








Engineering teaching in virtual environments: A literature review

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Abstract

Engineering education in virtual environments leverages digital technologies to deliver engineering knowledge remotely. While many studies address this topic, specific bibliometric research remains limited. This study explores research trends through a bibliometric analysis guided by PRISMA-2020, using data from Scopus and Web of Science. Results revealed a cubic polynomial growth, with 2021 and 2022 as prominent years. Key thematic references included Stefanovic, Computer Applications in Engineering Education, the United States, and Indonesia. Thematic evolution advanced from distance learning to emerging concepts such as experiential learning and mental cutting test. The keyword co-occurrence network emphasized the significance of e-learning, massive open online courses, and software engineering. Identified research gaps point to the need to examine the impact of virtual teaching on practical skill development and to explore the integration of augmented reality. Overall, the study offers a strong foundation for future research, aiming to enhance engineering education in digital and virtual environments.

Keywords: digital platforms, remote learning, virtual tools, PRISMA-2020, educational innovation

INTRODUCTION

The teaching of engineering in virtual environments has become a significant area of academic interest, particularly in the wake of the global pandemic that has profoundly impacted higher education. Engineering teaching in virtual environments refers to the educational process in which knowledge and skills related to engineering disciplines are imparted using digital media and platforms. In this study, the term “virtual environments” is used as an overarching conceptual category to encompass a broad range of digitally mediated educational settings, including online learning platforms, remote instruction systems, learning management systems, and interactive digital tools

employed in engineering education. While the term is often associated with immersive technologies such as virtual reality or augmented reality, its use in this article is intentionally broader, reflecting the dominant terminology adopted in the analyzed literature. This conceptual choice allows for the integration of diverse educational approaches under a unified analytical framework, while maintaining consistency with existing research on digitally supported engineering education. This pedagogical approach takes advantage of information and communication technologies (ICT) to facilitate the delivery of educational content. Furthermore, the interaction between students and teachers, as well as the carrying out of learning and evaluation activities remotely (Bujaco et al., 2019), has

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Contribution to the literature

- This study contributes to the existing body of knowledge by offering a thorough bibliometric analysis of engineering education in virtual environments, a subject that has received scant systematic evaluation to date.
- The study's originality lies in its application of the PRISMA-2020 framework and its exploration of thematic evolution, highlighting emerging trends such as experiential learning and mental cutting tests.
- By identifying key gaps and proposing a detailed future research agenda, the article offers valuable insights to guide and expand scholarly inquiry in digital engineering education.

been identified as a key area of interest. This is evidenced by the growing body of research in this field, which underscores the importance of understanding how digital tools are being integrated into engineering education. This may have significant implications for the development of new educational strategies (Benabdelouahab et al., 2023). Other research has explored the specific challenges and opportunities of distance education in engineering, highlighting the need for rapid adaptation during crises such as the pandemic (Khan & Abid, 2021). Additionally, a case study was conducted on the perception of teaching staff about online learning during the pandemic, which provides valuable information about attitudes and perceptions towards this educational modality in the context of engineering (Gormaz-Lobos et al., 2022).

Conversely, the lessons learned after the period of confinement have been examined, with particular focus on the importance of understanding how science and engineering education has migrated towards online learning (Gill et al., 2022). Additionally, an analysis was carried out of student preferences regarding the attributes of online learning in industrial engineering, using an approach that could be relevant for the design of sustainable educational programs in the future (Ong et al., 2021).

The importance of engineering teaching in virtual environments has grown significantly in contemporary education, particularly in light of the need to adapt to technological changes and emerging circumstances. The applicability of distance learning in construction engineering education has been the subject of study. In Egypt, for instance, the ability to overcome geographical and temporal barriers has enabled students and teachers to participate in educational activities remotely. Similarly, Basha et al. (2021) highlight the potential of the research community of the e-learning for engineering education framework to promote interaction and collaboration in virtual learning environments. Purwandari et al. (2022) also emphasize this framework's ability to facilitate such interactions.

The significance of engineering instruction in virtual environments is exemplified by research that proposes a real-time power electronics laboratory to reinforce distance engineering education on smart electrical grids and microgrids. This proposal demonstrates how digital

technologies can be utilized to provide practical and enriching experiences in virtual environments, complementing theoretical teaching (López Gutiérrez et al., 2021). Additionally, it analyzes the efficacy of online learning from the perspective of engineering students, providing a multidimensional model that highlights the positive perception of students towards this educational modality, especially during the COVID-19 pandemic (Gabriel et al., 2021).

Furthermore, the adaptation of experiential learning in engineering education is explored with the vision of Industry 4.0, pointing out the need to integrate emerging technologies in educational processes to prepare students for the challenges of the contemporary world of work. These investigations highlight the critical importance of engineering education in virtual environments for the training of professionals who are trained and updated in a technologically advanced and constantly evolving context. (Mehrtash, 2022)

Empirical evidence supports this perspective. For example, Mehrtash (2022) demonstrated that the integration of experiential e-learning strategies aligned with Industry 4.0 significantly enhances students' engagement, problem-solving abilities, and readiness for real-world engineering contexts. Similarly, Gabriel et al. (2021) reported that engineering students perceived online and virtual learning environments as effective for knowledge acquisition and skill development during the COVID-19 pandemic, particularly when interactive and practice-oriented components were incorporated. These findings illustrate how virtual and digital learning environments can move beyond content delivery to actively support competency development, thereby reinforcing the relevance of synthesizing existing empirical evidence through a structured literature review.

Despite the growing body of empirical research on engineering education in virtual environments, the literature remains highly fragmented in terms of theoretical perspectives, technological approaches, educational contexts, and methodological designs. Existing studies tend to focus on isolated dimensions—such as student perceptions, specific technological tools, or short-term learning outcomes—without offering an integrated view of how these elements collectively shape engineering education in digital and virtual settings.

Moreover, the rapid expansion of publications following the COVID-19 pandemic has intensified this dispersion, making it increasingly difficult to obtain a comprehensive understanding of the field. In this context, a systematic literature review becomes necessary to synthesize diverse findings, identify dominant trends and research gaps, and provide a coherent framework that can guide future research and educational practice.

Research in engineering education in virtual environments reveals significant gaps that necessitate comprehensive evaluation. This justifies the performance of exhaustive bibliometrics to identify underrepresented research areas and emerging trends. However, despite the considerable number of studies on this topic, specific bibliometrics in this field remain limited. This is evidenced by the references consulted. For instance, in 2023, a bibliometric study on e-learning-oriented software engineering education was conducted, while in 2022, the evolution and trends in e-learning approaches in STEM and corporate education were examined (Benabdelouahab et al., 2023; Castillo-Velazquez & Silva-Lopez, 2022). Nevertheless, there are still underexplored areas, such as the integration of emerging technologies in engineering education, as evidenced by research on the digitalization of engineering education (Makarova et al., 2019). These research gaps underscore the necessity for a systematic evaluation of the existing literature to inform and guide future research in this rapidly evolving field. Consequently, the objective of this research is to examine research trends in relation to engineering education in virtual environments.

RESEARCH QUESTIONS

To ensure analytical transparency and to guide the systematic examination of the literature, this study is structured around a set of clearly defined research questions. These questions serve as the central analytical axis of the bibliometric approach, linking the objectives of the study with the methodological procedures and the organization of the results. By explicitly formulating the research questions, the analysis allows for a coherent and systematic interpretation of publication trends, intellectual structures, and thematic dynamics within the field of engineering education in virtual environments.

Accordingly, the following research questions were developed to address both the temporal evolution and the conceptual configuration of the field:

- What are the years in which the highest level of research activity in engineering education in virtual environments has been observed?
- What type of growth characterizes the scientific production on engineering education in virtual environments over time?

- Who are the main research references shaping the development of engineering teaching in virtual environments?
- How has the thematic evolution of scientific production on engineering education in virtual environments progressed?
- What are the main thematic clusters structuring the research field?
- Which keywords are identified as growing and emerging within the literature?
- Which themes emerge as central for the formulation of a future research agenda in engineering education in virtual environments?

