", with papers from knowledge areas like Computer Science, Geography, Chemistry, and Mathematics, which were approached in less than 2% each.

The Education area was targeted by 8.57% of the papers. Engineering and biology focused on 5.71% of studies each, followed by the Military and the Linguistics area, corresponding to 4.29% of papers each. The knowledge area of History was covered by 3.57% of the studies. It can be exemplified with Natsis et al. (2012) study, which focused on learning ancient Greek history with a VE that simulated an excavation site. Finally, the Physics and Social Sciences areas were represented by 2.86% of the papers each.

Form of instruction

Informal education was the most approached form of instruction, representing a little more than half of the papers (50.71%). The study of Roettl and Terlutter (2018), for example, analyzed how a video game, which was either played in 2D, stereoscopic 3D, or HMD version, was experienced by the players, evaluating memory recall of the brands. This result reflects the interest of researchers in investigating the effects of VR on the enhancement of daily life human activities in society.

Subsequently, Formal education was responsible for 27.86% of the papers. One example is in the study of Makransky et al. (2019), in which undergraduate students participated in a Science lab simulation on the topic of mammalian transient protein expression to investigate whether the principles of multimedia learning generalize to immersive VR. Non-formal education represents the remaining 21.43% of the papers; it can be exemplified with the publication of Barbosa et al. (2017), which

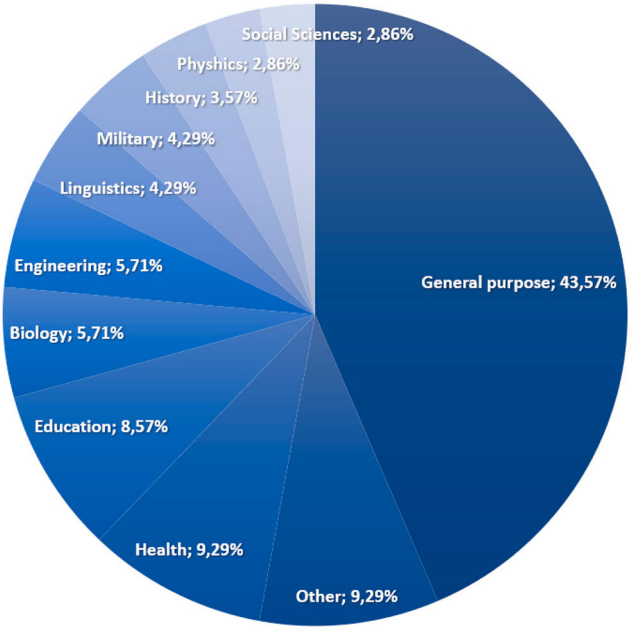

Figure 5. Summary of studies' knowledge areas.

developed a multisensory environment for the training of firefighters, aiming at studying the impact of haptic feedback on presence, satisfaction, and task performance.

Educational stage

Table 4 presents the dataset classification on each educational stage, considering only the proportion of papers categorized as Formal education. It allows observing that most studies were developed towards stages after Secondary education (53.85%), with two papers (5.13%) having participants from all three stages after Secondary education. However, the larger proportion of these studies was from the first stage of Tertiary education, which can be exemplified with the work of Dubovi et al. (2017); they applied VR with nursing students to learn medication administration processes.

The remaining parcel of studies was divided into middle school (23.08%), high school (15.38%), and elementary school (5.13%). One publication (2.56%) involved these first three educational stages.

Learning theory

Regarding learning theories used to support the studies, the results placed in Figure 6 allow observing that most papers did not specify or did not explicitly associate a recognized educational foundation to their research (80.71%). According to Hamilton et al. (2021), a fundamental component of any educational tool or activity is to ground its use in a learning theory or educational paradigm. Most studies also do not mention a theoretical approach underpinning the intervention in their systematic review. Therefore, they highlight that it is essential that future experimental and applied research is based on a sound theoretical basis that can advise how the technology can be appropriately utilized and assessed.

Among the remaining 19.29% of the studies, the Constructivism theory was the most salient, being approached in 4.29% of the papers. For instance, Natsis et al. (2012) followed Constructivism by allowing students to explore a pot's collection in a virtual world to compare styles and shapes and afterwards visit a virtual excavation site to collect determined types of pots.

In the sequence, tied with 2.14% of the studies each, are the theories of Active Learning, Collaborative Learning, and papers that linked their studies to more than one educational theory (category "Multiple"), followed by the Cognitive Theory of Multimedia Learning, represented in 1.43% of the papers. One example of the Collaborative Learning theory is seen in the study of Schild et al. (2018), which involved trainees in taking roles in paramedic emergency; they worked as a team, communicating, supervising, and helping each other by giving hints and handing out instruments. The Cognitive Theory of Multimedia Learning, on the other hand, can be exemplified with the work of Makransky et al. (2019), which investigated whether the principles of this theory could generalize to immersive VR.

Table 4. Educational stages covered in the formal education studies.

