Journal of Scientometric Research, 2024; 13(2):406-418.
https://www.jscires.org

Research Article

Virtual Teaching for Online Learning from the Perspective of Higher Education: A Bibliometric Analysis

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ABSTRACT

Virtual education began to emerge with the advent of the internet and digital technologies in the late 20th and early 21st centuries. It has been instrumental in overcoming geographical limitations, expanding educational access and reducing the gap between learners worldwide who have and have nots. Over the last few decades, a significant number of investments and initiatives (at both government and institutional levels) have been observed aiming to establish a sustainable online education system. The objective of the study is to provide an overview of the research trend on virtual teaching for online learning from the perspective of higher education across the globe in the 21st century. The required publication data has been collected from Scopus and Web of Science databases and various bibliometrics tools and techniques have been employed to visualize publication growth. It is found that the highest contribution has been made by China (16.92%), followed by the United States (15.38%), Spain (12.05%) and the UK (6.15%). The study identifies three dominant trends: 1) the evolution of technology-driven learning and training systems; 2) the rise and impact of immersive learning in digital environments; and 3) a systematic review of e-learning methodologies. This research outlines the overall progression of scientific literature in virtual education and highlights the need for comparative and nuanced research among online learning modalities, essential for guiding educational policymakers and university administrations in the optimal combination of traditional and virtual learning methods. This integration promises to enhance the accessibility and effectiveness of education in an increasingly digital world.

Keywords: Teaching, Higher education, Information technologies, Virtual education, Online learning.

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Received: 04-07-2023;
Revised: 27-01-2024;
Accepted: 01-05-2024.

INTRODUCTION

Technologies have transformed teaching, offering unique challenges and opportunities. With the Learning Management System (LMS) since 2000, educational policies and technological infrastructure have changed significantly, creating specific learning environments across various disciplines. The evolution of Virtual Teaching in Higher Education (VTHE) accelerated with SARS-CoV-2, highlighting the importance of understanding VTHE for online learning. With the advancement of these technologies, educational institutions have adapted to meet the needs of a student population immersed in increasingly technological scenarios. For example, Pereira *et al.*[1] highlight how digital platforms have become essential tools in universities for distance learning. Also, Alhasan *et al.*[2] highlight the wide flexibility of virtual education, which allows access to courses and educational material at any time and place. Burgess and Ice[3] highlight the evolution of LMS learning management to open access asynchronous learning platforms.

However, there are still significant challenges such as the assessment of student performance in virtual environments,[4] which relates to important challenges of VTHE, for example: how to improve its implementation, which digital tools are more suitable and what kind of digital resources are more effective for online learning in VTHE. These questions allow understanding and improving VTHE and its connection with other variables, such as didactics and virtual pedagogy. In this regard, this study aims to identify the main theoretical contributions and subareas of virtual teaching in higher education for online learning.

According to our search, three review articles have outlined the landscape for VTHE and are important for introducing the topic: Fernandez *et al.*[5] explore the impacts of flipped classes

DOI: 10.5530/jscires.13.2.32

in mathematics; Marí-Beffa[6] analyzes the challenges of virtual education in developmental biology and embryology in Spanish universities, while Ham and Davey[7] offer a reflection on teaching experiences in virtual environments. Consequently, this paper represents the first to analyze VTHE through a scientometric lens, filling a critical gap in the existing literature.

In this study, VTHE is approached by means of a scientometric approach. The methodology is divided into two parts. The first part maps the scientific production of the VTHE by analyzing countries, journals and authors. It analyzes the scientific production documented in the Scopus and Web of Science (WoS) databases from 2000 to 2022, specifically focusing on VTHE geared towards online learning. The second part shows the different theoretical contributions and subareas of VTHE through Tree of Science (ToS). Databases such as Web of Science and Scopus were utilized to map contributions and fields within VTHE. The study provides insights into the evolution of the construct in online learning, highlighting both opportunities and challenges. The article synthesizes findings and calls for further research. It recommends educational practices and future studies aimed at optimizing digital and virtual tools for online teaching and learning. The scope of the study seeks to provide clear directions for future research on new pedagogies and teaching practices that utilize digital tools and platforms, thus representing a new challenge in higher education across various contexts

The article is structured in the following sections: objective and scope of the study, methodology, results, literature review and conclusions.

METHODOLOGY

The methodology of this article is divided into two parts. The first part maps the scientific production of VTHE through the analysis of countries, journals and authors. This type of analysis is common in research aimed at understanding a thematic area from a quantitative point of view.[8] The second part shows the different theoretical contributions and subareas of the VTHE through the ToS algorithm, which locates the articles in the root, trunk and branches (subareas)[9] and allows understanding the development of an area of knowledge. From these two perspectives, VTHE and its scientific development can be better understood.

The search for articles related to virtual teaching in higher education for online learning was conducted in Scopus and WoS, the most widely used databases in academic communities.[10] WoS has more than 90 million records and Scopus has more than 60 million.[11] It is only in recent research that these two databases have been used to map a knowledge area.[12] Hence, the relevance of this study lies in consolidating the articles generated in WoS and Scopus to provide a broader scope for the scientometric mapping of virtual teaching (Table 1).

The merging of these two databases is a complex task. In some studies, it has even been done manually.[13] However, the Bibliometrix package,[14] along with ToS R, allows for the unification of the main records and references from both sources. Through its application, a total of 376 unique records were found between the two databases, indicating that from 261 records in Scopus, there are 116 in WoS that are not in Scopus (30.76%). The results showed 250 articles (66.48%), 99 conference papers (26.32%), 13 books and book chapters (3.46%), 12 reviews (3.20%), 1 editorial (0.27%) and 1 note (0.27%). These findings highlight the importance of conferences and scientific articles in the academic production of virtual teaching.