Each research question is addressed through specific bibliometric indicators and visualizations, enabling a structured presentation of the results and facilitating a focused discussion of their theoretical and practical implications.

METHODOLOGY

This study adopts an exploratory research design grounded in bibliometric analysis to examine the scientific literature on engineering education in virtual environments. The methodological procedure follows the reporting standards established in the PRISMA 2020 statement, which provides a structured framework for the identification, screening, eligibility assessment, and inclusion of relevant studies (Page et al., 2021). By applying bibliometric techniques to secondary data sources, this approach ensures a systematic and transparent collection and organization of the literature. This section is strictly methodological and focuses on describing the research design and analytical procedures, while the presentation and interpretation of results are addressed exclusively in the results and discussion sections.

Eligibility Criteria

Specific inclusion criteria have been established for the titles and keywords as the primary metadata. This guarantees an accurate selection of the relevant literature, ensuring that the selected documents directly address the topic of interest. The combination of key terms such as “engineering education” and “virtual environments” is used to identify relevant literature. The software is employed to filter and identify relevant works within the database. Additionally, the various citation methods for these concepts are considered, including synonyms and lexical variations, in order to encompass the largest possible amount of literature related to teaching engineering in virtual contexts.

Conversely, the exclusion process is divided into three distinct phases to ensure the quality and relevance of the documents analyzed. In the initial phase, all records that present erroneous or inadequate indexing

are excluded, thereby purifying the initial sample of documents. In the second phase of the research, documents are excluded if they lack full-text access. This exclusion only applies to systematic literature reviews, ensuring the availability of complete information for analysis. The third phase of exclusion focuses on eliminating texts with incomplete or insufficient metadata. This guarantees the integrity and reliability of the data used in bibliometrics on engineering education in virtual environments.

Source of Information

The Scopus and Web of Science databases were selected due to their recognition as the main sources of academic and scientific information today. These databases are widely used by researchers and academics due to their extensive coverage of scientific journals, conferences, and academic literature in various disciplines. Both platforms offer unique features and functionalities that make them valuable for research, such as advanced search capabilities. In addition, the integration of Scopus and Web of Science into the academic community has contributed to their reputation as reliable and rigorous sources of scientific information, justifying their choice as the main databases for this bibliometrics.

Furthermore, bibliometric analysis tools and the indexing of high-impact journals (Zhu & Liu, 2020) are available on both platforms.

Search Strategy

To conduct the search in the two selected databases, two specialized search equations were designed that responded to the defined inclusion criteria and the specific search characteristics of each platform. These equations were carefully developed to guarantee exhaustiveness and precision in the search, with the objective of recovering relevant literature on engineering education in virtual environments.

For the Scopus database: TITLE ("Engineering Education" OR "Teaching Engineering" OR "Instruction in Engineering") AND TITLE ("Virtual Environment" OR "Online Learning" OR "Remote Instruction" OR "Digital Education" OR "E-Learning" OR "Distance Learning").

For the Web of Science database: TI = ("Engineering Education" OR "Teaching Engineering" OR "Instruction in Engineering") AND TI = ("Virtual Environment" OR "Online Learning" OR "Remote Instruction" OR "Digital Education" OR "E-Learning" OR "Distance Learning").

Data Management

The Microsoft Excel® tool was employed to extract, store, and process the information derived from each

database. The Microsoft Excel® software proved an effective platform for the organization of the collected bibliographic data, the performance of bibliometric calculations, and the generation of summary tables for analysis (Astuti & Bhakti, 2018). Similarly, the free VOSviewer® software was employed for the visualization and analysis of networks of citations and co-authorship. Additionally, the tool facilitated the creation of interactive graphs and network maps that facilitated the understanding and visualization of the different bibliometric indicators, complementing the analysis carried out with Microsoft Excel®.

Selection Process

In accordance with the PRISMA 2020 statement, it is imperative to disclose whether an internal automatic classifier was utilized to streamline the selection process, as well as whether internal or external validation was employed to assess the risk of omitting studies or erroneous classifications (Page et al., 2021). In this study, Microsoft Excel® automation tools were leveraged as an internal tool, which was developed collectively by all the researchers involved. Each researcher employed this tool independently in the application of inclusion and exclusion criteria. This collaborative approach and autonomy helped to reduce the risk of missing studies or incorrect classifications, as the convergence of the results obtained by each researcher provided effective internal validation of the bibliographic selection process.

Data Collection Process

It is crucial to delineate the methodologies employed to gather bibliometric report data, including the number of reviewers involved in data collection for each report, whether they operated independently, and any procedures employed to obtain or corroborate data from study researchers. Furthermore, details about the automation tools used in the process must be provided (Page et al., 2021). In the present study, Microsoft Excel® was used as an automated tool for the data collection process of the reports obtained from the selected databases. All the authors of the study served as a review team, conducting an independent review of the collected data. This was followed by a collective data confirmation process until absolute convergence in the results was achieved, thus ensuring the quality and reliability of the data analyzed.

Data Elements

In order to achieve the research objective, we sought to compile results from all articles that responded to the research question. This was achieved through the use of specialized search equations designed for each database. These equations were used to identify all articles that specifically mentioned engineering teaching in virtual environments. However, if the information in the articles

was missing or unclear, they were excluded from the results. In instances where texts were identified as irrelevant, they were excluded from the analysis. This exclusion strategy was implemented to ensure consistency with the purpose and scope of the research, thus ensuring the integrity and coherence of the results obtained.

Assessment of the Risk of Bias of the Study

In the context of this research, a risk of bias assessment was carried out in the included studies, following a collaborative approach between all study authors. This was because the data collection process was also carried out through the participation of all authors. For all authors, the risk of bias assessment was carried out in a similar way. This was done using the same automated Microsoft Excel® tool that was used in the data collection phase. The tool utilized during the data collection phase enabled all participating authors to evaluate the risk of bias in each included study independently and systematically. This approach ensured the quality and integrity of the results obtained. The use of an automated tool in this process contributed to standardizing the evaluation and facilitating comparability between the different studies analyzed.

Measures of Effect

It is crucial to delineate the effect measures employed in the synthesis or presentation of the results. While these measures are more prevalent in primary research, in the context of bibliometrics based on secondary sources, different indicators are utilized to analyze the scientific literature. Among these indicators are the number of publications, the number of citations, and the temporality of use of each keyword. The data are analyzed using tools such as Microsoft Excel® for data processing and VOSviewer® for the visualization of thematic networks. This approach enables the identification of thematic association patterns between the analyzed documents, which provides relevant information on trends and areas of interest in engineering education in virtual environments.

Synthesis Methods

In the context of this research, several processes were carried out to determine which studies were eligible for each synthesis. These processes included the tabulation of the study's intervention characteristics and their comparison with the groups planned for each synthesis. Additionally, employed methods to prepare data for presentation or synthesis, which involved handling missing summary statistics or data conversions, to tabulate. The results of individual studies and syntheses were then quantified and displayed in a visual format. This was achieved through the use of an automated approach that applied bibliometric indicators of

quantity, quality, and structure. These indicators were implemented in an automated manner through the use of Microsoft Excel® in all documents that passed the three exclusion phases established in the research methodology (Durieux & Gevenois, 2010).

Assessment of Reporting Bias

In order to assess the risk of bias due to the lack of results in a synthesis, which may arise from reporting biases, it is necessary to consider the possibility of bias towards certain synonyms found in thesauri, such as the IEEE, which is reflected in the inclusion criteria, the search strategy and the data collection itself. Moreover, the presence of documents with incomplete indexing could result in the exclusion of valuable information for the construction of knowledge on the subject, which could introduce a bias in the results of bibliometrics.