	Educational stage	Student age (approx.)	%	%	Total
1	Primary education or first stage of basic education (elementary school)	from 7 to 10 years old	5.13%	2.56%	46.15%
2	Lower secondary or second stage of Basic education (middle school)	from 10 to 14 years old	23.08%		
3	(Upper) Secondary education (high school)	from 14 to 17 years old	15.38%		
4	Post-secondary non-Tertiary education	more than 17 years old	2.56%	5.13%	53.85%
5	First stage of Tertiary education		43.59%		
6	Second stage of Tertiary education		2.56%		
Total			**92.31%**	**7.69%**	**100.00%**

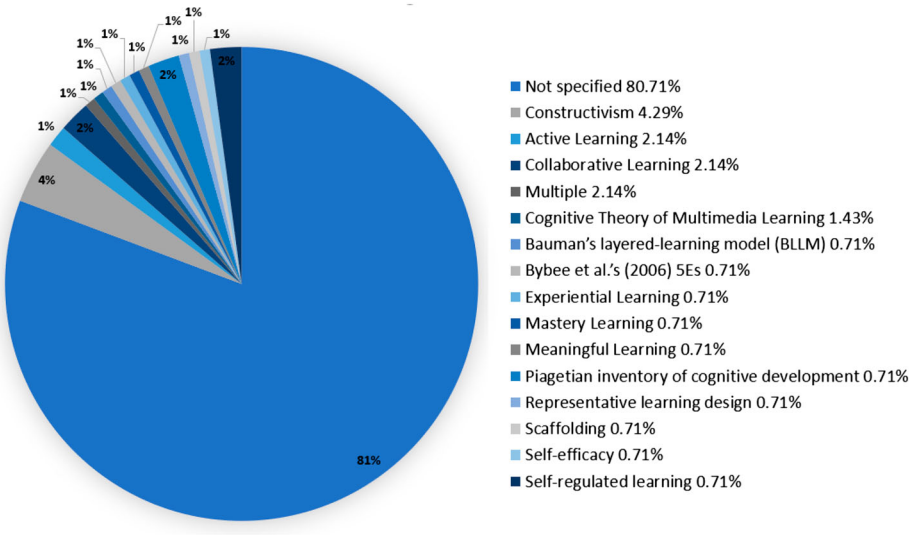

Figure 6. Educational theories underlying the studies.

Table 5. Research gaps identified in the SLR.

ID	Research gap	%
1	Objective measures of the sense of presence	0.00%
2	Qualitative assessments of learning	3.57%
3	Focus on the Affective learning domain	15.00%
4	Analysis of multisensory immersion	16.43%
5	Educational theories supporting the study	19.29%

Another ten theories listed in Figure 6 were mentioned in one paper each (0.71%). Experiential Learning, for example, was approached in the study of Kwon (2019), which examined the degree of enhancement of the experientiality felt by the students through the interaction with a moon exploration learning game.

Conclusion

The field of research involving VR, sense of presence, and learning, although not recent, is still maturing. Thus, sharing knowledge and increasing the research community are needed to accelerate this process. This SLR organized a worldwide panorama from the last 24 years of investigation to contribute in this regard.

The results allowed a diagnosis of scarcity in some areas and aspects of research. Some do not necessarily represent a research gap; it simply represents a tendency in empirical studies. For example, the small use of the exploratory research method can be a consequence of the design choice by scientists.

On the other hand, some research scarcity can evidence current and emerging challenges for the literature, as their investigation could enrich the scientific community's understanding of the field. Table 5 summarizes these research gaps, with an ascending percentual order of papers that addressed them.

Table 5 allows observing that objective measurements of the sense of presence were non-existent, and few papers performed a qualitative assessment of learning. In addition, a smaller parcel of studies was developed towards the Affective learning domain. According to Hamilton et al. (2021),

although affective behavioral change has been widely studied in non-educational applications of immersive VR, this domain was also underrepresented in their review and is an important area for future investigation.

Finally, less than 20% of the studies included multisensory immersion aspects in the scope of research and/or were supported by educational theories.

As a limitation of the SLR, the keywords selected potentially left out some important studies since they may have used different descriptors or indexations from those used in the present search. For example, "immersive experience," "immersion," "authentically (near real-life) situated experiences", etc., are highly relevant keywords in the context of this SLR. Also, the digital databases selected to recover the documents must be mentioned, which, although representative of high-quality scientific indexing systems, do not allow assuming that all the literature was covered.

In addition, we acknowledge a limitation of the study on diagnosing the conduction of research on VR, the sense of presence and learning outcomes. Given the natural publication size constraints, this paper did not specifically analysed the literature under the perspective of potential associations between the sense of presence and learning outcomes. However, we believe that this foundational study can be useful to launch a knowledge base necessary to sustain future works in this line of research.

To conclude, this review organized an overview of the empirical studies that have investigated the sense of presence and learning outcomes when VR is employed as the media to help researchers and practitioners consolidate this technology. It advances the field by contributing with a reasoned illustration of research gaps that need to be addressed and an agenda for future studies.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributors

Aliane Loureiro Krassmann is PhD in Informatics in Education from the Federal University of Rio Grande do Sul, Master and Bachelor in Computer Science from the Federal University of Santa Maria. She works as Information Technology Analyst at the Federal Institute Farroupilha (Brazil). Her research interests include Affective Computing, Distance Education, Virtual and Augmented Reality, and Conversational Agents.

Darque Pinto has a Master degree in Multimedia and a Bachelor degree in Communication and Multimedia, both from University of Trás-os-Montes and Alto Douro, Portugal. His research is mostly about learning a foreign language with the use of gamification in virtual reality.

Bruno Peixoto received the MSc in Multimedia degree from the University of Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal. He is currently a PhD student in Informatics at UTAD. His research interests are mainly Virtual Reality for Education. Since 2019, he has been a Research Fellow with the INESC TEC, Porto, Portugal.

Miguel Melo is an assistant researcher at INESC TEC, specializing in Computer Graphics. He is the R&D manager of the MASSIVE Virtual Reality Laboratory and a member of the Eurographics Executive Committee. His research interests are Computer Graphics, HDR, and Multisensory Virtual Reality.