The search equations were Scopus (TITLE (virtual AND teaching) AND TITLE-ABS-KEY (higher AND education)) and WoS VIRTUAL TEACHING (Title) AND HIGHER EDUCATION (Topic). The year 2000 was adopted due to the expansion of the Learning Management System (LMS) that allowed the creation of virtual learning systems with specific content for education, which motivated to retake this historical period for the study.

Scientometric mapping

Scientometric analyses are used to understand the scientific dynamics of a knowledge area.[15] In this study, four scientometric analyses were identified: scientific production, country analysis, journal analysis and author analysis[16] (Figure 1). Thus, it is possible to have a broad and comprehensive view of virtual teaching in higher education. It is important to indicate that the relevant publications to be analyzed are grouped together. Then, the quantities found and how the information was reduced according to criteria of inclusion and exclusion of the material are indicated. Finally, the group of articles is characterized according to the variables of interest for the analysis.

The analysis of scientific production allows identifying the different peaks and valleys that a knowledge area has experienced.[17] In this case, the production between WoS and Scopus was compared and the overlap between them was identified (Figure 2), along with the total citations received by each article in each year, which are derived from the data provided by WoS and Scopus. This data is important as it demonstrates the overall impact of the contributions, not only in the field of virtual education.

The analyses of countries, journals and authors are divided into two parts: the first presents tables of scientific production and the second displays the network of interactions. Country analysis is common in scientometric research,[18] as it allows macro-level understanding of a country's productive capacities in a specific topic. For the country analysis, three indicators were identified: production (number of articles per country), impact (measured by received citations) and quality, determined by Scimago quartiles. In this case, the interactions based on author affiliations are also presented. This analysis identifies the quantity, impact and quality of the scientific production from major countries.

Regarding the journal analysis, using Scimago metrics, parameters of productivity, quality and impact were identified. To generate the citation network, a list of links was created based on articles and their references. When an article from one journal cites another reference, a link is established between these two journals. From this graph, thematic clusters among journals can be identified. This exercise has been conducted in other studies to identify the most significant journals in a scientific field.[19]

The analysis of authors provides insights into the patterns of scientific collaboration[20] and the networking strategies employed by authors to enhance the productivity, impact and quality of their publications.[21] This study identifies the most influential researchers based on the number of articles related to virtual education in universities. The personal social network of these authors is constructed using the approach proposed by Hurtado-Marín *et al.*[22] The scientific collaboration network is formed from the initially selected articles (376) and their references. As multiple authors appear in the same article, a collaboration network is established, which expands as these authors collaborate with others on subsequent articles. Additionally, the use of references helps creating a comprehensive scientific collaboration network, offering a better understanding of the factors that drive scientific collaboration in virtual education in universities.

RESULTS

Scientific production

As observed in Figure 2, scientific production has significantly grown from 2017 to 2022. There is a consistent production trend in Scopus since 2011, with a relative percentage increase of 52.78% in 2021. Similarly, WoS shows a relative percentage increase of 37.78%, highlighting the significance of the topic within the scientific community. Examining the scientific production over the years provides insights into the evolution of research in this field. Contrasting the production between Scopus and WoS databases helps identify the limitations and advantages

Table 1: Search criteria used in Scopus and WoS for virtual teaching.

Parameters	Web of Science	Scopus
Range	2000-2022	
Date	January 9, 2023	
Document types	Papers, books, chapters, conferences	
Field and words	Title: "virtual teaching" and Topic: "higher education"	
Results	200	261
Total (Wos+Scopus)	376	

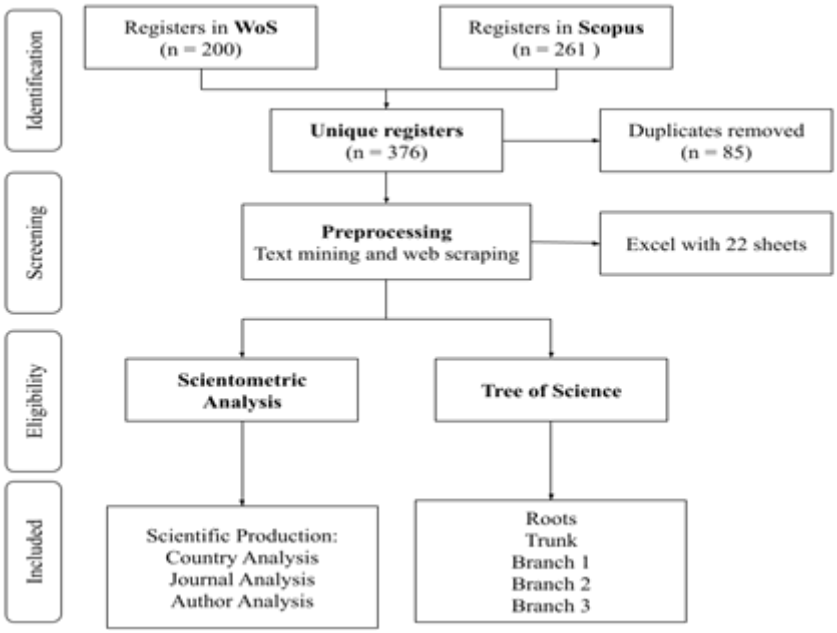

Figure 1: Filtering process of the records found in Scopus and WoS.

of selecting both databases. By analyzing publications between 2000 and 2022 and considering the total annual citations, the impact of scientific production can be determined (Figure 2), revealing similarities and differences between the publications in both databases. The development of VTHE production is divided into three stages: initial growth, rapid development and stability.

