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An Immersive Virtual Learning Environment for the Development of Hard Skills: A Scientometric Analysis and Systematic Review

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Abstract

A scientometric analysis and systematic review of an immersive virtual learning environment (IVLE) designed to improve the development of hard skills comprised this study. The review focused on the period between 2016 and 2023 and was conducted using the Scopus database. This study employed a scientometrics analysis and systematic review methodology. In this study, a comprehensive analysis was conducted on a corpus of 12 scholarly articles that have been published within the last 8 years. This study looked at the aggregate magnitude and trajectory of scholarly publications and looked at a number of trends in scholarly research, including annual reports, article counts, article distribution across different sources, finding the most useful sources, keyword analysis, looking into the best collaboration groups, looking at how themes have changed over time, judging contributions, and practical implications. The primary findings regarding the data and document types indicated that a total of 12 articles were published across 10 different sources within the timeframe of 2016 to 2023. The research conducted on IVLE for the development of hard skills exhibited fluctuations in its pace, alternating between deceleration and positive acceleration. The growth rate of the articles peaked in 2022. The primary publication with the greatest of source is “Lecture Notes in Networks and Systems.” Keyword Plus growth rate for terms like “virtual reality,” “e-learning,” and “teaching” The nations exhibit a high degree of collaboration in the field of research. The findings indicated that the authors hailing from Mexico and Colombia exhibited the greatest frequency (n = 2). The thematic evolution of the study indicated two significant advancements: firstly, the emergence of e-learning studies that have propelled the field of e-learning, and secondly, the integration of virtual reality into e-learning practices. The classification of applications encompasses various components: title, solution, learning strategy, and learning tasks.

Keywords: immersive learnning, virtual learning, virtual learning environment, virtual reality, hard skills, scientometric analysis, systematic review, scopus

1. Introduction

Developing hard, soft, and strong skills presents both challenges and opportunities. In the current labor market, technical skills alone are insufficient for employment in big organizations and in-demand professions (Karavidas et al., 2023). Therefore, there is a significant focus on the development of soft skills, which are crucial for work performance (Majumdar, 2016). However, there are challenges in addressing skills shortages, particularly in the organized and unorganized sectors (Rao, 2013). On the other hand, the demand for skilled workers is increasing, creating opportunities for individuals to enhance their skills and find employment. Developing a gamification framework through a learning management system can be an effective approach to improve both soft and hard skills. This framework categorizes skills into distinct groups and assigns points based on user engagement, encouraging students to engage more with the system. Overall, developing hard, soft, and strong skills is essential for success in the current labor market, and leveraging innovative approaches can help address the challenges and seize the opportunities. The development of hard skills is confronted with challenges when utilizing immersive virtual learning environments. The presence of intricate information components within these environments has the potential to increase cognitive load, thereby diminishing learners’ interest and motivation (Korhonen et al., 2022). Immersive virtual environments present challenges related to extraneous cognitive load and heightened requirements for self-regulated learning, as they often lack linear progression and

definitive conclusions. Furthermore, it is imperative to acknowledge the task of incorporating tutoring systems into virtual immersive environments (Gordon & Brayshaw, 2017). The effective utilization of human-computer interaction features in virtual environment platforms is crucial for enhancing educational value, particularly in the context of computer-mediated instruction (Jiang et al., 2018). There remain unresolved questions regarding the capabilities and limitations of modern technology in relation to the effectiveness of knowledge and skill acquisition in the domain of virtual reality (Carruth, 2017). The implementation of a virtual immersive learning environment for the development of hard skills offers a multitude of benefits. To begin, using immersive virtual learning environments makes it possible to create learning environments that are very similar to real-life situations. This solves many of the problems that come up in the industry when it comes to timeliness, accuracy, and scalability (Korhonen et al., 2022). Secondly, recent research conducted by Gao et al. (2022) has revealed that individuals who engage in immersive virtual reality learning environments exhibit notably superior performance on tests assessing conceptual and procedural knowledge transfer when compared to those who partake in traditional video learning. Furthermore, it is worth noting that immersive virtual learning environments possess the capacity to facilitate the transfer of knowledge and foster the cultivation of intricate problem-solving abilities (Zhang & Liu, 2023). It is crucial to take into account the cognitive load associated with immersive virtual learning environments, as the presence of intricate information components has the potential to divert learners' attention and diminish their interest and motivation (Serag-Bolos et al., 2022). In general, immersive virtual learning environments offer prospects for immersive experiences, flexibility in learning, and efficient learning approaches (Cao et al., 2022).

The advancement of immersive virtual reality (VR) technology has facilitated the creation of immersive VR learning environments (VRLEs) that have the capability to facilitate training in hard skills (Jantakun et al., 2023). The integration of VRLEs with intelligent tutoring systems (ITS) has the potential to enhance adaptive and self-directed acquisition of procedural skills (Laine et al., 2022). According to Huang et al. (2022), a comprehensive analysis of existing literature in this field demonstrated that VRLEs commonly replicate authentic work conditions or equipment. The tutoring agents within these environments possess the ability to observe and comprehend the actions and progress of learners, allowing them to offer guidance in the form of procedural hints or interjections during specific events. Nevertheless, it is crucial to acknowledge that none of the studies under review presented empirical data regarding the efficacy of the training and tutoring interventions. A lot of research has already been done on immersive VRLEs for training hard skills. This research shows that these environments have a lot of potential for helping people learn procedural skills in a variety of different areas without being able to interact with others at the same time.