Certainty Evaluation

The evaluation of certainty in the body of evidence is conducted on a global scale, in contrast to the individual evaluation of primary studies, which assess certainty. This process is carried out through the independent application of the inclusion and exclusion criteria, as well as the definition of bibliometric indicators that reflect as well as the definition of bibliometric indicators that reflect the quality, relevance, and impact of the analyzed studies. In addition, the quality and relevance of the documents analyzed are reported, along with any potential biases identified in the study's methodological design. Limitations of the study are also discussed during the discussion phase, which contributes to the transparency and validity of the analysis.

In the initial phase of this bibliometric study on engineering teaching in virtual environments, the identification of records was carried out based on the search strategy in each selected information source, as well as the elimination of duplicate records. This was followed by three exclusion phases, through which those records that did not meet the established inclusion criteria were discarded. Finally, after this selection process, a total of 97 articles were obtained that were included in the bibliometric analysis on the aforementioned topic.

As detailed in **Figure 1**, the process began with 161 records (141 from Scopus and 20 from Web of Science). After removing 25 duplicates, 136 records were screened, and all were retrieved for assessment. During the eligibility phase, 39 studies were excluded due to incomplete or insufficient indexing, which prevented their inclusion in the bibliometric analysis. Therefore, the final sample comprised 97 studies. The exclusion phases were structured as follows:

- (1) removal of duplicates and records with erroneous indexing;

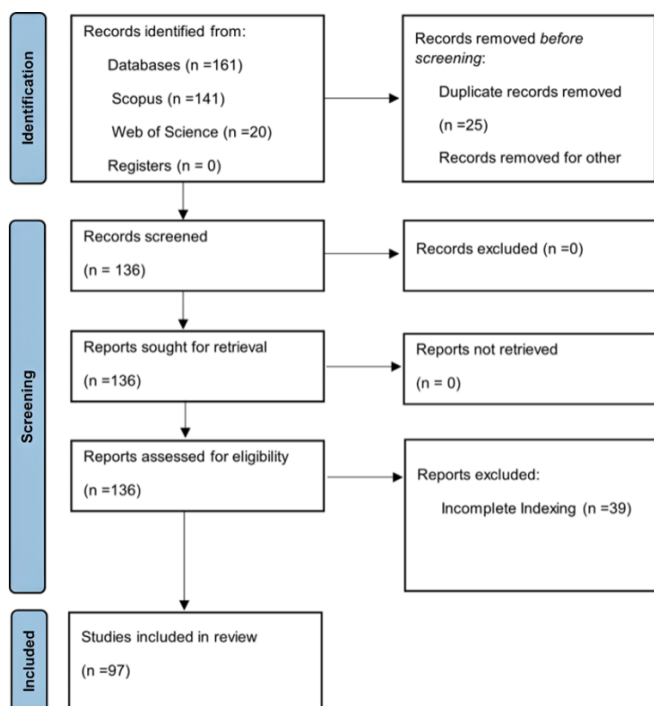


Figure 1. PRISMA flowchart (Source: Authors' own elaboration, based on Scopus and Web of Science data)

- (2) exclusion of documents without full-text availability, applied only to systematic reviews; and
- (3) exclusion of records with incomplete metadata.

The inclusion criteria required that studies explicitly refer to "engineering education" and "virtual environments" in their titles or keywords, including synonyms and lexical variations, ensuring that only research directly addressing the topic was considered.

RESULTS

The results section presents the findings derived from the analysis of the 97 selected articles. These findings offer a detailed vision of the trends, patterns, and characteristics of scientific production in this field, as well as the main research areas and the methodological approaches used. The presentation and discussion of these results aim to provide a comprehensive understanding of the current state of knowledge in engineering education in virtual environments and to identify possible areas of future development in engineering educational research.

The present bibliometric analysis has allowed us to identify, in Figure 2, a notable cubic polynomial growth, evidenced by an increase of 98.43%. This growth suggests a significant increase in scientific production related to the topic over time. In particular, the years with the greatest number of publications are 2022, 2021, 2010, and 2011. This indicates periods of particular relevance in research on engineering education in virtual environments. This finding highlights the evolution and

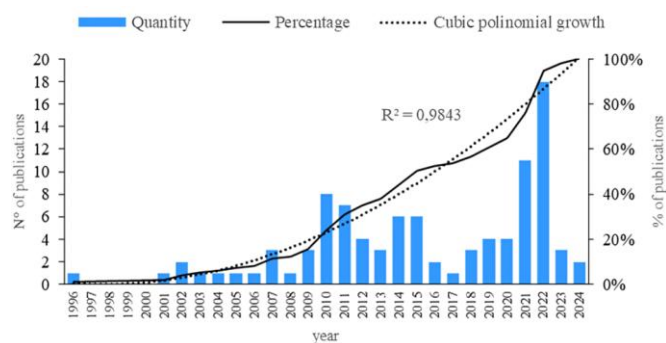


Figure 2. Publications by year (Source: Authors' own elaboration, based on Scopus and Web of Science data)

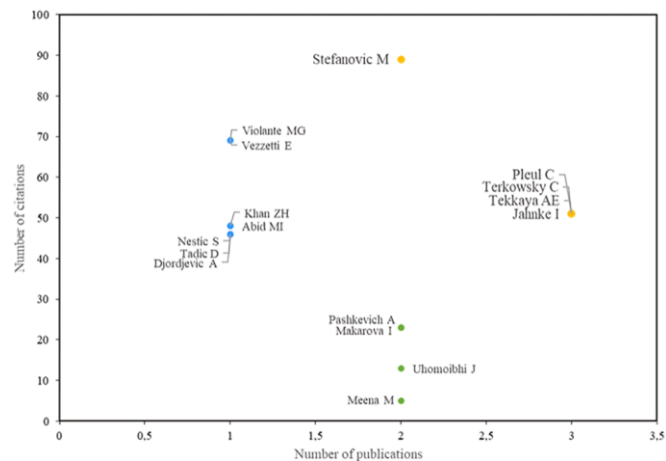


Figure 3. Main authors (Source: Authors' own elaboration, based on Scopus and Web of Science data)

continued interest in this field of study, as well as the need to continue exploring and advancing in this area to meet current educational demands and challenges.

In terms of the main authors identified in the bibliometrics on engineering education in virtual environments, three distinct groups have been identified (Figure 3). Firstly, authors such as Stefanovic, M., Pleul, C., Terkowsky, C., Tekkaya, A. E., and Jahnke, I. stand out, demonstrating both high productivity and significant scientific impact. Another group of authors, despite exhibiting a relatively low productivity index, are positioned as references in terms of impact. These include Violante, M. G. and Vezzetti, E. also identifies a second group of authors who are distinguished by their high scientific productivity, although not necessarily by the number of citations they have received. This group includes Pashkevich, A. and Makarova, I., who have made significant contributions to the field of engineering education in virtual environments.