Initial Growth Stage (2000-2008): During this period, the total number of publications was 18 (6.5%). The publications corresponding to each search engine during this timeframe were 7 in WoS and 20 in Scopus. This difference can be attributed to the continuous production of Scopus on VTHE in the emerging modalities of education during that historical moment. The citations received during this stage represent 9.3% (325) of the total. The most cited study was by Crosier *et al.*,[23] who demonstrated the initial effectiveness of Virtual Reality (VR) teaching in a laboratory course with high school students.

Stability Stage (2009-2016): This stage represents a period of growth in publications. The most significant result is the notable increase in citations in 2009. This stage accounts for 22.91% (85) of the total publications and 48.86% (1,697) of the total citations. The most cited articles are relevant as they refer to comparative empirical studies on VTHE. The studies with the highest number of citations were: Jarmon *et al.*[24] (245 citations), who demonstrate experiential learning through SL with concrete experiences in university students; Warburton[25] (343 citations), asserts that virtual worlds in education requires improving virtual identity management and digital literacy and the links between immersion, empathy and learning; Codd and Choudhury[26] (103 citations) demonstrate that VR is suitable for anatomy learning and Häfner *et al.*[27] (103 citations) indicate that VR enables learning through experimentation in engineering.

Rapid Development Stage (2017-2022): In this stage, the total production continues to grow, with a total of 70.3% (261 publications). It is noteworthy to mention that during this time window, the context of SARS-CoV-2 becomes relevant in driving educational dynamics in virtual environments, as evidenced by Marks and Thomas.[28] However, the total number of citations received decreased due to the delayed effect of this variable. These authors also explain the limitations from a pedagogical perspective for effective teaching and learning.

Analysis of Countries

A scientometric analysis reveals that certain countries have already implemented online teaching, positioning themselves as pioneers in adopting cognitive tools for the future. China, in particular, contributes 16.9% of publications on the topic, considering all publications including unrelated countries. These publications appear in highly influential journals, fifteen of them in Q1, seven in Q2, six in Q3 and four in Q4 (Table 2 for details). Notably, there is scientific collaboration between researchers in China and the United States, indicating a shared interest in the subject. The analyzed citations further demonstrate the importance of this topic, with 263 related articles cited in other researches in WoS and Scopus. Notably, Zhao *et al.*[29] article on the use of VR in anatomy learning received 79 citations, highlighting its effectiveness in enhancing students' knowledge.

Regarding the United States, there are 60 publications with 996 citations, of which 22 are classified in Q1 journals. When compared to the ten countries under study, researchers from the United States exhibit a higher interest in the subject. Based on the findings, the article by Dyer *et al.*[30] cited 71 times, which focuses on the use of VR in health education and the patient-student

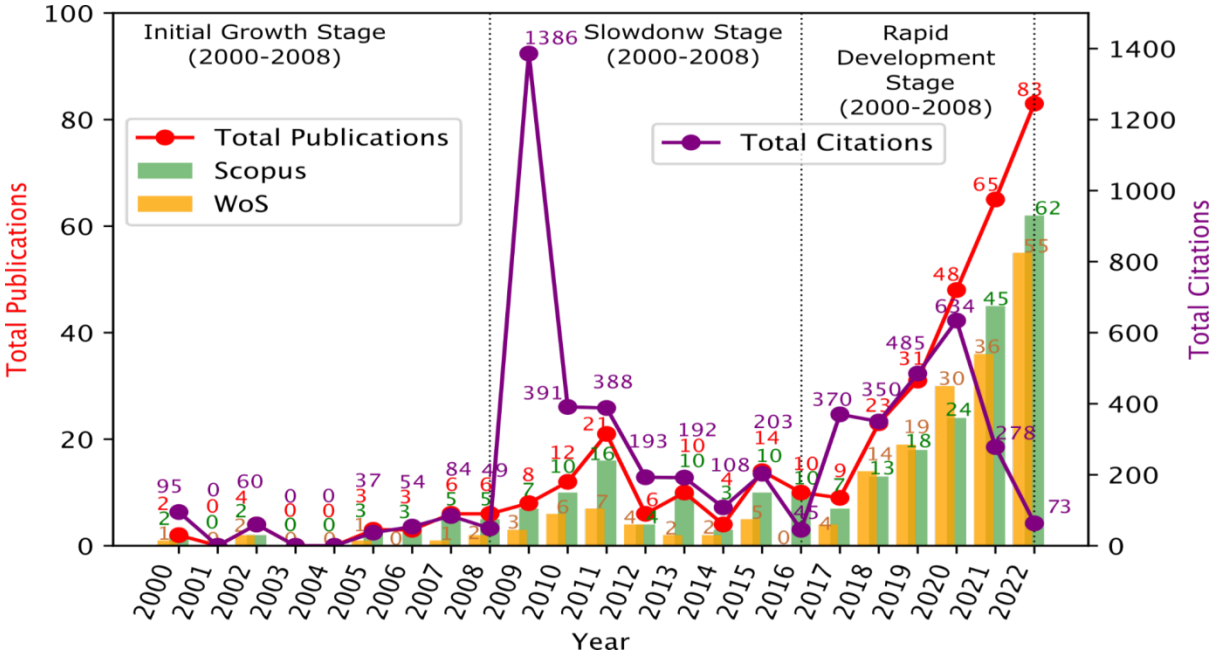

Figure 2: Measurement of Scientific Production vs. Total Citations.

Table 2: Collaboration Among Countries.