Maximino Bessa is Assistant Professor, with Habilitation, of the Department of Engineering of the University of Trás-os-Montes and Alto Douro, Portugal, Senior Researcher of INESC TEC since 2009 and Director of the Multisensory Virtual Reality Laboratory MASSIVE. He's Member of the Eurographics Association since 2003 and Vice-President of the Portuguese Computer Graphics Chapter for the period 2016–2020.

Magda Bercht is Associate Professor, with Habilitation, of the Department of Informatics at the Federal University of Rio Grande do Sul. She works in the Graduate Program of Informatics in Education. Has experience in Computer Science, acting on the following subjects: affective computing, teaching and learning environments, pedagogical agents, intelligent teaching systems, artificial intelligence and programming languages.

ORCID

Aliane Loureiro Krassmann http://orcid.org/0000-0001-7553-5518
Miguel Melo http://orcid.org/0000-0003-4050-3473

Darque Pinto http://orcid.org/0000-0003-4146-017X
Bruno Peixoto http://orcid.org/0000-0002-5645-8147
Maximino Bessa http://orcid.org/0000-0002-3002-704X
Magda Bercht http://orcid.org/0000-0002-8943-5574

References

Anderson, P. H., & Lawton, L. (2009). Business simulations and cognitive learning: Developments, desires, and future directions. *Simulation & Gaming*, *40*(2), 193–216. https://doi.org/10.1177/1046878108321624

Barbosa, L., Monteiro, P., Pinto, M., Coelho, H., Melo, M., & Bessa, M. (2017, October 12–13). *Multisensory virtual environment for firefighter training simulation: Study of the impact of haptic feedback on task execution*. Paper presented at the 24° Encontro Português de Computação Gráfica e Interação (EPCGI) (pp. 1–7).

Bloom, B. S. (1956). *Taxonomy of educational objectives. Vol. 1: Cognitive domain*. McKay. 20(24), 1.

Bormann, K. (2006). Subjective performance. *Virtual Reality*, *9*(4), 226–233. https://doi.org/10.1007/s10055-006-0019-5

Cooper, N., Milella, F., Pinto, C., Cant, I., White, M., & Meyer, G. (2018). The effects of substitute multisensory feedback on task performance and the sense of presence in a virtual reality environment. *PloS one*, *13*, 2. https://doi.org/10.1371/journal.pone.0191846

Dengel, A., & Mäzdefrau, J. (2018, December 4–7). *Immersive Learning Explored: Subjective and Objective Factors Influencing Learning Outcomes in Immersive Educational Virtual Environments*. Paper presented at the IEEE International Conference on Teaching. Assessment, and Learning for Engineering (TALE), (pp. 608–615).

Dubovi, I., Levy, S. T., & Dagan, E. (2017). Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation. *Computers & Education*, *113*, 16–27. https://doi.org/10.1016/j.compedu.2017.05.009

Fokides, E., & Atsikpasi, P. (2018). Development of a model for explaining the learning outcomes when using 3D virtual environments in informal learning settings. *Education and Information Technologies*, 1–23. https://doi.org/10.1007/s10639-018-9719-1

Fuchs, P. (1996). *Les interfaces de la réalité virtuelle (pp. 210-pages)*. éditeur AJIIMD.

Girvan, C., & Savage, T. (2019). Virtual worlds: A new environment for constructionist learning. *Computers in Human Behavior*, *99*, 396–414. https://doi.org/10.1016/j.chb.2019.03.017

Grassini, S., & Laumann, K. (2020). Questionnaire measures and physiological correlates of presence: A systematic review. *Frontiers in Psychology*, *11*, 349. https://doi.org/10.3389/fpsyg.2020.00349

Grassini, S., Laumann, K., & Skogstad, M. R. (2020). The use of virtual reality alone does not promote training performance (but sense of presence does). *Frontiers in Psychology*, *11*, 1–11. https://doi.org/10.3389/fpsyg.2020.01743

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*, 1–32. https://doi.org/10.1007/s40692-020-00169-2

Hein, D., Mai, C., & Hußmann, H. (2018, May 21–22). *The usage of presence measurements in research: A review*. Proceedings of the 17th Conference of the International Society for Presence Research (ISPR).

Kim, H., Park, J. Y., & Kim, K. K. (2018). Spatial learning and memory using a Radial Arm Maze with a head-mounted display. *Psychiatry Investigation*, *15*(10), 935. https://doi.org/10.30773/pi.2018.06.28.3

Kitchenham, B. (2004). Procedures for performing systematic reviews. *Joint Technical Report. Keele, UK, Keele University*, *33*, 1–26.

Kwon, C. (2019). Verification of the possibility and effectiveness of experiential learning using HMD-based immersive VR technologies. *Virtual Reality*, *23*, 101–118. https://doi.org/10.1007/s10055-018-0364-1

Lee, E. A. L., Wong, K. W., & Fung, C. C. (2010). How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach. *Computers & Education*, *55*(4), 1424–1442. https://doi.org/10.1016/j.compedu.2010.06.006

Lee, K. M. (2004). Presence, explicated. *Communication Theory*, *14*(1), 27–50. https://doi.org/10.1111/j.1468-2885.2004.tb00302.x

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators and Virtual Environments*, *10*(3), 282–297. https://doi.org/10.1162/105474601300343612

Lombard, M., Ditton, T. B., & Weinstein, L. (2009). Measuring presence: The temple presence inventory. Paper presented at the 12th Annual International Workshop on Presence (pp. 1–15), October.