The field of scientometrics is of significant importance as it encompasses the study of science, including its organizational structure, dynamic processes, and intricate relationship with society. According to Roslan et al. (2022), the platform offers a range of tools that facilitate the monitoring of scientific accomplishments and provide support for the advancement of scientific research. Scientometric research methods and indicators are widely employed on a global scale to evaluate the efficacy of scientific endeavors and inform science policy. Nevertheless, there are apprehensions regarding the commercialization of the publishing industry and the potential repercussions of formal scientometric indicators on the overall caliber of scientific publications (Khokhlov, 2020). Even with these worries, using scientometric analysis can lead to important and useful discoveries in many areas, such as chemical management, learning analytics, and flexible display technology (Mirriahi et al., 2014; Yan et al., 2019). These analyses facilitate the identification of trends in publication, research focus areas, and regional distribution. This information can be utilized to make informed decisions and allocate resources effectively within these fields. Overall, in the realm of scientific management, the field of scientometrics assumes a pivotal position by facilitating the management of scientific endeavors, evaluating the inherent scientific capabilities, and providing guidance for research undertakings.

This study aims to conduct a comprehensive scientometric analysis and systematic review of an immersive virtual learning environment for developing hard skills. This research will explore the growth, impact, and trends within the field. Through the examination of data derived from the Scopus dataset spanning the years 2016 to 2023, By employing scientometric analysis and conducting a systematic review, the present study aims to investigate and evaluate the relevant literature in a comprehensive and rigorous manner. The primary objective of this study is to investigate and provide answers to eight distinct research questions (RQs):

RQ1. What is the overall volume and growth pattern of publications in IVLE for developing hard skills literature?

RQ2. Who are the top sources in IVLE for developing hard skills literature in terms of publications?

RQ3. Which are the top sources (journals, book series, conferences) in IVLE for developing hard skills literature in terms of volume of publications and citations?

RQ4. What are the Keywords Plus in IVLE for developing hard skills?

RQ5. Who are the top collaboration groups in IVLE for developing hard skills in terms of publications?

RQ6. What are thematic evolutions of IVLE for developing hard skills?

RQ7. What are applications in IVLE for developing hard skills?

2. Research Methodology

2.1 The Approach

This study employs a unique combination of scientometrics and systematic review methodologies, specifically utilizing the PRISMA 2020 framework, in order to achieve its research objective. This approach is deemed crucial and appropriate for examining the thematic progression of emerging technologies in the field of education, as well as less investigated topics (Chen et al., 2021). The present study employs scientometrics to provide a descriptive analysis and thematic evolution (Santana & Cobo, 2020) prior to presenting the systematic review. The present study employs the PRISMA 2020 guidelines (Brennan & Munn, 2021) for conducting a systematic review, which is subsequently presented in accordance with scientometric principles. Figure 1 illustrates the PRISMA flow diagram, which outlines the process of article selection.