Countries	Production		Citation		Q1	Q2	Q3	Q4
China	66	(16.92%)	263	(7.29%)	15	7	6	4
USA	60	(15.38%)	996	(27.62%)	22	11	1	1
Spain	47	(12.05%)	302	(8.37%)	9	9	8	3
United Kingdom	24	(6.15%)	815	(22.6%)	3	6	2	1
Germany	19	(4.87%)	247	(6.85%)	4	5	1	2
Australia	17	(4.36%)	221	(6.13%)	4	2	0	0
Peru	15	(3.85%)	32	(0.89%)	1	3	0	1
Brazil	9	(2.31%)	16	(0.44%)	0	1	1	1
India	7	(1.79%)	14	(0.39%)	1	0	0	2
Saudi Arabia	7	(1.79%)	26	(0.72%)	0	1	3	1

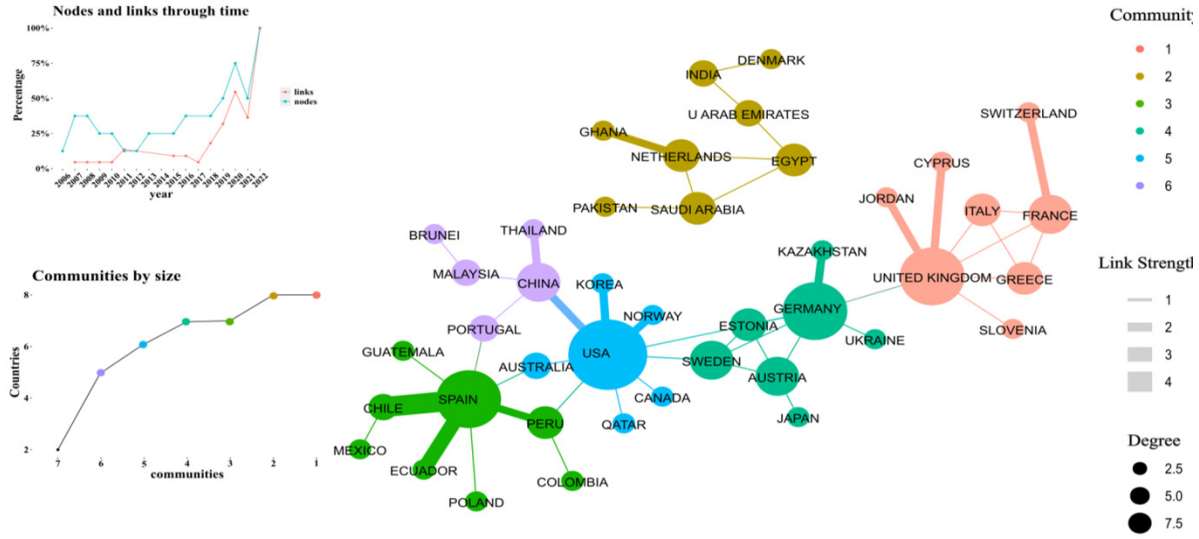

Figure 3: Collaboration between Countries.

relationship through VR, stands out in the investigated field. It is also important to note the strong connection between the United States and Norway, where Johannesen *et al.*[31] emphasizes teaching practices using Educational Virtual Environments (EVA) with 36 citations.

However, the absence of certain countries in the table does not imply a lack of interest in research. Interest does exist and it appears to be steadily increasing. For example, Spain contributes 47 publications, with 9 classified in Q1, 9 in Q2, 8 in Q3 and 3 in Q4 journals, receiving a total of 302 citations, highlighting the significance of work in this area. This indicates that WoS and Scopus record citations from various countries regarding articles related to online learning and virtual teaching. The scientific community is increasingly interested in exploring virtual tools that enhance models related to the web, AI and VR tools and augmented reality in virtual and distance programs, which have a notable impact on higher education.

As for the United Kingdom, its 24 publications receive a substantial number (815) of citations. The UK's search interest in specific knowledge related to online learning and teaching processes is reflected in the following journal distribution: 3 in Q1, 6 in Q2, 2 in Q3 and 1 in Q4. This perspective demonstrates the contributions to research and the extent to which other researchers seek to contribute to science.

Now, let us compare the overall production: Summing the contributions of the ten countries, we have 271 journals and 2932 citations in total. From this, we can infer that China has a prominent role in virtual teaching and pedagogical practice in higher education, surpassing the mentioned countries. Furthermore, the proportion of citations from the United States and the United Kingdom indicates that their production is under intense investigation, far exceeding standard norms and drawing considerable attention from fellow researchers. These findings

suggest that these two nations have been vigorously paving the way towards virtuality compared to the countries under study.

Turning our attention to Latin America, Peru and Brazil rank 7th and 8th with 15 and 9 publications, respectively, surpassing India and Saudi Arabia, which have 32 and 16 citations, respectively. Notable articles include Trends in Virtual Education Pedagogy[32] with 14 citations and in Brazil, the article Development in Virtual Learning of Electrical Circuits[33] with 8 citations. Comparing Peru and Brazil as the leading countries in this field, their publication numbers are similar to Germany and Australia. However, in terms of citations, the latter countries demonstrate a stronger interest in the scientific community.

Researchers from India and Saudi Arabia each contributed seven indexed publications, with 14 and 26 citations per country, respectively. According to Yalagi *et al.*[34] in India, articles related to the use of platforms for learning and teaching and in Saudi Arabia, studies on histology and pathology through virtual means, already indicate a clear path towards virtual learning.

Figure 3 illustrates the strength of the connections among researchers from different countries, their collaborative efforts that contribute to the scientific community with specific themes and the citations made from one country to an article from another nation. The level of collaboration between countries is delineated based on the quantity of published works and the thickness of the links represents the number of collaborations. It is evident that, in the specific cases of China and the United States, Ghana and the Netherlands, Spain and Chile, Spain and Peru, Spain and Ecuador, the United Kingdom and Jordan and the United Kingdom and Cyprus, there is a greater degree of collaborative work compared to that between Germany and the United Kingdom.