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, *60*, 225–236. https://doi.org/10.1016/j.learninstruc.2017.12.007

Massey, A. P., Montoya, M. M., & Wu, P. F. (2013, January 7–10). *3D virtual environments and corporate learning: An empirical investigation of benefits*. Paper presented at the, 46th Hawaii International Conference on System Sciences (HICSS) (pp. 893–902).

McGinn, M., & Arnedillo-Sánchez, I. (2015). Developing adolescents' resistance to sexual coercion through role-playing activities in a virtual world. *International Association for Development of the Information Society,* 275–278.

Nash, E. B., Edwards, G. W., Thompson, J. A., & Barfield, W. (2000). A review of presence and performance in virtual environments. *International Journal of Human-Computer Interaction*, *12*(1), 1–41. https://doi.org/10.1207/S15327590IJHC1201_1

Natsis, A., Vrellis, I., Papachristos, N. M., & Mikropoulos, T. A. (2012, July 4–6). *Technological factors, user characteristics and didactic strategies in educational virtual environments*. Paper presented at the IEEE, 12th International Conference on Advanced Learning Technologies (ICALT) (pp. 531–535).

Rheinberg, F., Vollmeyer, R., & Engeser, S. (2003). "Die erfassung des flow-erlebens".

Roettl, J., & Terlutter, R. (2018). The same video game in 2D, 3D or virtual reality–How does technology impact game evaluation and brand placements? *PloS one*, *13*, 7. https://doi.org/10.1371/journal.pone.0200724

Rupp, M. A., Odette, K. L., Kozachuk, J., Michaelis, J. R., Smither, J. A., & McConnell, D. S. (2019). Investigating learning outcomes and subjective experiences in 360-degree videos. *Computers & Education*, *128*, 256–268. https://doi.org/10.1016/j.compedu.2018.09.015

Schild, J., Lerner, D., Misztal, S., & Luiz, T. (2018, May 16–18). *Epicsave—enhancing vocational training for paramedics with multi-user virtual reality*. Paper presented at the IEEE, 6t. h International Conference on Serious Games and Applications for Health (SeGAH) (pp. 1–8).

Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. *Presence: Teleoperators and Virtual Environments*, *10*(3), 266–281. https://doi.org/10.1162/105474601300343603

Sutcliffe, A., & Alrayes, A. (2012). Investigating user experience in second life for collaborative learning. *International Journal of Human-Computer Studies*, *70*(7), 508–525. https://doi.org/10.1016/j.ijhcs.2012.01.005

Szczurowski, K., & Smith, M. (2017, October 31–November 4). *Measuring presence: Hypothetical quantitative framework*. Paper presented at the 23rd International Conference on Virtual System & Multimedia (VSMM) (pp. 1–8).

Takatalo, J., Häkkinen, J., Kaistinen, J., & Nyman, G. (2010). Presence, involvement, and flow in digital games. In R. Bernhaupt (Ed.), *Evaluating user experience in games. Human-computer interaction series* (pp. 23–46). Springer. https://doi.org/10.1007/978-1-84882-963-3_3.

Takatalo, J., Kawai, T., Kaistinen, J., Nyman, G., & Häkkinen, J. (2011). User experience in 3D stereoscopic games. *Media Psychology*, *14*(4), 387–414. https://doi.org/10.1080/15213269.2011.620538

Tao, G., & Archambault, P. S. (2016). Powered wheelchair simulator development: Implementing combined navigation-reaching tasks with a 3D hand motion controller. *Journal of Neuroengineering and Rehabilitation*, *13*(1), 3. https://doi.org/10.1186/s12984-016-0112-2

United Nations Educational, Scientific and Cultural Organization (UNESCO) official website. (2011). ISCED, The International Standard Classification of Education. Retrieved May 20, 2021, from http://uis.unesco.org/en/topic/international-standard-classification-education-isced

Usoh, M., Catena, E., Arman, S., & Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators and Virtual Environments*, *9*(5), 497–503. https://doi.org/10.1162/105474600566989

Vorderer, P., Wirth, W., Gouveia, F. R., Biocca, F., Saari, T., Jäncke, L., Böcking, S., Holger, S., Gysbers, A., Hartmann, T., Klimmt, C., Laarni, J., Ravaja, N., Sacau, A., Baumgartner, T. & Jäncke, P. (2004). Mec spatial presence questionnaire. *Retrieved Sept*, *18*(2004), 2015.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, *7*(3), 225–240. https://doi.org/10.1162/105474698565686

Yang, F. C. O., Lo, F. Y. R., Hsieh, J. C., & Wu, W. C. V. (2020). Facilitating communicative ability of EFL learners Via high-immersion virtual reality. *Journal of Educational Technology & Society*, *23*(1), 30–49.

Appendix I

List of extracted and analysed papers.

ID	Authors	Title	Year	Source
P1	Strickland, D.	A Virtual Reality Application with Autistic Children	1996	Scopus
P2	Hoffman, Prothero, Wells & Groen	Virtual Chess: Meaning Enhances Users' Sense of Presence in Virtual Environments	1998	Scopus
P3	Bystrom & Barfield	Collaborative task performance for learning using a virtual environment	1999	Scopus
P4	Darken, Bernatovich, Lawson & Peterson	Quantitative Measures of Presence in Virtual Environments: The Roles of Attention and Spatial Comprehension	1999	Scopus
P5	Winn, Hoffman, Hollander, Osberg, Rose & Char	Student-built virtual environments	1999	Scopus

(*Continued*)

Continued.