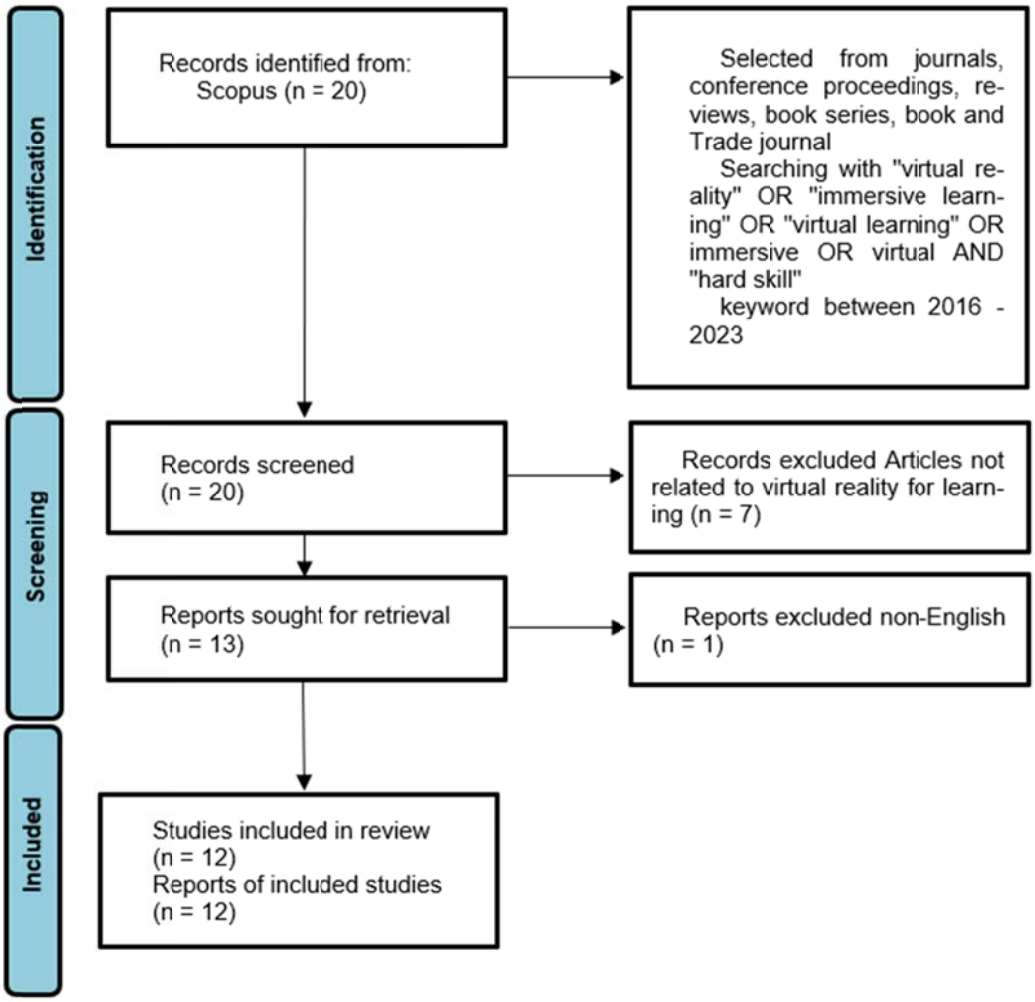

Figure 1. PRISMA 2020 of article selection

2.2 Database and Keyword Selection

The terms “virtual reality,” “immersive learning,” “virtual learning,” “immersive,” “virtual,” and “hard skill” are commonly employed to refer to the advancement of the “Immersive virtual approach to hard skill learning” within the context of integrated virtual learning environments. The assessment of their compatibility with virtual reality has been conducted in conjunction with the development of hard skills. Therefore, this study employed six specific keywords (“Virtual reality” OR “immersive learning” OR “virtual learning” OR “immersive” OR “virtual”) and (“hard skill”) to refine the search results in the SCOPUS database, aligning with its research objectives. As of November 15, 2023, the preliminary findings indicate that the SCOPUS database contains a total of 20 indexed documents.

2.3 Inclusion and Exclusion Criteria

The documents analyzed in this study did not pertain to the utilization of virtual reality for the acquisition of hard skills. Additionally, any documents that were not published in the English language were excluded from the research. Therefore, the study exclusively included articles that were published in SCOPUS, with a total of 12 articles being selected. The presentation of the Inclusion and Exclusion Criteria can be observed in Table 1.

Table 1. Inclusion and exclusion criteria

Criteria		
Inclusion	I1	Documents related to IVLE for developing hard skills
	I2	Documents published from 2016 to 2023
	I3	Journals, conference proceedings, reviews and book chapters
Exclusion	E1	Articles are written in non-English
	E2	Documents not related to IVLE for hard skills learning

2.4 Tools and Techniques

The analysis of the selected articles (n = 12) was conducted using the Bibliometrix package (Aria & Cuccurullo, 2017) in the R programming language (Chan & Chan, 2018). The findings of this scientometric analysis are presented in the following section.

3. Descriptive Analysis

The table labeled as Table 2 provides a descriptive summary of the articles that were utilized in this particular study. The primary findings regarding the data and document types indicate that a total of 12 articles were published across 10 different sources within the timeframe of 2016 to 2023. The research in this domain exhibits a low level of collaboration, as evidenced by the fact that there are 37 authors with an average of 3.33 co-authors per article. Only one document was authored by a single individual. Another salient aspect derived from the descriptive analysis pertains to the mean number of citations per document. The mean number of citations per document in this corpus is 3.083, indicating that the articles published in this field receive relatively few references. The subsequent section presents the content of the document, including the author’s keywords (n = 44) and Keyword Plus (n = 109).

Figure 2. The descriptive summary of Article Selection

Table 2. Descriptive

Description	Results
"MAIN INFORMATION ABOUT DATA"	
"Timespan"	2016:2023
"Sources (Journals, Books, etc)"	10
"Documents"	12
"Annual Growth Rate %"	5.96
"Document Average Age"	2.33
"Average citations per doc"	3.083
"References"	290
"DOCUMENT CONTENTS"	
"Keywords Plus (ID)"	109
"Author's Keywords (DE)"	44
"AUTHORS"	
"Authors"	37
"Authors of single-authored docs"	1
"AUTHORS COLLABORATION"	
"Single-authored docs"	1
"Co-Authors per Doc"	3.33
"International co-authorships %"	16.67
"DOCUMENT TYPES"	
"article"	2
"Book chapter"	2
"Conference paper"	8

3.1 Annual Scientific Production

In the year 2016, a limited number of studies, specifically two, were published that specifically examined the utilization of IVLE for the purpose of enhancing hard skills development. Nevertheless, the frequency of articles has exhibited a decline, with only one article published in 2018 and another in 2020. However, there has been a subsequent increase, with four articles published in 2022. The findings from the annual scientific production, as depicted in Figure 3 and Table 3, demonstrate a notable increase in research interest within this field during the period of 2022–2023.