In terms of the main journals identified in the bibliometrics on engineering teaching in virtual environments, two different groups have been observed (Figure 4). On the one hand, there are those journals that stand out as references in terms of impact, despite having a low index of scientific productivity. These include journals such as Computer Applications in

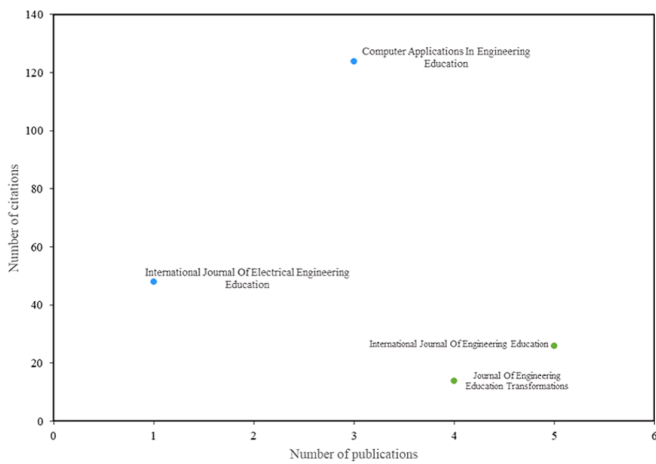


Figure 4. Main journals (Source: Authors’ own elaboration, based on Scopus and Web of Science data)

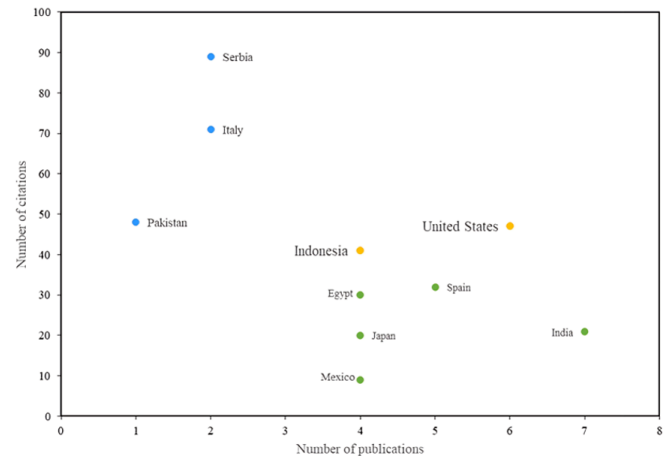


Figure 5. Main countries (Source: Authors’ own elaboration, based on Scopus and Web of Science data)

Engineering Education and International Journal of Electrical Engineering Education. In contrast, a second group of journals is identified as stand out primarily for their high scientific productivity, although not necessarily for the number of citations they receive. One notable example is the International Journal of Engineering Education, which demonstrates the diversity of journal profiles in this field and the importance of both the quantity and quality of publications in engineering education in virtual environments.

Three groups of leading authors in the field were observed. The first group includes countries such as the United States and Indonesia, which stand out in both productivity and scientific impact. The second group comprises countries that, despite showing a low productivity index, are positioned as references in terms of impact, as measured by the number of citations received in their works. Among these countries are Serbia and Italy. The third group includes countries that stand out in terms of scientific productivity, although not necessarily due to the number of citations received. These countries include India and Spain. Finally, we note that Serbia and Italy also exhibit high scientific productivity, although this is not necessarily due to the number of citations received. India and Spain are particularly noteworthy in this regard. These findings reveal the diversity of country profiles in terms of their contribution to research in engineering education in virtual environments. They highlight both the quantity and quality of their contributions in this area.

For the purposes of this analysis, “main countries” were defined based on a minimum publication threshold. Only countries with at least three publications indexed in Scopus and Web of Science within the analyzed dataset were included in Figure 5. This cut-off criterion was applied to ensure analytical clarity and to focus on countries with a sustained contribution to the field, avoiding visual noise generated by isolated or single-publication cases. Although additional countries

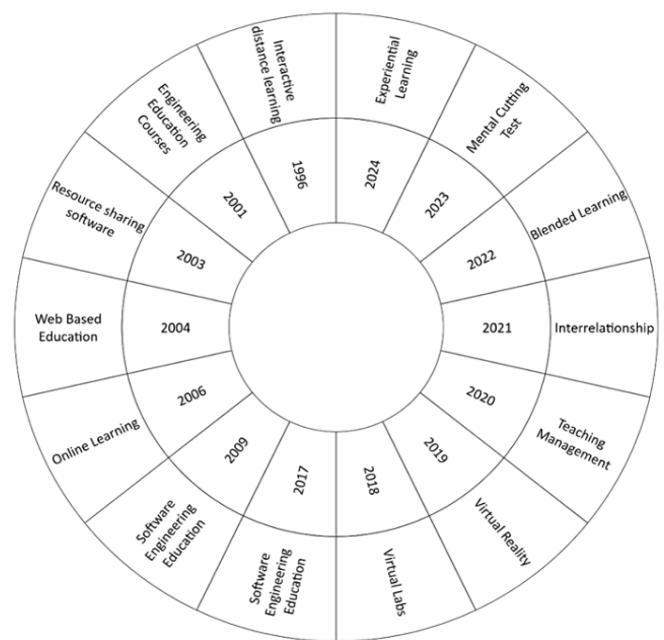


Figure 6. Thematic evolution (Source: Authors’ own elaboration, based on Scopus and Web of Science data)

have contributed to the literature on engineering education in virtual environments, they were not displayed in Figure 5 due to their limited publication frequency within the selected time frame.

The present research examines the evolution of themes in the related literature, as evidenced in Figure 6. This investigation was based on the most frequently used keywords in each year of research, spanning from 1996 to 2024. It is observed that in the year 1996, as a starting point, concepts such as interactive distance learning emerge. However, in more recent years, a predominance of topics such as experiential learning, mental cutting test, blended learning, and interrelationship can be seen, which reflects current research trends in this field. This thematic analysis over time provides a comprehensive view of the evolution and areas of interest in engineering education in virtual environments over the last decades.

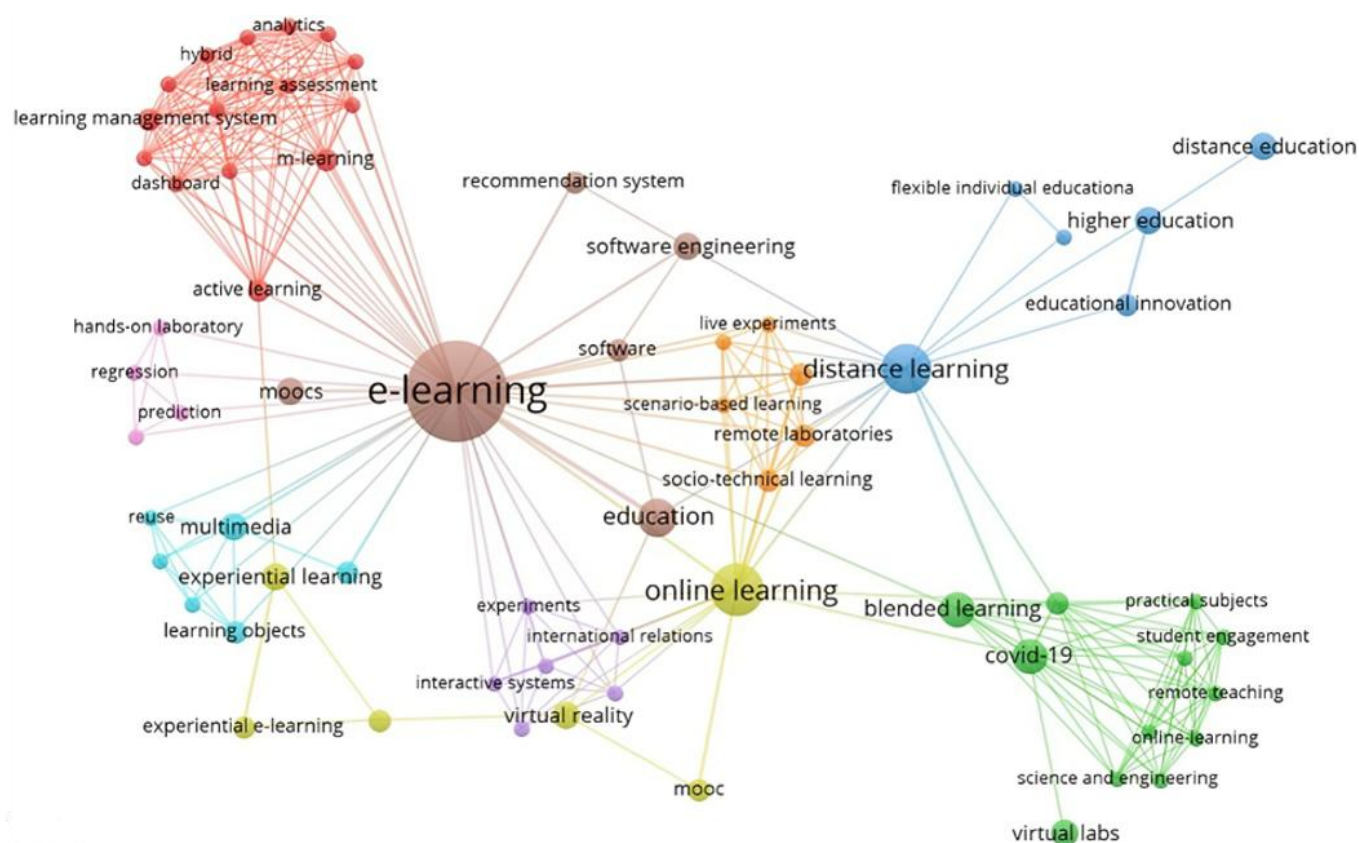


Figure 7. Keyword co-occurrence network (Source: Authors' own elaboration, based on Scopus and Web of Science data)