ID	Authors	Title	Year	Source
P6	Moreno & Mayer	Learning Science in Virtual Reality Multimedia Environments: Role of Methods and Media	2002	Scopus
P7	Whitelock, Romano, Jelfs & Brna	Perfect presence: What does this mean for the design of virtual learning environments?	2000	Scopus
P8	Mania & Chalmers	The Effects of Levels of Immersion on Memory and Presence in Virtual Environments: A Reality Centered Approach	2001	Scopus
P9	Lin, Duh, Parker, Abi-Rached & Furness	Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment	2002	Scopus
P10	Banerjee, Bochenek & Ragusa	Analyzing the Relationship of Presence and Immersive Tendencies on the Conceptual Design Review Process	2002	Scopus
P11	Stanney, Kingdon, Graeber & Kennedy	Human Performance in Immersive Virtual Environments: Effects of Exposure Duration, User Control, and Scene Complexity	2002	Scopus
P12	Li, Daugherty & Biocca	Impact of 3-D Advertising on Product Knowledge, Brand Attitude, and Purchase Intention: The Mediating Role of Presence	2002	Scopus
P13	Lok, Naik, Whitton & Brooks	Effects of Handling Real Objects and Self-Avatar Fidelity on Cognitive Task Performance and Sense of Presence in Virtual Environments	2003	Scopus
P14	Mania, Troscianko, Hawkes & Chalmers	Fidelity Metrics for Virtual Environment Simulations Based on Spatial Memory Awareness States	2003	Scopus
P15	Youngblut & Huie	The Relationship Between Presence and Performance in Virtual Environments: Results of a VERTS Study	2003	Scopus
P16	Figueroa, Bischof, Boulanger & Hoover	Efficient comparison of platform alternatives in interactive virtual reality applications	2005	Scopus
P17	Johnsen et al.	Experiences in Using Immersive Virtual Characters to Educate Medical Communication Skills	2005	Elsevier (Science Direct)
P18	Kizony, Raz, Katz, Weingarden & Weiss	Video-capture virtual reality system for patients with paraplegic spinal cord injury	2005	Scopus
P19	Ma & Kaber	Presence, workload and performance effects of synthetic environment design factors	2006	Scopus
P20	Mikropoulos	Presence: a unique characteristic in educational virtual environments	2006	Elsevier (Science Direct)
P21	Sebok & Nystad	Procedural training in virtual reality: A comparison of technology types	2006	Scopus
P22	Bormann	Subjective performance	2006	Scopus
P23	Mania, Wooldridge, Coxon & Robinson	The effect of visual and interaction fidelity on spatial cognition in immersive virtual environments	2006	Scopus
P24	Suh & Chang	User interfaces and consumer perceptions of online stores: The role of telepresence	2006	Scopus
P25	Kontogeorgiou, Bellou & Mikropoulos	Being inside the Quantum Atom	2008	Scopus
P26	Lee & Kim	Effects of haptic feedback, stereoscopy, and image resolution on performance and presence in remote navigation	2008	Scopus
P27	Phang & Kankanhalli	How Do Perceptions of Virtual Worlds Lead to Enhanced Learning? An Empirical Investigation	2009	Elsevier (Science Direct)
P28	Huthmann	Presence-dependent Performance Differences Between Virtual Simulations And Miniature Worlds	2009	Scopus
P29	Jeong, Song, Chang & Hodges	User experimentation: an evaluation of velocity control techniques in immersive virtual environments	2009	Scopus
P30	Groenegress, Holzner, Guger & Slater	Effects of P300-based BCI use on reported presence in a virtual environment	2010	Scopus
P31	Lee, Wong & Fung	How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach	2010	Scopus
P32	Lane, Hays, Auerbach & Core	Investigating the Relationship between Presence and Learning in a Serious Game	2010	Elsevier (Science Direct)

(*Continued*)

Continued.