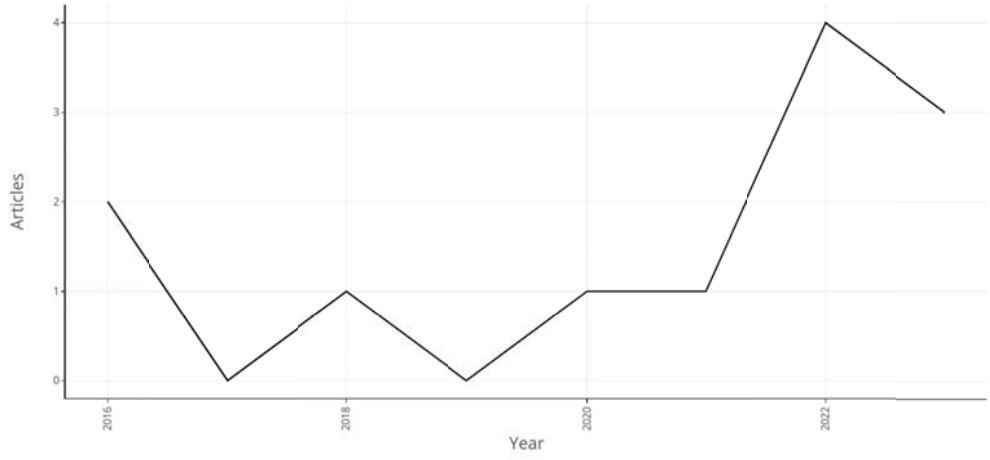

Figure 3. Annual scientific production

Table 3. Annual scientific production

Year	Articles
2016	2
2017	0
2018	1
2019	0
2020	1
2021	1
2022	4
2023	3
Total	**12**

3.2 Top 5 Sources of IVLE for the development of hard skills Research in Zone 1 (Bradford's Law)

The application of Bradford law, as proposed by Bradford in 1934, involves the utilization of the Pareto distribution to categorize articles into three distinct zones, specifically referred to as Zone 1, Zone 2, and Zone 3. Based on the findings of Bradford's law as presented in Table 4, it is evident that the sources "LECTURE NOTES IN NETWORKS AND SYSTEMS," "ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING," "AI IN LEARNING: DESIGNING THE FUTURE," "INDUSTRY AND HIGHER EDUCATION," and "INTERNATIONAL JOURNAL OF ENGINEERING PEDAGOGY" exhibit the highest frequency of articles. Specifically, these sources have published 3, 1, 1, 1, and 1 article, respectively, within the specified time period.

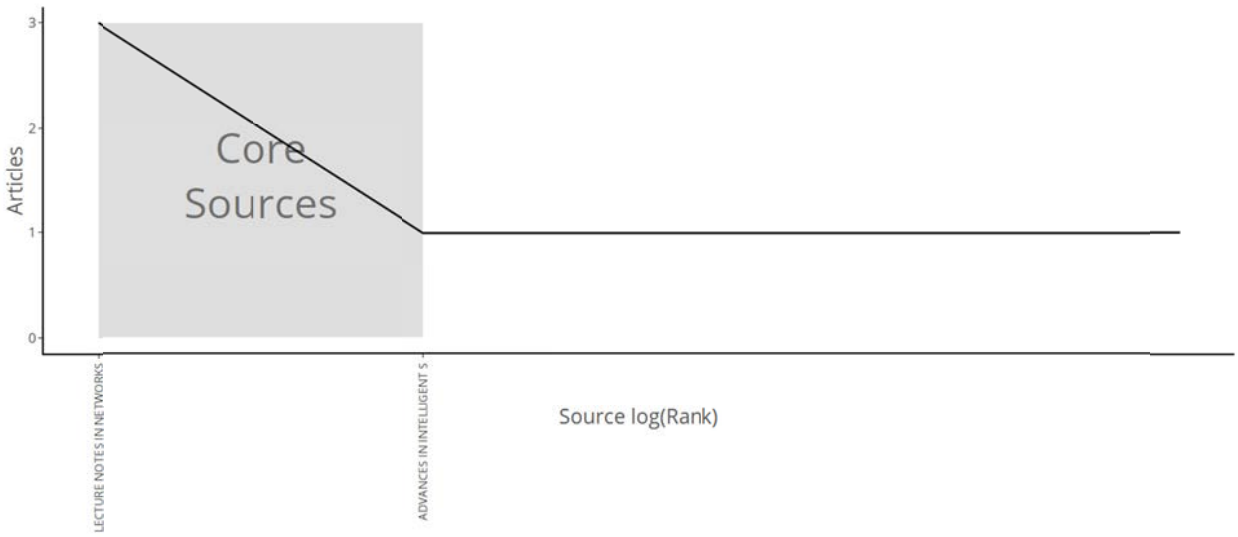

Figure 4. Core sources by Bradford's Law

Table 4. Top 10 Sources in Zone 1, Zone 2 and Zone 3 (Core Sources by Bradford's Law)