The keyword co-occurrence network provides a comprehensive overview of the data, with a total of seven thematic clusters visible in **Figure 7**. Of particular note is the purple-brown cluster, which is composed of terms such as e-learning, massive open online courses (MOOCs), education, software, recommendation systems, and software engineering. This cluster stands out as the most prominent, followed by the blue cluster, which includes terms such as distance learning, educational innovation, and higher education. In addition, other clusters are identified in light blue, lilac purple, yellow, red, and green, each representing different aspects of conceptual affinity within the analyzed corpus. This analysis provides a deep understanding of the predominant themes and research areas in the field of teaching engineering in virtual environments.

The present research introduces an innovative approach to the analysis of keywords in the field of engineering education. This approach involves the creation of a Cartesian plane, which measures the frequency of use of keywords on the X axis and the validity of their use on the Y axis. This allows for a clear and structured visualization of the evolution of concepts over time. As shown in **Figure 8**, this approach allows space to be divided into four different quadrants, each with different characteristics. The fourth quadrant contains concepts that exhibit a decreasing trend in their use and relevance. In contrast, the third quadrant

includes concepts that have not yet been fully consolidated in the literature. The second quadrant identifies keywords that, although infrequent, are highly current. These concepts are positioned as emerging and worthy of attention, such as experiential e-learning, STEM, online teaching and virtual reality. In contrast, consolidated and growing concepts, such as Online Learning, are found in quadrant 1, reflecting their continued importance in the field of study. They provide valuable perspective on emerging and established trends in engineering education in virtual environments, facilitating the identification of areas of interest and future research opportunities.

DISCUSSION

The discussion section plays a foundational role in research on engineering education in virtual environments. It provides a comprehensive analysis of the results obtained, examining and contextualizing the findings, exploring their practical implications, and identifying the limitations of the study. Additionally, a classification of keywords is presented according to their function, the main research gaps identified are discussed, and a future research agenda is proposed to advance knowledge on this topic. This section presents a critical reflection on the results obtained and their relevance for the academic and professional community interested in engineering education in virtual environments.

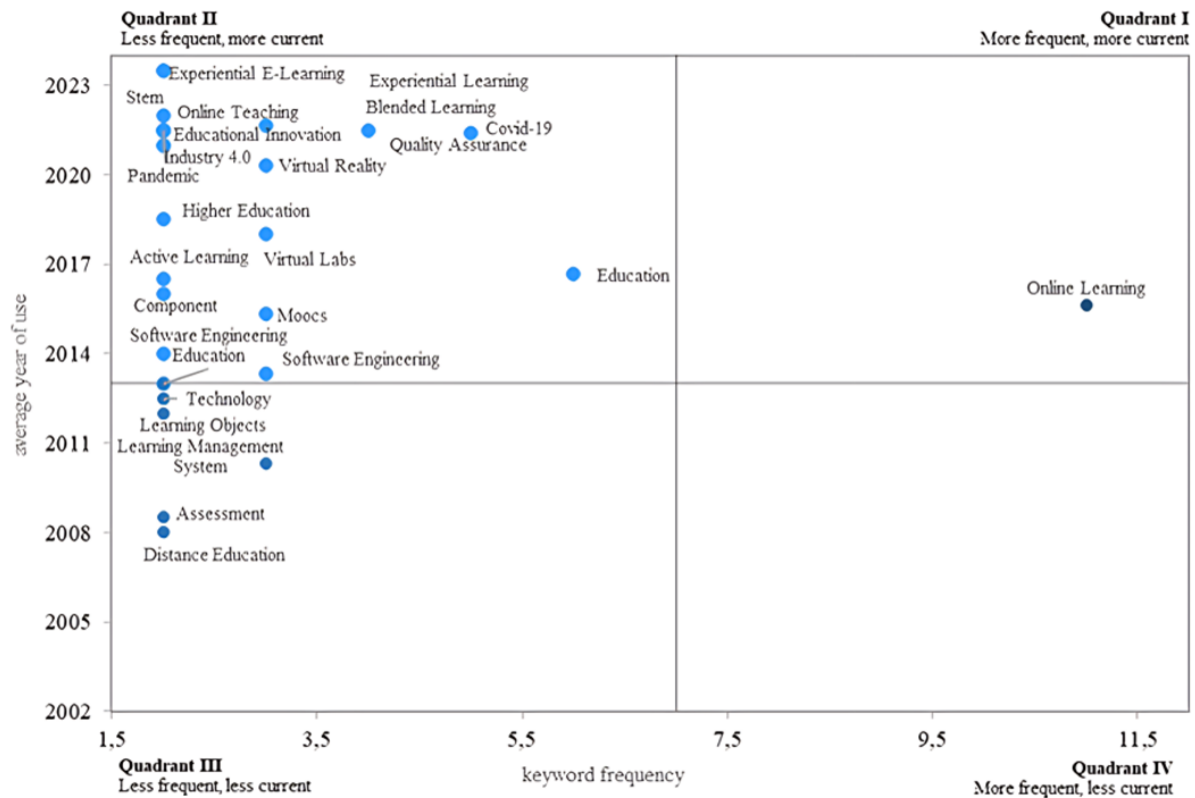


Figure 8. Validity and frequency of keywords (Source: Authors' own elaboration, based on Scopus and Web of Science data)

Analysis of the Growth of Scientific Literature on Engineering Education in Virtual Environments

The results indicated that the years with the greatest number of publications on the subject were 2022, 2021, 2010, and 2011. In recent years, there has been a notable increase in scientific production in the field of engineering education in virtual environments. It is noteworthy that in 2022, the application of e-learning systems in engineering education was highlighted, with the identification of challenges and obstacles and an exploration of the community framework of e-learning inquiry for engineering education. This evidenced a focus on this pedagogical approach (Abumandour, 2022; Purwandari et al., 2022).

In 2021, an analysis was conducted on student preferences regarding the attributes of online learning in industrial engineering education, with particular relevance in the context of the COVID-19 pandemic. The study highlighted the necessity for the adaptation of educational environments in the face of disruptive situations (Ong et al., 2021). In 2010, the importance of distance learning in engineering continuing education was highlighted, with the view that this modality is crucial for the continuous training of professionals in the field of engineering (Baukal, 2010).

In 2011, they introduced teleoperated laboratories for online production engineering education, offering a platform for telemetric experimentation and e-learning. This represents an innovation in engineering education,

facilitating student participation in hands-on activities at a distance (Terkowsky et al., 2011).

Analysis of Research References on Engineering Teaching in Virtual Environments

In the results section, it was found that the authors who had the greatest impact and productivity were Stefanovic, M. and Pleul, C., together with Terkowsky, C., Tekkaya A. E., Jahnke I., while Violante M. G. with Vezzetti, E. appeared to have the greatest impact and Pashkevich, A. with Makarova, I. appeared to have the greatest productivity. Prominent authors conducted an evaluation of the objectives of distance learning laboratories for education in control engineering, emphasizing the significance of this modality in the training of engineers (Stefanovic et al., 2015). Additionally, the objectives were investigated, as well as the architectures and effects of distance learning laboratories for industrial engineering education, offering a comprehensive perspective on their application and effectiveness (Stefanovic, 2013).