ID	Authors	Title	Year	Source
P33	Kartiko, Kavakli & Cheng	Learning science in a virtual reality application: The impacts of animated-virtual actors' visual complexity	2010	Scopus
P34	Viciana-Abad, Lecuona & Poyade	The influence of passive haptic feedback and difference interaction metaphors on presence and task performance	2010	Scopus
P35	Jeong, Bohil & Biocca	Brand logo placements in violent games: Effects of violence cues on memory and attitude through arousal and presence	2011	Scopus
P36	Kirshner, Weiss & Tirosh	Meal-Maker: A virtual meal preparation environment for children with cerebral palsy	2011	Scopus
P37	Bernardet, Väljamäe, Inderbitzin, Wierenga, Mura & Verschure	Quantifying human subjective experience and social interaction using the eXperience Induction Machine	2011	Scopus
P38	Schrader & Bastiaens	The influence of virtual presence: Effects on experienced cognitive load and learning outcomes in educational computer games	2012	Scopus
P39	Wang & Lindeman	Comparing isometric and elastic surfboard interfaces for leaning-based travel in 3D virtual environments	2012	Scopus
P40	Sutcliffe & Alrayes	Investigating user experience in Second Life for collaborative learning	2012	IEEE Xplore
P41	Schrader & Bastiaens	Learning in educational computer games for novices: The impact of support provision types on virtual presence, cognitive load, and learning outcomes	2012	Elsevier (Science Direct)
P42	Schrader & Bastiaens	Relations Between the Tendency to Invest in Virtual Presence, Actual Virtual Presence, and Learning Outcomes in Educational Computer Games	2012	Scopus
P43	Yim, Cicchirillo & Drumwright	The impact of stereoscopic three-dimensional (3-D) advertising	2012	Scopus
P44	Merchant, Goetz, Keeney-Kennicutt, Kwok, Cifuentes & Davis	The learner characteristics, features of desktop 3D virtual reality environments, and college chemistry instruction: A structural equation modeling analysis	2012	Scopus
P45	Massey, Montoya & Wu	3D virtual environments and corporate learning: An empirical investigation of benefits	2013	Elsevier (Science Direct)
P46	Kalyvioti & Mikropoulos	A virtual reality test for the identification of memory strengths of dyslexic students in higher education	2013	Scopus
P47	Rus-Calafell, Gutiérrez-Maldonado & Ribas-Sabaté	Neurocognition, presence and acceptance of a VR programme for psychotic patients: A correlational study	2013	Scopus
P48	Wallis & Tichon	Predicting the efficacy of simulator-based training using a perceptual judgment task versus questionnaire-based measures of presence	2013	Scopus
P49	Grewe et al.	Learning real-life cognitive abilities in a novel 360°-virtual reality supermarket: A neuropsychological study of healthy participants and patients with epilepsy	2013	Scopus
P50	Schrader	The Relation between Virtual Presence and Learning Outcomes in Serious Games – The Mediating Effect of Motivation	2013	Scopus
P51	Viciana-Abad, Reyes-Lecuona, Rosa-Pujazón & Pérez-Lorenzo	The influence of different sensory cues as selection feedback and co-location in presence and task performance	2014	Scopus
P52	Papachristos, Vrellis, Natsis & Mikropoulos	The role of environment design in an educational Multi-User Virtual Environment	2014	Scopus
P53	McGinn & Arnedillo-Sánchez	Developing adolescents' resistance to sexual coercion through role-playing activities in a virtual world	2015	Scopus
P54	Liu & Uang	Effects of depth perception cues and display types on presence and cybersickness in the elderly within a 3D virtual store	2015	Scopus
P55	Lackey, Maraj & Barber	Immersion, Presence, and Flow in Robot-Aided ISR Simulation-Based Training	2015	Scopus
P56	Heydarian, Carneiro, Gerber, Becerik-Gerber, Hayes & Wood	Immersive virtual environments versus physical built environments: A benchmarking study for building design and user-built environment explorations	2015	Scopus
P57	Repetto, Colombo & Riva	Is Motor Simulation Involved During Foreign Language Learning? A Virtual Reality Experiment	2015	Scopus

(*Continued*)

Continued.

ID	Authors	Title	Year	Source
P58	Cho, Yim & Paik	Physical and social presence in 3D virtual role-play for pre-service teachers	2015	Scopus
P59	Ntokas, Maratou & Xenos	Usability and presence evaluation of a 3D virtual world learning environment simulating information security threats	2015	Scopus
P60	Parmar et al.	A comparative evaluation of viewing metaphors on psychophysical skills education in an interactive virtual environment	2016	Scopus
P61	Tao & Archambault	Powered wheelchair simulator development: Implementing combined navigation-reaching tasks with a 3D hand motion controller	2016	Scopus
P62	Ke, Lee & Xu	Teaching training in a mixed-reality integrated learning environment	2016	Scopus
P63	Tüzün & Özdinç	The effects of 3D multi-user virtual environments on freshmen university students' conceptual and spatial learning and presence in departmental orientation	2016	Scopus
P64	Makowski, Sperduti, Nicolas & Piolino	"Being there" and remembering it: Presence improves memory encoding	2017	Scopus
P65	Makransky, Terkildsen & Mayer	Adding immersive virtual reality to a science lab simulation causes more presence but less learning	2019	Elsevier (Science Direct)
P66	Cooper, Milella, Cant, Pinto, White & Meyer	Augmented Cues Facilitate Learning Transfer from Virtual to Real Environments	2017	Scopus
P67	Chowdhury, Costa & Quarles	Information Recall in a Mobile VR Disability Simulation	2017	Scopus
P68	Chowdhury, Ferdous & Quarles	Information recall in a virtual reality disability simulation	2017	Scopus
P69	Chowdhury, Costa & Quarles	Information recall in VR disability simulation	2017	Scopus
P70	Barbosa, Monteiro, Pinto, Coelho, Melo & Bessa	Multisensory virtual environment for firefighter training simulation	2017	Scopus
P71	Dubovi, Levy & Dagan	Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation	2017	Scopus
P72	Schroeder, Bailey, Johnson & Gonzalez-Holland	Presence and usability do not directly predict procedural recall in virtual reality training	2017	Scopus
P73	Avveduto, Tanca, Lorenzini, Tecchia, Carrozzino & Bergamasco	Safety training using virtual reality: A comparative approach	2017	Scopus
P74	Fokides & Atsikpasi	Development of a model for explaining the learning outcomes when using 3D virtual environments in informal learning settings	2018	Scopus
P75	Schild, Lerner, Misztal & Luiz	EPICSAVE - Enhancing Vocational Training for Paramedics with Multi-user Virtual Reality	2018	Scopus
P76	Khashe, Becerik-Gerber, Lucas & Gratch	Persuasive Effects of Immersion in Virtual Environments for Measuring Pro-Environmental Behaviors	2018	Scopus
P77	Kim, Park & Kim	Spatial Learning and Memory Using a Radial Arm Maze with a Head-Mounted Display	2018	Web of Science
P78	Natsis, Vrellis, Papachristos & Mikropoulos	Technological Factors, User Characteristics and Didactic Strategies in Educational Virtual Environments	2012	Scopus
P79	Cooper, Milella, Pinto, Cant, White & Meyer	The effects of substitute multisensory feedback on task performance and the sense of presence in a virtual reality environment	2018	Scopus
P80	Gehrke, Iversen, Makeig & Gramann	The Invisible Maze Task (IMT): Interactive Exploration of Sparse Virtual Environments to Investigate Action-Driven Formation of Spatial Representations	2018	Scopus
P81	Roettl & Terlutter	The same video game in 2D, 3D or virtual reality – How does technology impact game evaluation and brand placements?	2018	Scopus
P82	Kwon	Verification of the possibility and effectiveness of experiential learning using HMD-based immersive VR technologies	2019	Scopus
P83	Rupp, Odette, Kozachuk, Michaelis, Smither & McConnell	Investigating learning outcomes and subjective experiences in 360-degree videos	2019	Scopus

(*Continued*)

Continued.