Sources	Rank	Frequency	cumFreq	Zone
"LECTURE NOTES IN NETWORKS AND SYSTEMS"	1	3	3	Zone 1
"ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING"	2	1	4	Zone 1
"AI IN LEARNING: DESIGNING THE FUTURE"	3	1	5	Zone 2
"INDUSTRY AND HIGHER EDUCATION"	4	1	6	Zone 2
"INTERNATIONAL JOURNAL OF ENGINEERING PEDAGOGY"	5	1	7	Zone 2
"PROCEEDINGS - 2020 14TH TECHNOLOGIES APPLIED TO ELECTRONICS TEACHING CONFERENCE, TAEE 2020"	6	1	8	Zone 2
"PROCEEDINGS - 2022 IEEE INTERNATIONAL SYMPOSIUM ON MIXED AND AUGMENTED REALITY ADJUNCT, ISMAR-ADJUNCT 2022"	7	1	9	Zone 2
"PROCEEDINGS - 2022 INTERNATIONAL CONFERENCE ON ENGINEERING AND MIS, ICEMIS 2022"	8	1	10	Zone 3
"PROCEEDINGS - WEB3D 2018: 23RD INTERNATIONAL ACM CONFERENCE ON 3D WEB TECHNOLOGY"	9	1	11	Zone 3
"PROCEEDINGS OF THE ANNUAL INTERNATIONAL CONFERENCE OF THE IEEE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY, EMBS"	10	1	12	Zone 3

3.3 Word Dynamics (Keyword Plus Growth Rate)

Figure 5 illustrates the cumulative frequency of Keyword Plus and its corresponding rate of growth over the period from 2016 to 2023. Terms such as "adolescent," "adult," "aged," "auscultation," "cardiovascular diseases," "e-learning," "students," "teaching," and "virtual reality" arose and expanded throughout the specified period. The inclusion of the keyword "plus" alongside the growth rate suggests the emergence of novel research themes within this particular field. Therefore, the subsequent section will undertake an analysis and presentation of the thematic evolution of Keyword Plus.

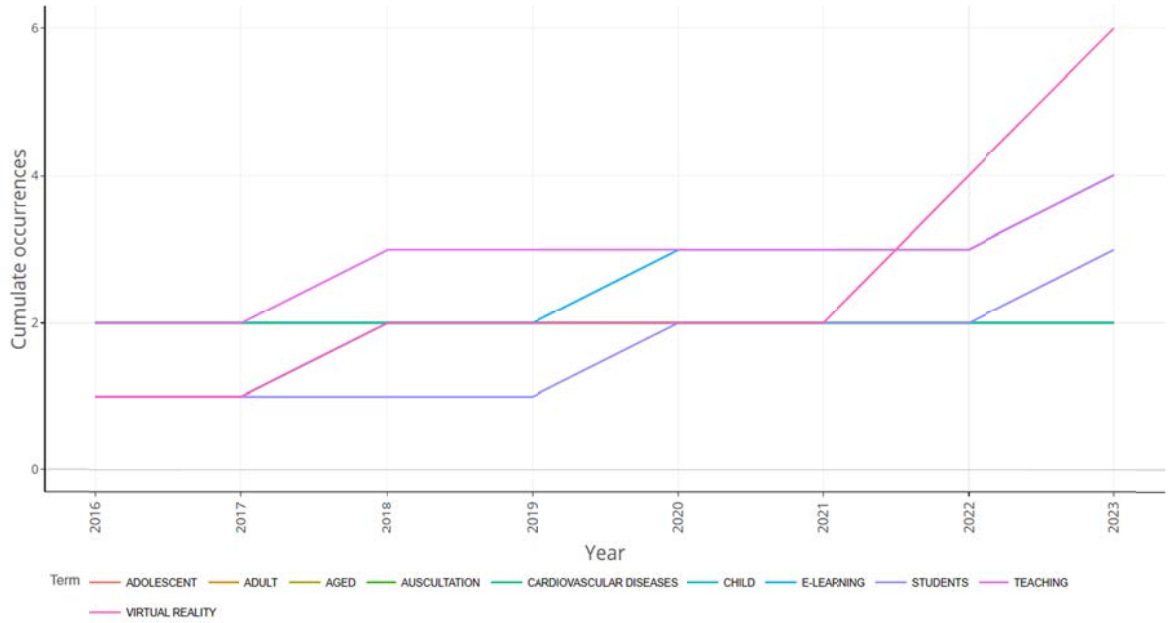

Figure 5. Work Growth (Keyword Plus)

3.4 Countries' Scientific Production

The data presented in Figure 6 and Table 5 illustrate the scientific production of various countries in the field of research, highlighting the contribution of authors from different nations. The findings indicated that the authors hailing from Mexico exhibited the most substantial quantity (n = 6) of scientific publications within this particular research field. The second sample is derived from Portugal (n = 5), the third sample is a combination of Finland and Poland (n = 4), and the fourth sample originates from Kazakhstan (n = 3). The participants in this

study were selected from five different countries: Colombia (n = 2), Costa Rica (n = 2), Germany (n = 2), Ireland (n = 2), and Saudi Arabia (n = 1). Authors from Spain and the United States collaborated on a joint project (n = 1).