Regarding this type of collaborative work, an example can be found in the partnership between a university in Australia and a university in Spain[35] which explores and analyzes the ontological ideas and claims of the Airbnb platform. Additionally, a strong connection can be observed in several research efforts between Chile and Spain, where Espinosa *et al.*[36] provide an insightful study on the technical and didactic knowledge of Moodle movies in education. Finally, the circular figures depict the degree of research with publications and the "Strength" link indicates the number of collaborative works between researchers from the related countries.

Analysis of Journals

The journal with the highest number of publications is BMC Medical Education. Other noteworthy journals include Education and Information Technologies, which specializes in discussions related to the use of informatics and technology in various contexts and the International Journal of Engineering Education, which focuses on the role of technology in engineering education. Table 3 lists the most relevant journals based on their Scimago Journal Ranking (SJR) impact index.

Figure 4 displays the citation analysis using references from Scopus and WoS. The network of journal citations reveals three distinct clusters. Based on these findings, Group 1 consists of medical journals, Group 2 comprises education journals and Group 3 represents veterinary journals.

The red community (Group 1) represents publications in virtual education for medical training across various medical fields. BMC Medical Education stands out as the journal with the highest degree of connectivity in relation to VTHE in the medical domain. In recent studies published in BMC Medical Education, Moll-Khosrawi *et al.*[37] explain VR as an effective tool in the learning process of Basic Life Support (BLS) and emphasize its essential role in resuscitation instruction. The yellow community (Group 2) corresponds to the field of education, with Education Sciences as the journal displaying the highest degree

Table 3: Journals with the highest SJR impact index.

Journal	Wos	Scopus	Impact Factor	H index	Quantile
BMC Medical Education.	9	5	0.74	76	Q1
Journal of Physics: Conference Series.	0	6	0.21	85	-
Computers and Education.	5	0	3.68	197	Q1
Education and Information Technologies.	4	3	1.06	48	Q1
International Journal of Engineering Education.	5	3	0.44	54	Q2
Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics).	0	5	0.41	415	Q2
ACM International Conference Proceeding Series.	0	4	0.23	128	-
British Journal of Educational Technology.	4	2	1.87	102	Q1
Computer Applications in Engineering Education.	4	0	0.59	32	Q1
Education Sciences	3	3	0.52	30	Q2

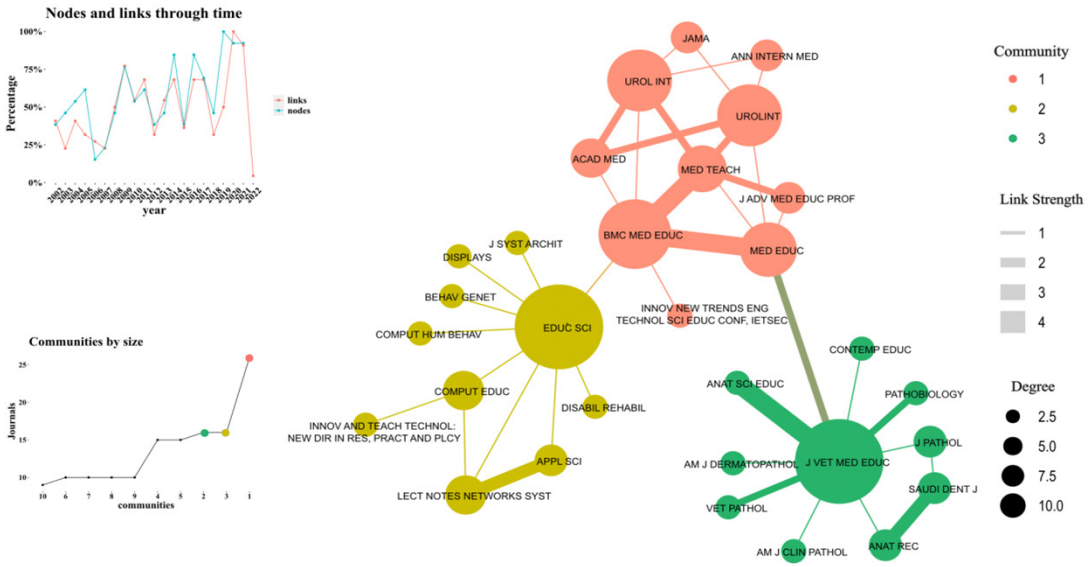

Figure 4: Network of Journal Citations.

Table 4: Authors with the Highest Production.

No.	Researcher	Number of articles*	Scopus h-index	Filiation
1	Gregory, Sue	4	15	University of New England Australia, Armidale, Australia.
2	Li, Yongxiang	4	5	Zhejiang Normal University, Jinhua, China.
3	Liu, Yunlai	4	6	Third Military Medical University, Chongqing, China.
4	Wang, Jaw Kai	4	3	University of Southampton, Southampton, United Kingdom.
5	Grant, Scott	3	9	Monash University, Melbourne, Australia.
6	Li, Chengren	3	12	Weifang People's Hospital, Weifang, China.
7	Mayrath, Michael Charles	3	10	The University of Texas at Austin, Austin, United States.
8	Traphagan, Tomoko Watanabe	3	7	Texas Education Agency, Austin, United States.
9	Wang, Xiaoyan	3	17	Peking University Hospital of Stomatology, Beijing, China.

*Total articles: WoS + Scopus.

of connectivity. Notably, a link is identified with BMC Medical Education, indicating cooperation between these communities in the context of VTHE. Among their recent studies, Mu *et al.*[38] present a set of indicators for challenges in Emergency Remote Teaching (ERT). Lastly, the green community (Group 3) represents veterinary medicine, with Veterinary Medical Education as the highest-ranked and most connected journal. In relation to VTHE, Evans *et al.*[39] discuss the effective use of Virtual Microscopy (VM) in veterinary medicine for cytology instruction.