ID	Authors	Title	Year	Source
P84	Vora, Nair, Gramopadhye, Duchowski, Melloy & Kanki	Using virtual reality technology for aircraft visual inspection training: Presence and comparison studies	2002	Elsevier (Science Direct)
P85	Mikropoulos & Strouboulis	Factors that influence presence in educational virtual environments	2004	Scopus
P86	Slater, Linakis, Usoh & Kooper	Immersion, Presence, and Performance in Virtual Environments: An Experiment with Tri-Dimensional Chess	1999	ACM Digital Library
P87	Calvert & Abadia	Impact of immersing university and high school students in educational linear narratives using virtual reality technology	2020	Elsevier (Science Direct)
P88	Sallnäs, Rassmus-Gröhn & Sjöström	Supporting Presence in Collaborative Environments by Haptic Force Feedback	2000	ACM Digital Library
P89	Scoresby & Shelton	Visual perspectives within educational computer games: effects on presence and flow within virtual immersive learning environments	2011	Scopus
P90	Taylor & Barnett	Training effectiveness of wearable and desktop simulator interfaces	2010	Scopus
P91	Ahmad, Wan & Jiang	Immersive environment courseware evaluation	2011	Elsevier (Science Direct)
P92	Tiffany & Hoglund	Teaching/Learning in Second Life: Perspectivesof Future Nurse-Educators	2014	Elsevier (Science Direct)
P93	Shu, Huang, Chang & Chen	Do virtual reality head-mounted displays make a difference? A comparison of presence and self-efficacy between head-mounted displays and desktop computer-facilitated virtual environments	2019	Scopus
P94	Larrue, Sauzeon, Aguilova, Lotte, Hachet & Nkaoua	Brain Computer Interface vs Walking Interface in VR: The Impact of Motor Activity on Spatial Transfer	2012	ACM Digital Library
P95	Yeh, Hwang, Wang & Chen	Effects of Multi-symbols on Enhancing Virtual Reality Based Collaborative Task	2012	Scopus
P96	Jo, Kim & Kim	Effects of Avatar and Background Representation Forms to Co-Presence in Mixed Reality (MR) Tele-conference Systems	2016	ACM Digital Library
P97	Tcha-Tokey, Loup-Escande, Christmann & Richir	Effects on User Experience in an Edutainment Virtual Environment: Comparison Between CAVE and HMD	2017	ACM Digital Library
P98	Peixoto, Cabral, Melo, Krassmann, Pinto & Bessa	Virtual Reality in Education: Learning a Foreign Language	2019	Scopus
P99	Bozgeyikli, Raij, Katkoori & Dubey	Locomotion in Virtual Reality for Individuals with Autism Spectrum Disorder	2016	ACM Digital Library
P100	Kolkmeier, Harmsen, Giesselink, Reidsma, Theune & Heylen	With a Little Help from a Holographic Friend: The OpenIMPRESS Mixed Reality Telepresence Toolkit for Remote Collaboration Systems	2018	ACM Digital Library
P101	Lombardo	Study of an interactive and total immersive device with a personal 3D viewer and its effects on the explicit long-term memories of the subjects	2014	Scopus
P102	Yue, Wang, Yang, Hu, Liu & Zhu	Evaluation of the user experience of "astronaut training device": An immersive, vr-based, motion-training system	2016	Scopus
P103	Parong, Pollard, Files, Oiknine, Sinatra, Moss & Khooshabeh	The mediating role of presence differs across types of spatial learning in immersive technologies	2020	Elsevier (Science Direct)
P104	Eiris, Jain, Gheisari & Wehle	Safety immersive storytelling using narrated 360-degree panoramas: A fall hazard training within the electrical trade context	2020	Elsevier (Science Direct)
P105	Krassmann, Nunes, Bessa, Tarouco & Bercht	Virtual Companions and 3D Virtual Worlds: Investigating the Sense of Presence in Distance Education	2019	Scopus
P106	Ferguson, van den Broek & van Oostendorp	On the role of interaction mode and story structure in virtual reality serious games	2020	Scopus
P107	Bhowmick, Darbar & Sorathia	Pragati: Design and Evaluation of a Mobile Phone-Based Head Mounted Virtual Reality Interface to Train Community Health Workers in Rural India	2018	ACM Digital Library

(*Continued*)

Continued.