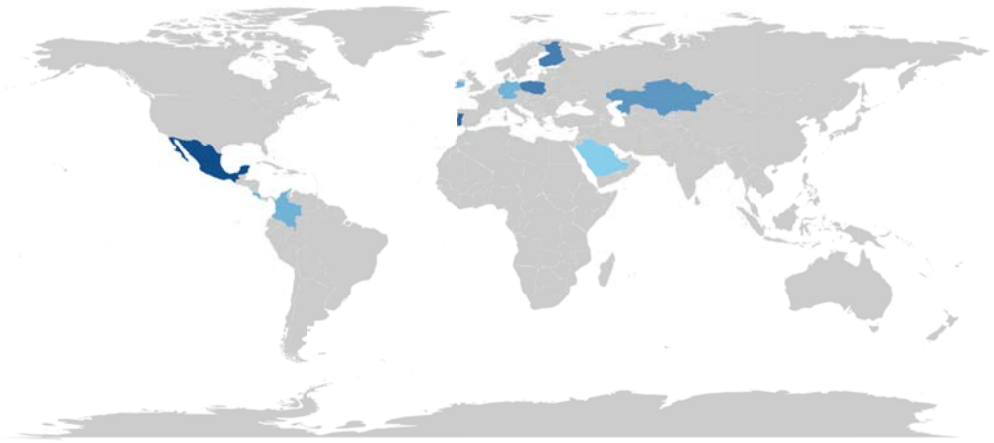

Figure 6. Countries' scientific production

Table 5. Countries' scientific production

Region	Frequency
MEXICO	6
PORTUGAL	5
FINLAND	4
POLAND	4
KAZAKHSTAN	3
COLOMBIA	2
COSTA RICA	2
GERMANY	2
IRELAND	2
SAUDI ARABIA	1

3.5 Social Structure (Collaboration World Map)

The collaborative network diagram (referred to as the "social structure") visually represents the patterns of collaboration among authors from various countries within the research domain. This information is presented in Figure 7, while Table 6 provides additional details. The findings indicate that authors hailing from Mexico and Colombia exhibited the greatest frequency (n = 2) of international collaborations within this particular field of research. Therefore, the findings of the social structure analysis, specifically the collaboration world map, indicate that research in this field is characterized by a limited degree of collaboration.

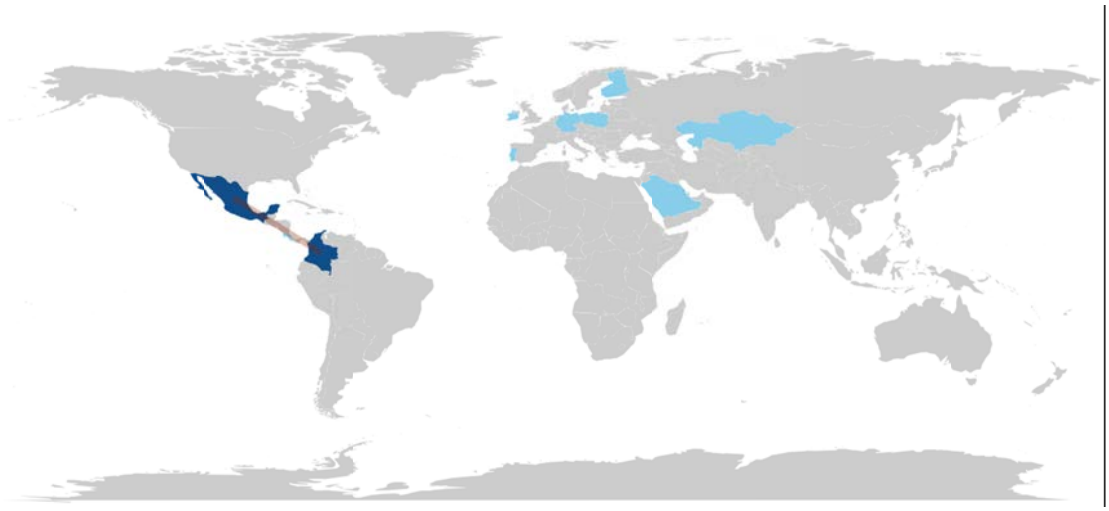

Figure 7. Social structure of the research

Table 6. Countries' collaboration world map

From	To	Frequency
MEXICO	COLOMBIA	2

4. Thematic Evolution of an Immersive Virtual Learning Environment for Developing Hard Skills

The utilization of co-word analysis, as demonstrated by Chen et al. (2016), can yield valuable insights into the expansion of words by examining their centrality and density when represented in a two-dimensional visualization. This approach has been further supported by the findings of Rahmani et al. (2018). Therefore, in line with the concept of dynamics, this study employed the year 2018 as a delineating threshold. The findings of the study indicated two significant advancements: (1) the progression of e-learning was driven by e-learning-related research; and (2) the integration of virtual reality in e-learning was a notable development (see Figure 8).

Figure 8. Thematic evolution

4.1 Thematic Evolution (2016–2018)

The initial publication pertaining to an immersive virtual learning environment aimed at cultivating hard skills, as documented in the SCOPUS database, emerged in the year 2016. Therefore, the initial thematic evolution map

was generated to encompass the temporal span from 2016 to 2018. The findings of the study indicated that the primary themes identified were “teaching” and “education,” while secondary themes included “e-learning,” “personnel training,” and “virtual reality” (see Figure 9).