Other prominent authors developed teleoperated laboratories for online production engineering education, providing a platform for telemetric experimentation and e-learning (Terkowsky et al., 2010, 2011). These studies represent a significant contribution to the field of engineering education in virtual environments, as they offer new forms of practical distance learning.

Similarly, an innovative approach was employed in the design of an e-learning platform for engineering education, underscoring the significance of adaptability and efficiency in online teaching. The study offers valuable insights for the development of effective and student-centered educational platforms (Violante & Vezzetti, 2014). As the field of engineering education continues to evolve, the study offers a prospective view on the future of engineering education in virtual environments. It highlights the evolution of educational technologies in the field of engineering and explores the digitalization of engineering education, from e-learning to smart education.

Furthermore, it was observed that the most impactful journals in the field of engineering education were *Computer Applications in Engineering Education*, *International Journal of Electrical Engineering Education*, and *International Journal of Engineering Education*. These journals demonstrated a high level of productivity. The journal *Computer Applications in Engineering Education* has made a significant contribution to the field of engineering education through its research on the implementation of a new approach to the design of e-learning platforms in engineering education. This research has provided valuable insights on how to design effective and student-centered educational programs, which has helped advance the integration of technology in engineering education (Violante & Vezzetti, 2014).

The *International Journal of Electrical Engineering Education* has also played a pivotal role in advancing knowledge in engineering education. A study published in the journal addressed the challenges and opportunities of distance learning in engineering education during the COVID-19 pandemic in Pakistan. The research highlights the importance of adapting to new teaching models in times of crisis and has contributed to the development of effective strategies for distance engineering education (Khan & Abid, 2021).

The *International Journal of Engineering Education* has served as a significant platform for the dissemination of knowledge in the field of engineering. A study focusing on design education for freshmen and seniors provides valuable insights into the importance of design education in the engineering curriculum and has influenced pedagogical approaches in engineering programs around the world (Marchman III & Mason, 1997).

Finally, it was determined that the countries that have distinguished themselves in scientific production are the United States and Indonesia. These countries have demonstrated high levels of impact and productivity, while other countries, such as Serbia and Italy, have been notable for their impact and India and Spain for their number of publications. The United States has been a prominent leader in scientific production in

the field of engineering education in virtual environments, as evidenced by several studies that have contributed significantly to the advancement of knowledge by exploring topics such as distance engineering education and the evolution of telecollaboration stations. For individualized distance learning, research conducted in the United States has established a foundation for the development of innovative engineering teaching strategies that have been applied both nationally and internationally (Abler & Wells, 2005; Baukal, 2010).

Indonesia has also emerged as an important player in scientific production related to engineering education in virtual environments. This is evidenced by studies that have addressed crucial issues such as student preferences in online learning and the exploration of frameworks for online learning communities for engineering education. The work done in Indonesia has provided valuable insights into how to adapt educational practices to the needs of students in virtual environments, thus contributing to the advancement of engineering education globally. The insights gained have been invaluable in enabling the adaptation of educational practices to the needs of students in virtual environments, thereby contributing to the advancement of engineering education globally (Ong et al., 2021; Purwandari et al., 2022).

Serbia has emerged as a leading country in scientific production on engineering education in virtual environments. Its studies have provided a detailed evaluation of the objectives of distance learning laboratories for control engineering education, which has contributed to improving understanding of how to design and develop effective online learning environments for engineering students. Research conducted in Serbia has offered valuable contributions to the field by addressing the specific challenges related to engineering education in virtual environments.

Italy has also made a significant contribution to research on engineering teaching in virtual environments. Italian researchers have explored the implementation of an innovative approach to the design of an online learning platform in engineering education, providing a new perspective on how to design platforms and effective learning strategies. Italian research has contributed to the advancement of engineering educational practices globally, highlighting the importance of technological innovation in teaching and learning in virtual environments (Violante & Vezzetti, 2014).

India has emerged as a key player in scientific production on engineering education in virtual environments. A study focuses on the response of students towards online learning during the COVID-19 pandemic, providing crucial information on the effectiveness and acceptance of virtual teaching

methodologies in the engineering context. India offers a distinctive perspective on the manner in which students and educators have adjusted their learning and teaching practices in response to the challenges posed by the pandemic. This contributes significantly to the development of more effective educational strategies (Kaur et al., 2021).

Spain has also been a significant contributor to the scientific literature on engineering education in virtual environments. Research in this area has examined the impact of multi-user virtual environments on student motivation in engineering education, providing evidence of the potential benefits of virtual environments for improving student motivation. Spanish research has contributed to the advancement of educational practices in engineering, highlighting the importance of digital technology in improving the online learning experience (Sancho et al., 2009).

Analysis of the Thematic Evolution of Engineering Education in Virtual Environments

The concept of distance learning played a foundational role in the early years of research on engineering education in virtual environments. This is evidenced by a pioneering study that explored the application of distance learning using integrated services digital network technology in electronic engineering education. At that time, distance learning represented a significant innovation by allowing the delivery of educational content through electronic means, overcoming the barriers of time and space. This approach laid the foundation for the subsequent evolution of engineering education in virtual environments, by highlighting the possibilities of technology to expand access to education and facilitate learning regardless of the student's physical location. The delivery of educational content through electronic means, overcoming the barriers of time and space, established the foundation for the subsequent evolution of engineering education in virtual environments. This approach highlighted the possibilities of technology to expand access to education and facilitate learning regardless of the student's physical location (Davoli et al., 1996)

In recent years, there has been a notable shift in the conceptual approach to research. Concepts such as experiential learning have gained increasing relevance. This approach emphasizes the significance of practical experience and the application of knowledge in authentic or simulated settings. It enables students to cultivate practical and transferable skills pertinent to engineering (Mehrtash & Ghalkhani, 2024). Similarly, the concept of the mental cutting test has emerged as an area of interest is the exploration of how engineering education can influence students' spatial ability in virtual environments. This approach highlights the importance of understanding how educational practices

can affect the development of fundamental cognitive skills in the field of engineering.

Moreover, a study on blended learning demonstrates the adaptation of science and engineering education to the online learning environment, particularly in response to circumstances such as lockdowns due to the pandemic. The concept of blended learning combines traditional teaching methods with online resources, digital tools, and other online materials, offering flexibility and personalization in the learning process. Similarly, Gill et al. (2022) conducted an analysis on the interrelationship between e-learning and engineering education, identifying the various factors that influence the effectiveness of this educational approach (Prمود et al., 2021). These studies underscore the significance of elucidating the interrelationships between diverse variables and educational practices to enhance the caliber and efficacy of engineering learning in virtual environments.

The advent of virtual education has brought with it the necessity for the development of novel evaluation strategies. In order to foster the growth of analytical and critical thinking skills, students must be encouraged to engage with educational tools that facilitate such processes. Consequently, educators must possess the requisite skills to design evaluation strategies that assess students' critical thinking abilities (Zeashan & Muhammad, 2021). The preceding approach indicates that the teaching-learning process in virtual environments is not solely defined by the technological tools employed but is also shaped by evaluation strategies that include evidence and learning outcomes that are promoted and reinforced throughout the process.

Analysis of Thematic Clusters on Engineering Education in Virtual Environments

Upon examination of the primary co-occurrence network of keywords in engineering teaching in virtual environments, a purple-brown thematic cluster was identified that stands out for terms such as e-learning, MOOCs, education, software, recommendation systems, and software engineering. This cluster reflects the pivotal role of technology in education, particularly in the field of engineering, where recommendation systems and specific software are utilized to enhance the learning experience. Research has explored the role of online education and technological tools in engineering education, emphasizing the necessity to adapt to new educational paradigms and promote sustainability in the training of engineers (Sivapalan et al., 2016; Sommer et al., 2016).