Analysis of Authors

This section showcases researchers with the highest number of articles and their interactions in virtual education at universities. As shown in Table 4, four authors have each produced four articles and it is worth noting that only two of them are from the same country (China). Professor Sue Gregory from the University of New England (Australia) is one of the most prolific authors, having published four articles. Dr. Gregory's research focuses on the influence of VR on university students' learning processes.[40,41] The two Chinese researchers with the most articles are Professor Yongsiang Li from Zhejiang Normal University and Professor Yunlai Liu from the Third Military Medical University, respectively. Dr. Li is renowned for his research on

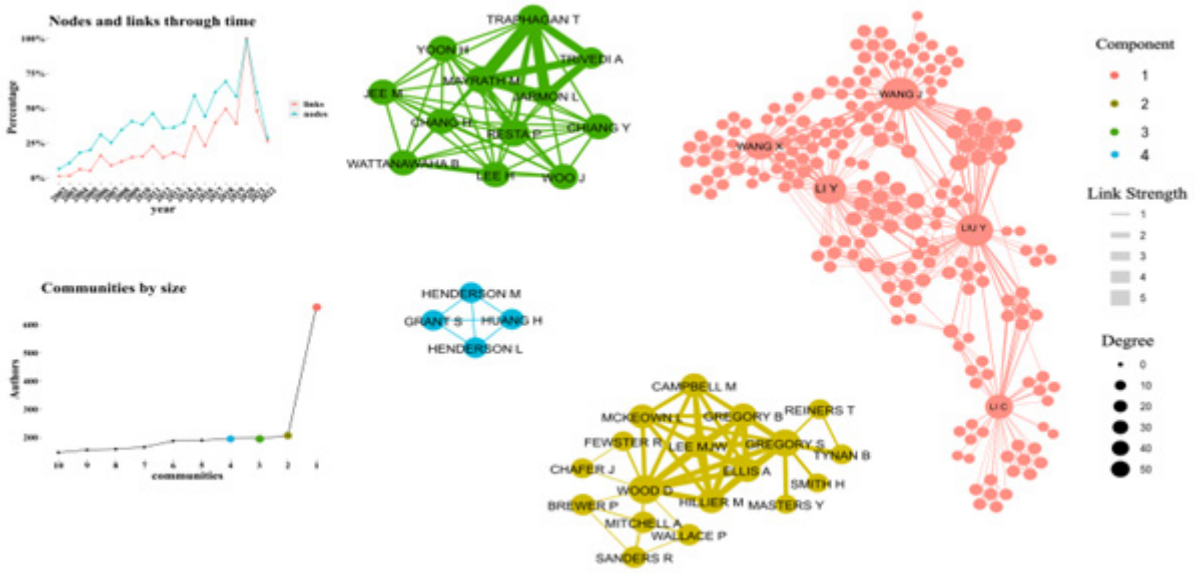

Figure 5: Academic Social Networks.

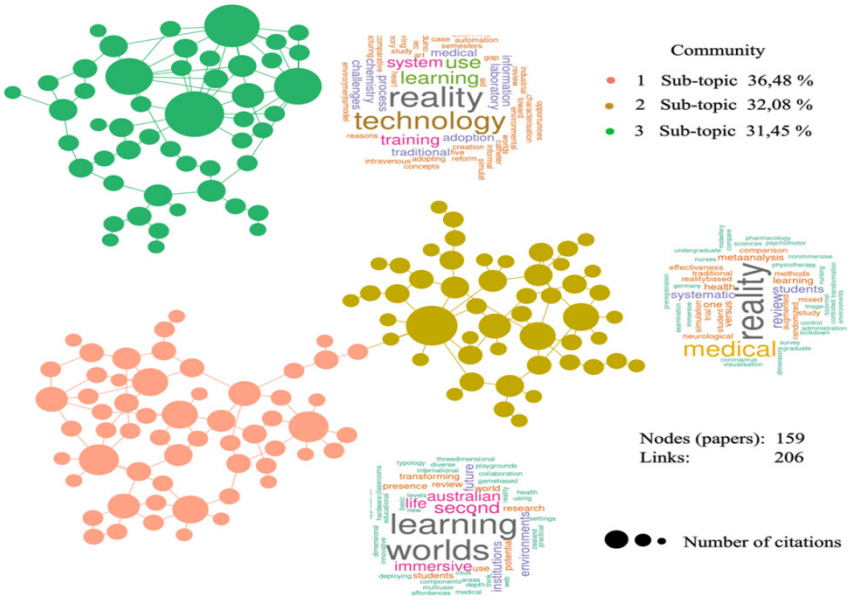

Figure 6: Citation Network.

virtual simulation technologies for learning[42] while Dr. Liu is recognized for his applications with medical students.[43]

Figure 5 illustrates the ego-networks of authors from Table 4. Four main components are identified: the first component (pink) features Asian authors, including Drs. Li, Liu and Wang. The second component represents the personal scientific collaboration network of Dr. Wood. The third component depicts the network of Professors Michael Charles Mayrath and Tomoko Watanabe Traphagan from Austin, United States. The final component (blue) showcases the collaboration network of Professor Scott Grant. The nodes and links demonstrate the consolidation of scientific collaboration networks over time. This graph represents the overall collaboration network for virtual education in universities. The blue line (authors) tends to be above the red line (links) from 2000 to 2008 and in 2009, these two lines merge, indicating increased connections among researchers, either by continuing to work together or forming new links. The Communities by Size graph highlights four clusters or groups of authors, according to the algorithm proposed by Blondel *et al.*,[44] this suggests the existence of significant academic communities in the field of distance virtual education.