ID	Authors	Title	Year	Source
P108	Lu & Davis	Effects of prolonged exposure to feedback delay on the qualitative subjective experience of virtual reality	2018	Scopus
P109	Hite, Jones, Childers, Ennes, Chesnutt, Pereyra & Cayton	Investigating Potential Relationships Between Adolescents' Cognitive Development and Perceptions of Presence in 3-D, Haptic-Enabled, Virtual Reality Science Instruction	2019	Scopus
P110	Narciso, Bessa, Melo & Vasconcelos-Raposo	Virtual reality for training-the impact of smell on presence, cybersickness, fatigue, stress and knowledge transfer	2019	Scopus
P111	Eiris, John, Gheisari, Jain, Wehle & Memarian	Hazard-Recognition Training Using Omnidirectional Cinemagraphs: Comparison between Virtual Reality and Lecture-Based Techniques	2020	Scopus
P112	Nie & Wu	Investigating the effect of immersive virtual reality and planning on the outcomes of simulation-based learning: A media and method experiment	2020	Scopus
P113	Wu, Hu & Wang	How do Head-mounted Displays and Planning Strategy Influence Problem- solving-based Learning in Introductory Electrical Circuit Design?	2020	Scopus
P114	Selzer, M. N., Gazcon, N. F., & Larrea	Effects of virtual presence and learning outcome using low-end virtual reality systems	2019	Elsevier (Science Direct)
P115	Schwind, Halbhuber, Fehle, Sasse, Pfaffelhuber, Tögel & Henze	The Effects of Full-Body Avatar Movement Predictions in Virtual Reality Using Neural Networks	2020	ACM Digital Library
P116	Huang, Luo, Yang, Lu & Chen	Influence of Students' Learning Style, Sense of Presence, and Cognitive Load on Learning Outcomes in an Immersive Virtual Reality Learning Environment	2020	Web of Science
P117	Yang, Lo, Hsieh & Wu	Facilitating Communicative Ability of EFL Learners via High-Immersion Virtual Reality	2020	Web of Science
P118	Braun, Davitti & Slater	'It's like being in bubbles': affordances and challenges of virtual learning environments for collaborative learning in interpreter education	2020	Scopus
P119	Cha, Zhang & Kim	Effects of Interior Color Schemes on Emotion, Task Performance, and Heart Rate in Immersive Virtual Environments	2020	Scopus
P120	Han	Immersive virtual field trips in education: A mixed-methods study on elementary students' presence and perceived learning	2020	Scopus
P121	Zhao, LaFemina, Carr, Sajjadi, Wallgrün & Klippel	Learning in the Field: Comparison of Desktop, Immersive Virtual Reality, and Actual Field Trips for Place-Based STEM Education	2020	Scopus
P122	Ratcliffe & Tokarchuk	Presence, Embodied Interaction and Motivation: Distinct Learning Phenomena in an Immersive Virtual Environment	2020	ACM Digital Library
P123	Corelli, Battegazzorre, Strada, Bottino & Cimellaro	Assessing the Usability of Different Virtual Reality Systems for Firefighter Training	2020	Scopus
P124	Yang, Lo, Hsieh & Wu	Facilitating Communicative Ability of EFL Learners via High-Immersion Virtual Reality	2020	Scopus
P125	Khenak, Vézien & Bourdot	Spatial Presence, Performance, and Behavior between Real, Remote, and Virtual Immersive Environments	2020	Scopus
P126	Fokides & Kefallinou	Examining the impact of spherical videos in teaching endangered species/environmental education to primary school students	2020	Scopus
P127	Makransky & Petersen	Investigating the process of learning with desktop virtual reality: A structural equation modeling approach	2019	Elsevier (Science Direct)
P128	Qian,, Ma, Pan & Yang	Effects of Virtual-real fusion on immersion, presence, and learning performance in laboratory education	2020	Elsevier (Science Direct)
P129	Krassmann, Melo, Peixoto, Pinto, Bessa & Bercht	Learning in Virtual Reality: Investigating the Effects of Immersive Tendencies and Sense of Presence	2020	Scopus
P130	Lerner, Mohr, Schild, Göring & Luiz	An immersive multi-user virtual reality for emergency simulation training: Usability study	2020	Scopus

(*Continued*)

Continued.

ID	Authors	Title	Year	Source
P131	Cadet & Chainay	Memory of virtual experiences: Role of immersion, emotion and sense of presence	2020	Elsevier (Science Direct)
P132	Chen & Hsu	Self-regulated mobile game-based English learning in a virtual reality environment	2020	Elsevier (Science Direct)
P133	Voinescu, Morgan, Alford & Caleb-Solly	The utility of psychological measures in evaluating perceived usability of automated vehicle interfaces – A study with older adults	2020	Elsevier (Science Direct)
P134	Eiris, Gheisari & Esmaeili	Desktop-based safety training using 360-degree panorama and static virtual reality techniques: A comparative experimental study	2020	Elsevier (Science Direct)
P135	Xu & Wang	Efficacy of vr-based reminiscence therapy in improving autobiographical memory for chinese patients with ad	2020	Scopus
P136	Le Noury, Buszard, Reid & Farrow	Examining the representativeness of a virtual reality environment for simulation of tennis performance	2020	Scopus
P137	Krassmann, Herpich, Tarouco & Bercht	Investigating the Relation Between Sense of Presence, Attention and Performance: Virtual Reality Versus Web	2020	Scopus
P138	Ferguson & Van Oostendorp	Lost in Learning: Hypertext Navigational Efficiency Measures Are Valid for Predicting Learning in Virtual Reality Educational Games	2020	Scopus
P139	Samosorn, Gilbert, Bauman, Khine & McGonigle	Teaching Airway Insertion Skills to Nursing Faculty and Students Using Virtual Reality: A Pilot Study	2020	Scopus
P140	Grassini, Laumann & Skogstad	The Use of Virtual Reality Alone Does Not Promote Training Performance (but Sense of Presence Does)	2020	Scopus