In contrast, the second most relevant cluster, in blue, is comprised of words such as distance learning, educational innovation, higher education, flexible individual education, and distance education. This

Table 1. Classification of keywords according to their function

Keyword	Associated tools	Applications	Characteristics
Experimental e-learning STEM	Simulations, virtual laboratories, educational games Interdisciplinary projects, digital educational resources, practical experiences	Virtual labs, immersive learning environments Integration of science, technology, engineering and mathematics in the curriculum	Promotes practical and experiential learning It fosters critical thinking and problem-solving abilities.
Online teaching	Online learning platforms, videoconferences, discussion forums	Teaching classes through the Internet, virtual tutorials	Flexibility of schedules and access from anywhere.
Virtual reality	Virtual reality viewers, interactive applications, simulators	Simulation of three-dimensional virtual environments, recreation of learning scenarios	Total immersion in educational experiences
Quality assurance	Automated assessments, performance metrics, personalized feedback	Quality assurance in content and delivery, continuous improvement of the educational process	Ensures the effectiveness and relevance of educational materials
Online learning	Learning management platforms, multimedia content, online assessments	Access to educational resources from any location, flexibility of study schedules	Facilitates autonomous and personalized learning

cluster reflects the evolution of educational models towards more flexible and adaptive forms, particularly in response to the need for distance education. Research (Buentello-Montoya & Carreon-Andujo, 2022; Olkhovaya & Poyarkova, 2021) has explored how distance learning is being adopted and adapted in engineering education, examining its benefits and challenges in the training of engineers in an increasingly digitalized world.

Analysis of the Frequency and Conceptual Validity Around Engineering Education in Virtual Environments

On the Cartesian level, quadrant 2 stands out as a space where key concepts emerge that will be crucial for the future development of the scientific field. Among these emerging concepts are experiential e-learning, STEM, and online teaching. The importance of these concepts lies in their potential to transform engineering education through innovative and technologically advanced approaches. For example, it is suggested that the adaptation of experiential e-learning in engineering education can improve the connection between theory and practice, preparing students for the challenges of Industry 4.0 (Mehrtash, 2022). Additionally, the application of online learning systems in the potential of engineering education is explored, with particular attention to the challenges and obstacles that must be overcome to fully exploit this field's potential (Abumandour, 2022). In contrast, the importance of online learning in engineering education is addressed, with a particular focus on the context of the COVID-19 pandemic. This analysis highlights the need to overcome the challenges and take advantage of the opportunities that virtual teaching offers in training engineers for the future (Khan & Abid, 2021).

In quadrant 1 of the Cartesian plane of bibliometrics on engineering education in virtual environments, consolidated and leading concepts such as online learning stand out. This term has acquired significant importance today and is projected as fundamental in the near future of engineering education. Online learning has revolutionized the way education is delivered, offering flexibility, accessibility, and personalized learning opportunities. The development of teleoperated laboratories for engineering education has been explored, using online learning platforms and telemetric experimentation to improve the quality and scope of teaching. These advances in online learning are transforming the way in which knowledge is acquired in engineering, preparing students for the challenges of the world of work and contributing to the continuous advancement of the scientific and technological field (Terkowsky et al., 2010).

Classification of Keywords on Engineering Education in Virtual Environments According to Their Function

Table 1 of the bibliometrics on engineering teaching in virtual environments presents a classification of the main emerging and growing keywords according to their function. This classification allows for the identification of the characteristics and applications of each of the categorized functions.

Keywords are grouped according to their function, which facilitates the understanding of trends and areas of interest in research on this topic. Each of these functions has its own characteristics and specific applications in the context of engineering education in virtual environments. The detailed analysis of these functions in **Table 1** provides a comprehensive view of the emerging and growing research areas in this field.

Theoretical Implications

The application of bibliometrics offers a comprehensive and systematic understanding of the evolution of knowledge in this field. The analysis of the frequency of publications per year provides a panoramic view of the temporal dynamics of research, revealing trends and critical moments in the development of the field. Furthermore, by identifying the main theoretical references, it allows us to recognize the most influential contributions and the dominant approaches that have shaped research in virtual engineering education.

The study of thematic evolution over time reveals changes and shifts in research interests and priorities. Initially, research in this field focused on topics such as distance learning, but over time, concepts such as experiential learning and blended learning emerged. This provides insight into the history of conceptual development in the field, which allows researchers to better understand the direction and breadth of research and adapt their methodological and theoretical approaches accordingly.

The identification of keyword co-occurrence and analysis of emerging and growing keywords offer detailed insight into emerging trends and areas of growing interest in research on engineering education in virtual environments. These findings can inform the formulation of agendas for research, the identification of new areas of study, and the identification of opportunities for innovation and interdisciplinary collaboration.

However, one of the most significant aspects is the identification of research gaps. By revealing underexplored or underrepresented areas in the scientific literature, it allows researchers to identify opportunities to fill gaps in knowledge and address challenges and problems not yet resolved in the field. Engineering teaching in virtual environments, these gaps may be promising research areas for future studies and may guide the formulation of more precise and relevant research agendas.

From a theoretical perspective, the findings of this bibliometric analysis contribute to consolidating engineering education in virtual environments as a multidimensional research field characterized by the convergence of pedagogical, technological, and organizational perspectives. The observed thematic evolution from distance learning toward experiential learning, blended learning, and advanced digital approaches suggests a progressive shift from technology-centered frameworks to learning-centered paradigms. This shift reinforces contemporary educational theories that emphasize active learning, student engagement, and competency development, extending their applicability to digitally mediated engineering education.

Furthermore, the identification of dominant thematic clusters and emerging keywords provides a structured conceptual map that helps clarify the intellectual foundations of the field. By synthesizing fragmented lines of research, this study contributes to theory-building efforts by highlighting how concepts such as e-learning, MOOCs, experiential e-learning, and virtual laboratories interact within engineering education. These insights support the development of integrative theoretical frameworks capable of explaining not only technological adoption but also pedagogical effectiveness and learning outcomes in virtual engineering contexts.

Practical Implications

This research has significant practical implications for researchers, educators, and policymakers in the field of education. The thematic shift from distance learning to more advanced concepts such as experiential learning, mental cutting test, blended learning, and interrelationship reflects an evolution towards more pedagogical approaches. These approaches are sophisticated and student-centered, suggesting the need to develop and adapt teaching strategies that incorporate practical experiences, innovative assessments, and more flexible and personalized learning methods to improve the effectiveness of learning in virtual environments.

The analysis of thematic clusters reveals the conceptual interconnection between terms such as e-learning, MOOCs, education, software, recommendation systems, and software engineering. This indicates the importance of integrating ICT in engineering education to offer more dynamic and personalized learning experiences. Educators can leverage these conceptual relationships to design more interactive and adaptive learning environments that promote student engagement and facilitate the acquisition of technical skills and knowledge.

Conversely, the analysis of keyword frequency and validity reveals the emergence of concepts such as experiential e-learning, STEM, online teaching, virtual reality, and quality assurance. Additionally, it indicates the continuous growth of online learning. These findings suggest areas of priority research and development to improve the quality and effectiveness of engineering education in virtual environments. Educators and program designers can utilize this information to identify emerging trends and adapt their pedagogical and technological approaches to meet the changing needs of students and the demands of the constantly evolving labor market. This valuable practical guidance is provided to improve the quality and effectiveness of engineering education in virtual environments by identifying emerging trends, conceptual relationships, and priority research areas.

Likewise, this study can offer valuable contributions in other dimensions and contexts. For example, by identifying the main theoretical references and most prolific authors in the field, this research can help educators and researchers identify the most relevant sources of knowledge and the most influential theoretical perspectives. This facilitates access to key literature and fosters a deeper understanding of the theoretical foundations that support engineering education in virtual environments.

Furthermore, this study offers crucial information on academic collaboration and research networks in the field of engineering education in virtual environments. It does so by analyzing the co-authorship and institutional affiliation of the authors, as well as the frequency of collaboration between different institutions and countries. Educational policy makers can use this information to identify opportunities for inter-institutional and international collaboration. Such collaboration can foster academic cooperation, the exchange of knowledge and good practices, and the development of strategic partnerships that drive innovation and quality in engineering education.