ToS algorithm- Literature Review

The literature review utilizes the ToS algorithm, which categorizes articles into root, trunk and branches.[8] The algorithm traverses the citation network, similar to the flow of sap in a plant. It identifies the articles in the root, trunk and leaves, flowing through nodes from root to leaves and back, allowing for chronological identification of main contributions to be noted. This process resembles photosynthesis in a plant. More details can be found in the research Valencia-Hernández *et al.*[9]

ToS originated from a doctoral thesis funded by the National University of Colombia, creating a prototype.[45] The Core of Science Corporation further developed it (https://coreofscience.org). The initial version processed data from WoS,[46] followed by a version integrating Scopus. The ToS R package now allows for the integration of both databases, enabling broader scientific mappings. Specifically, in this study, both databases are integrated into the tree. Previously, this integration was a manual and laborious process,[12] but recent research has highlighted the usefulness of combining these databases.[13] ToS has found applications in psychology,[47,48] marketing,[49,50] entrepreneurship[51] and education.[52]

Root

With the emergence of Information and Communication Technologies (ICT), virtual teaching has represented a paradigm shift and a rise to new platforms, that revolutionizes learning platforms, focusing on computer-based mechanisms and experiential learning. Kolb[53] recognize four stages of the learning process (concrete experience, reflective observation, abstract conceptualization and active experimentation) that are essential from a theoretical perspective. Nevertheless, intuition and the need to understand educational models lead us to reflect on educational models fosters curiosity and employs precise pedagogy to enhance students' interest.

This can be observed in the work of Nicholson *et al.*,[54] where the quality of learning in medical students shows remarkable results by developing interactive models for medical science through the use of computers and 3D image analysis. In this sense, medicine has taken the lead with patients through virtuality, striving to demonstrate the effectiveness of virtual appointments,[55] in facilitating and evaluating the development of clinical reasoning, which is seen as a non-analytical process that matures through practice.

Through this path, it is evident that the health sciences have embraced virtual teaching and learning using various methods. Huang *et al.*[56] introduce mechanisms that enhance learning through immersive, interactive, intuitive and exciting VR, all aimed at constructing learning with a defined pedagogy. There is no doubt, as affirmed by Dalgarno and Lee,[57] that three-dimensional virtual learning environments are an effective means of learning, with their effectiveness derived from the fidelity in machine-student interaction.

On the other hand, there are studies demonstrating that teaching practices with virtual tools significantly contribute to learning and cognitive models. For example, Merchant *et al.*[58] analyze the effectiveness of games, simulations and virtual worlds in learning outcomes. Other authors in the medical field also draw attention, such as Makransky *et al.*,[59] who provide clear evidence of how virtual simulations enhance students' knowledge, intrinsic motivation and self-efficacy in decision-making.

Virtual environments impact and challenge pedagogical and didactic processes in education, especially in medicine. According to Rose,[60] it is a new way of educating future doctors and it is no surprise considering that the experience of 2020 has transformed the teaching and learning model worldwide. Radianti *et al.*[61] mention three paths of VR as a means of learning that undoubtedly lead to exploration: the current domain structure in terms of learning content, VR design elements and learning theories. Today, these techniques gain greater precision in time and space thanks to the speed provided by 4G and 5G technologies.

Trunk

Initiatives advocating for active use of virtual tools[62] by teachers were present, but the COVID-19 pandemic accelerated the adoption of virtual teaching. Higher education institutions implemented technologies due to the catalytic effect of the pandemic. For instance, Nunes *et al.*[63] demonstrated the positive outcomes of virtual teaching in algorithm learning using OpenSimulator, Moodle and Sloodle software. Furthermore, Marei *et al.*[64] analyzed the impact of virtual patient scenarios on dental professionalization, showing improvements. Zhao *et al.*[65] found similar results in a meta-analysis on medical students learning anatomy through VR. Overall, medical students express high satisfaction with online teaching strategies,[66] although issues such as internet access or computer availability inequality are highlighted.

Fields like civil engineering have also embraced virtual teaching. In this discipline, the practical component is important but challenging to develop due to the requirement for expensive materials and infrastructure. In this regard, Walker *et al.*[67] study the repercussions of implementing a VR environment on civil engineering students. The results showed positive elements in practical learning, opening up a wide range of opportunities for developing various skills in construction professionals.

Next, the three most important subareas found in the citation network are explained (Figure 6). For this, the algorithm developed by Blondel *et al.*[68] was used to identify three clusters (subareas), which are the branches in the ToS.

Learning and Training Systems using Technology (Branch 1)

Álvarez-Blanco *et al.*[69] identified three variables that influence the quality of teaching in higher education: interaction with professors through the platform, students' abilities and prior knowledge. Rana *et al.*[70] also demonstrated that teaching efficiency, subject expertise, learning new technology and future growth opportunities are academic factors in the field of management for utilizing virtual teaching environments. On the other hand, Sepúlveda-Parrini *et al.*[71] emphasize the need to analyze current topics in virtual learning, such as feminism (cyberfeminism), which has gradually gained prominence. Roelofsen and Carter-White[72] propose the need to teach active body adaptations that allow students to move within a virtual space.

It is also important to consider the challenges of virtual education in developing countries. For example, Mu *et al.*[73] based on a survey, determined home facilities, difficulties in learning virtual platforms and financial problems as significant factors. Meanwhile, Martín-Cuadrado *et al.*[74] highlighted the need for versatile methodologies for students in remote areas with high digital gaps due to limited connectivity.

Elements such as self-efficacy and satisfaction in virtual teaching among professors have a positive relationship with student engagement,[75-77] but this requires a shift from traditional face-to-face instruction to virtual formats.[78]

Systematic Studies on Learning Methods (Branch 2)

Higher education is equipped with a tool that enables new learning and teaching models, which, in their evolution, give meaning to schools and training models. This is not limited to the social sciences, where virtual media are a fundamental support in teaching and learning. According to Liu and Lipowski,[79] in reference to physical education, virtual media achieve intrinsic motivation for learning. In civil engineering, Sampaio and Viana[80] demonstrate the execution of bridge decks or overpasses where various construction processes are applied; the authors analyze a 4D geometric model in a VR environment with prefabricated beams, establishing a schedule that simulates an interactive model and provides reliability.