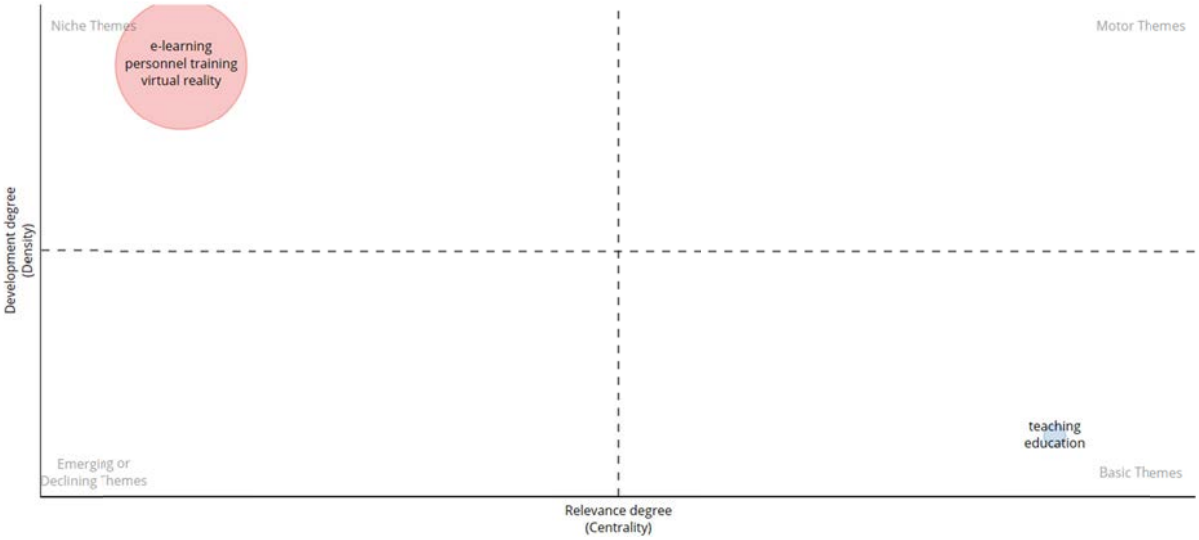

Figure 9. Thematic evolution 2016–2018

4.2 Thematic Evolution (2020–2023)

“Virtual reality” of an immersive virtual learning environment for developing hard skills have emerged basic themes. The results revealed that “e-learning”, and “students” were Niche themes.