During the analysis process, augmented reality was found, as described by Wu *et al.*,[81] aligning with instructional approach, technological design and learning experiences. Likewise, in the analysis of virtual realities, the study of videos and their cognitive importance in the learning processes is observed. Homer *et al.*[82] demonstrate a preference for visual/verbal elements, experiencing a higher degree of cognitive load through videos.

VR and collaborative learning environments provide communication tools to support student collaboration.[83] Boulos *et al.*[84] highlight the educational potential of the three-dimensional virtual world for librarians and medical educators in learning and teaching support. Garrison and Arbaugh[85] emphasize the role of computer conferences in online learning in higher education. Web management and machine-assisted learning play a crucial role in knowledge and discourse, as emphasized by Garrison *et al.*,[86] who have developed a tool to assess critical discourse and reflection.

Learning through immersion in virtual world environments (Branch 3)

VR has shown promising results in martial arts education, with Pu and Yang[87] identifying improved mastery of details and complex routines. Liu *et al.*[88] highlight that teaching with VR immersion enhances cognitive experience and positively impacts learning. Dengel *et al.*[89] emphasize the merits of immersive technologies in designing interactive experiences in virtual environments. Sounti *et al.*[90] advocate for a radical shift in communication and teaching methods through online tools. Jiang[91] emphasizes how new technologies improve vocational education and learning to meet industry and business needs. Finally, it is worth noting the findings presented by Khatoony[92] that demonstrate increased academic performance in language students through the use of VR games.

Solomon *et al.*[93] suggest VR platforms as effective teaching and learning tools in higher education. Ghanbarzadeh and Ghapanchi[94] support the use of 3D virtual worlds (3DVWs) in higher education as stablished tools for teaching and learning. Pellas[95] introduces game-based learning using the Open Sim 3D virtual world platform and the Scratch4O visual programming language for secondary education. Nunes *et al.*[63] propose integrating the Sloodle tool to create immersive virtual spaces with interactivity in VR for changed classroom techniques and methods. Additionally, technologies have also incorporated Big Data for research purposes, enabling the prediction of trends and understanding real situations.[96] Bortoluzzi[97] has explored teacher narratives to identify sociocultural and critical principles in higher education within Virtual Worlds (VWs) or Multiuser Virtual Environments (MUVEs), such as Second Life (SL).

Multiuser platforms, according to Jeffery *et al.*,[98] foster international collaboration, networked learning, participatory culture and knowledge management, enhancing students' higher-level cognitive skills. Gregory[99] emphasizes the applicability of SL as a teaching and learning tool in virtual worlds, catering to diverse learning outcomes. Gregory *et al.*[100] demonstrate the pedagogical value of immersive and authentic experiences in virtual worlds. Pantelidis[10] proposes a model for determining the appropriate use of VR environments based on their attributes and drawbacks. Finally, Dalgarno and Lee[57] highlight the need for a roadmap guiding the design, development and utilization of virtual environments, considering empirical studies on the learning potential of 3D-virtual platforms.

CONCLUSION AND RECOMMENDATIONS

A total of 376 records from WoS and Scopus databases were analyzed from 2000 to 2022. The findings indicate a growing trend in digital tools in virtual education for online learning. The study demonstrates the topic's relevance for the scientific community based on conferences and articles related to virtual education for online learning. According to the evidence, the main modeling themes focus on mapping virtual education for online learning and three clusters. The first cluster is technology-mediated reality for learning and training. The second cluster is virtual/augmented reality in medical education within virtual education for online learning. The third cluster is immersive learning experiences in virtual worlds for students. This scenario enhances our understanding of digital tool application and incorporation in online learning teaching.[3]

Furthermore, it is observed that the production has been increasing since 2017, with Scopus being the database with the highest number of publications (Figure 2). It is demonstrated that the countries with the highest scientific production are China and the United States. The authors who stand out for their high volume of production are S. Gregory, Yongxiang Li and Yunlar Liu. The most popular journals are BMC Medical, Computers and Education and Education and Information Technologies, which are associated with group 1 (medicine), group 2 (education) and group 3 (veterinary).

The study demonstrates that virtual education is a transformative system impacting education, teaching, training and learning. Virtual teaching in virtual and distance higher education creates a new scenario with digital tools. Future research should conduct comparative studies between different modes of online learning to identify effective techniques, tools and resources for higher education. Comparing asynchronous and real-time courses contributes to discussions on online collaborative activities and their effects on learning, student participation and knowledge retention, improving virtual and distance education processes.

It is important to consider, in the study of virtual education for online learning, from the perspective of comparative studies between virtual education, distance education and e-learning, the influence of other relevant aspects in these scenarios such as AI and other techniques or methodologies for online learning. In this regard, explanatory studies, among others, on the improvement of teaching through the use of virtual and augmented reality that enable specific pedagogical frameworks for virtual education for online learning are relevant.

Among the limitations of the study, the lack of homogeneity in the criteria for the evaluation of online learning in the different disciplines, as well as the variability of uses and tools used, due to the different pedagogical needs of each discipline, stand out. The diversity in tools and uses influences the implementation of online learning and finally the generalization of the results of the study in the application of online learning in different fields.

Thus, this study structured a systematic literature review supported by data analysis, applying the methodology of graph theory and social networks and grouping authors and documents based on the number of citations.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Cite this article: Vargas-Hernández A, Robledo S, Rojas-Quiceno G. Virtual Teaching for Online Learning from the Perspective of Higher Education: a Bibliometric Analysis. JScientometric Res 2024;13(2): 406-18