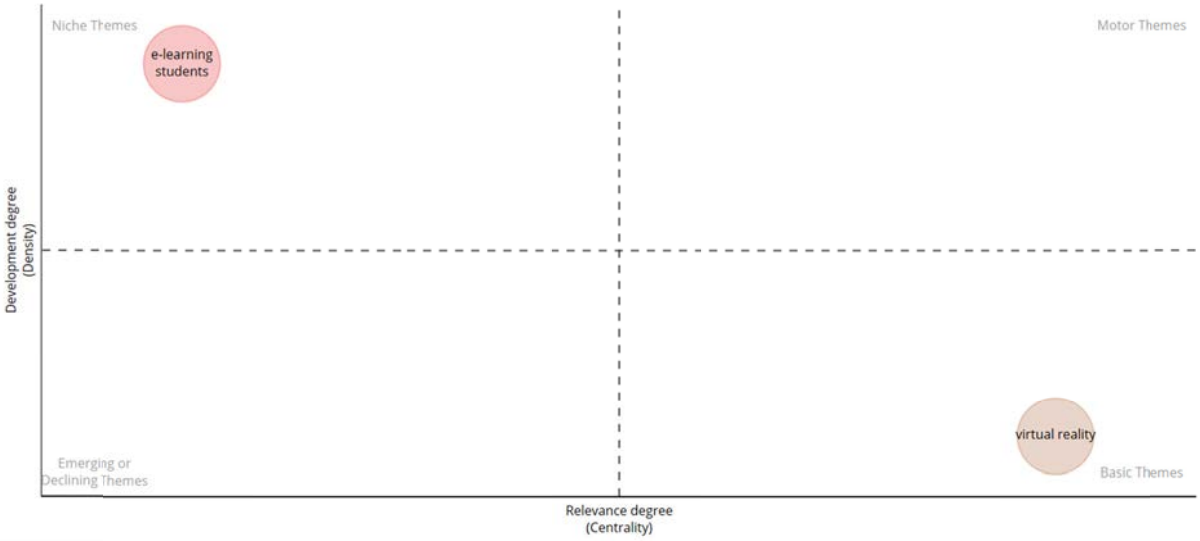

Figure 10. Thematic evolution 2020–2023

5. Application in Immersive Virtual Learning Environment for Developing Hard Skills

Table 7. Application in immersive virtual learning environment for hard skills

Items	Title and authors	Solution	Learning Strategic	Learning tasks
P1	"Homo Digitalis in Media Convergence Processes: A Sociological Portrait" (Vasilenko, & Molchanova, 2023)	Self-organize, digital mobility, and IT literacy	Digital sociology	"Homo Digitalis as a modern journalist possesses hard skills, the culture of the interaction of Homo Digitalis in virtual reality"
P2	"Digital Global Classroom, a Collaborative Online International Learning (COIL) Approach: An Innovative Pedagogical Strategy for Sustainable Competency Development and Dissemination of SDGs in Engineering Higher Education" (Membrillo-Hernández et al., 2022)	Sustainable Competency Development and Dissemination of SDGs in Engineering Higher Education	Technological tools that facilitate distance learning in multicultural virtual environments	"Teaching models involve active and experiential learning, developing soft and hard skills"
P3	"Global Shared Learning Classroom Model: A Pedagogical Strategy for Sustainable Competencies Development in Higher Education" (Membrillo-Hernández et al., 2023)	The Global Shared Learning Classroom experience	Challenge Based Learning, multicultural virtual environments	"Teaching models involve active and experiential learning, developing soft and hard skills"
P4	"Technology driven change in the retail sector: Implications for higher education" (Woods & Stephens, 2022)	Retail sector	work-based learning	"Advances in technology necessitate the provision of new hard skills, Digital and traditional skills"
P5	"Training Hard Skills in Virtual Reality: Developing a Theoretical Framework for AI-Based Immersive Learning" (Korhonen et al., 2022)	AI tutor software agent	VR-native pedagogical principles	"Pedagogical setting of immersive virtual reality-based hard skills training"
P6	"Extended Reality Training for Business and Education: The New Generation of Learning Experiences" (Palmas et al., 2022)	Real business environment	Real-world challenges	"The lessons learned from the integration of XR training into a real business environment and educational settings"
P7	"Cardiovascular System Pathologies Studying Using Virtual Reality Tools" (Tsoy et al., 2022)	Medical Education	Simulate interaction	"A tool that will show pathologies of the cardiovascular system"
P8	"Virtual Reality–Enhanced Soft and Hard Skills Development Environment for Higher Education" (Abdelouahab, 2020)	Learning system	Short work placements and industrial training programs	"Virtual reality, as a revolutionary technology, can support achieving"
P9	"Application of the EMONA TIMS platform for the Telecomunications Engineering career at UNED Costa Rica" (Santamaría-Sandoval & Chanto-Sánchcz, 2020)	Teaching engineering	Simulates laboratories	"Tools that enable virtual teaching, its thematic skills and participations from the students"
P10	"Virtual reality training of hard and soft skills in production" (Górski et al., 2018)	Engineering, Production	Test procedure is presented	"Virtual Reality systems for training of skills necessary in a modern production company"
P11	"Teaching cardiopulmonary auscultation in workshops using a virtual patient simulation technology - A pilot study" (Pereira et al., 2016)	Medical Education	A virtual patient simulation technology	"Assessment of a patient's clinical condition, and a hard skill to master"
P12	"Virtual environment for creative and collaborative learning" (Bilyatdinova et al., 2016)	Master theses preparation	Virtual Learning Environment	"Elective courses in Scientific Visualization, and Virtual Reality of Double Degree Master's Program in Computational Science"

6. Conclusion

This study presents a report on the scientometrics and systematic review findings of articles pertaining to the utilization of IVLE for the purpose of developing hard skills. The articles included in the analysis were sourced from journals that are indexed in the Scopus database. According to the Scopus database, the findings indicated that there were consistent modifications in the research on the utilization of immersive virtual learning environments for the enhancement of hard skills, spanning the period from 2016 to 2023. There are several potential factors that may have contributed to this phenomenon, including the broad and multidimensional nature of the subject matter, which was perceived as encompassing a wide range of related topics. The findings indicate

a notable increase in the utilization of IVLE for the acquisition of hard skills in recent years. The majority of articles published within the timeframe of 2022 and 2023 suggest that the subject matter is experiencing an increasing level of attention and interest. The primary findings regarding the data and document types indicate that a total of 12 articles were published across 10 different sources within the time frame of 2016 to 2023. The analysis reveals that among the 37 authors, the average number of authors per article is 2.33. The top five sources with the highest occurrence of articles are identified as "LECTURE NOTES IN NETWORKS AND SYSTEMS", "ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING", "AI IN LEARNING: DESIGNING THE FUTURE", "INDUSTRY AND HIGHER EDUCATION", and "INTERNATIONAL JOURNAL OF ENGINEERING PEDAGOGY". This study examines the growth rate of Keyword Plus from 2016 to 2023. Terms such as "adolescent," "adult," "aged," "auscultation," "cardiovascular diseases," "e-learning," "students," "teaching," and "virtual reality" surfaced and expanded over the specified period. The social structure, represented by a collaboration world map, illustrates the patterns of collaboration among authors from various countries within the research domain. The findings indicated that the authors hailing from Mexico and Colombia exhibited the most substantial frequency (n = 2) of international collaborations within the scope of this research field. The thematic evaluation identified two significant advancements: (1) the progression of e-learning studies in the field of e-learning; and (2) the emergence of virtual reality in relation to e-learning. The twelve articles that were chosen based on the established criteria were individually examined to assess their respective contributions and practical implications. The classification of applications in an immersive virtual learning environment for hard skills encompasses various components, namely the title, solution, learning strategy, and learning tasks.

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Authors contributions

Assistant Professor Jantakun was responsible for the conceptualization, methodology, formal analysis, writing-original draft preparation, and writing-reviewing and editing preparation for the creation of the published work, project administration, and funding acquisition. Assistant Professor Dr. Jantakoon supervised the conceptualization, methodology, validation, investigation, writing review, and editing preparation. Assistant Professor Dr. Laoha participated in the data curation. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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