Concurrently, it facilitates the identification of nascent trends and promising research domains that warrant enhanced attention and resources. By identifying deficiencies in knowledge and underdeveloped areas, educators and policymakers can direct research and development towards critical areas that they can address. This can result in the creation of more relevant and updated study programs, as well as the design of new teaching methodologies and educational technologies that enhance the learning experience of students and facilitate the achievement of optimal learning outcomes. These practical implications illustrate the value of bibliometrics as a tool to inform and enhance engineering educational practice in virtual environments across multiple dimensions and contexts.

From a practical standpoint, the results offer valuable guidance for educators and instructional designers involved in engineering programs delivered through virtual or digital environments. The prominence of experiential learning, virtual laboratories, and interactive online platforms highlights the importance of designing learning experiences that move beyond passive content delivery. Engineering educators can leverage these insights to incorporate practice-oriented activities, simulations, and problem-based learning strategies that foster the development of practical skills and professional competencies in online settings.

In addition, the identified research gaps and emerging themes provide relevant input for institutional decision-makers and policymakers. Understanding the growing relevance of quality assurance, virtual laboratories, and advanced digital tools can inform strategic investments in educational infrastructure and

faculty development. By aligning curricular design and institutional policies with the trends identified in this study, higher education institutions can enhance the effectiveness, resilience, and sustainability of engineering education in virtual environments, particularly in contexts marked by technological change and educational disruption.

Limitations

One of the limitations of this study lies in the selection of the databases used, namely Scopus and Web of Science. These databases may not cover all of the scientific literature available on engineering education in virtual environments. While these databases are widely recognized and used in academia, it is possible that some relevant publications are excluded due to access or indexing restrictions. Furthermore, the use of tools such as Microsoft Excel® and VOSviewer® for bibliometric analysis introduces potential biases, as these tools depend on the accuracy of the input data and the decisions made during the analysis process. Therefore, it is important to recognize that the results obtained could be subject to certain biases and limitations inherent to the methodology used. The use of tools such as Microsoft Excel® and VOSviewer® for bibliometric analysis may introduce potential biases, as these tools depend to a great extent on the accuracy of the input data and the decisions made during the analysis process. Consequently, it is important to recognize that the results obtained could be subject to certain biases and limitations inherent to the methodology used.

Investigative Gaps

Table 2 presents the principal research gaps identified in the field of study. These gaps must be addressed in future research in order to advance knowledge and improve educational practices in this field. The identified gaps may include areas where a lack of knowledge has been identified, studies or limited research, as well as specific aspects that require further in-depth study or innovative approaches.

To close these research gaps, an interdisciplinary and collaborative approach is required, as well as the use of mixed methodologies that combine quantitative and qualitative methods. Moreover, it is crucial to facilitate collaboration between researchers, educators, and professionals in the field to ensure that research addresses genuine needs in engineering teaching in virtual environments and generates applicable and relevant results for educational and professional practice.

Research Agenda

The significance of software engineering in engineering education in virtual environments lies in its foundational role in development and implementation

Table 2. Research gaps

Category	Investigative gaps	Justification	Questions for future research
Thematic	The impact of virtual teaching on the development of practical engineering skills	Despite the growing use of virtual environments in engineering education, there is a paucity of studies that evaluate the impact on the development of practical skills	What is the actual impact of virtual laboratories on the development of practical skills in comparison to in-person laboratories?
	The incorporation of augmented reality in engineering teaching in virtual environments	Augmented reality offers new possibilities in online education, but there is still a dearth of research on how to effectively integrate it into engineering education	How can augmented reality be effectively designed and implemented in online engineering courses to enhance the learning experience?
Geographic	Investigation of engineering education in virtual environments in developing countries	The majority of research is conducted in developed countries, leaving a gap in our understanding of how specific challenges are addressed in developing countries	What are the optimal methodologies for adapting and optimizing engineering education in virtual environments in resource-limited contexts?
	Comparative analysis of different geographical regions regarding the adoption and efficacy of virtual teaching	There is a lack of systematic comparisons between different geographic regions to understand how cultural and socioeconomic factors influence virtual teaching	What distinctions and similarities exist in the implementation and outcomes of virtual teaching across different countries or regions?
Interdisciplinary	Integration of pedagogical approaches from other disciplines into engineering education in virtual environments	The integration of innovative pedagogical approaches from disciplines such as educational psychology or cognitive neuroscience can enhance the effectiveness of teaching in virtual environments	What pedagogical principles from other disciplines can be applied to enhance engineering education in virtual environments?
	Collaboration between engineers and educators in the design of virtual teaching programs	Interdisciplinary collaboration between engineers and educators can facilitate the development of more effective teaching programs that address the specific needs of engineering students	What are the optimal strategies for fostering and sustaining productive collaboration between engineers and educators in the development of virtual learning programs?
Temporal	Long-term impact of virtual teaching on the performance and career paths of engineering students	The majority of studies focus on immediate outcomes, yet there is a pressing need to comprehend the long-term impact of virtual teaching	What methodologies can be employed to assess the ongoing impact of virtual teaching on academic performance and employability?
	Evolution and adaptation of virtual teaching in response to technological and social changes over time	Given the rapid advancement of technology and shifts in educational expectations, it is crucial to understand how virtual teaching evolves to remain effective	What changes have been observed in virtual teaching practices and tools in response to technological advances and changing educational needs?

of technological tools and systems utilized in the educational process. This field encompasses the design, construction, and management of software, which are critical aspects in guaranteeing the effectiveness and quality of virtual educational platforms.

In the future, research could focus on improving software engineering methods and techniques that are specifically adapted to virtual environments. Additionally, research could explore new strategies to optimize the development and deployment of educational applications, as well as to address the

unique challenges that arise in this context, such as interoperability, accessibility, and security.

Experiential learning has emerged as an effective pedagogical approach in teaching engineering in virtual environments. This approach offers students the opportunity to acquire knowledge and skills through practical and participatory experiences. It promotes exploration, active experimentation, and problem-based learning, which is especially relevant in disciplines such as engineering, where the practical application of theoretical concepts is essential.

It is also essential to consider how theoretical concepts can be effectively integrated into experiential learning strategies in the virtual environment. Future research could explore ways to optimize and adapt these strategies, developing new methodologies and technological tools that allow for a more immersive, collaborative, and personalized learning experience. Additionally, it would be valuable to evaluate their effectiveness in terms of academic achievements and skills development.

The term “software” plays a foundational role in the context of engineering education in virtual environments, as it encompasses all applications, programs, and computer systems utilized to facilitate the educational process. Currently, educational software is experiencing significant growth due to increased demand for digital platforms and tools for online teaching and learning. Future research could focus on various aspects related to software in online education, including the design and development of innovative educational applications, the evaluation of their effectiveness in student learning, the analysis of trends in the adoption and use of different types of software in virtual environments, and the exploration of new technologies and methodologies to improve the educational experience.

The term “experiential e-learning” is emerging as a relevant pedagogical approach in engineering teaching in virtual environments, focused on providing students with practical and meaningful learning experiences. Currently, the importance of experiential learning to develop practical skills and professional competencies in disciplines such as engineering, where the practical application of knowledge is essential, is being recognized. Future research could explore various areas related to Experiential e-learning encompasses the design of virtual learning environments that facilitate authentic hands-on experiences, the development of effective pedagogical strategies to implement this online approach, the evaluation of its impact on the achievement of learning objectives and the development of skills, as well as the identification of key factors for the success and effectiveness of experiential e-learning in virtual environments.

The concept of “online learning” has gained unprecedented relevance in engineering education in virtual environments, particularly in the post-COVID-19 era, where distance education has become the norm. This approach allows students to access learning materials and participate in educational activities from any location with an internet connection, thereby increasing the accessibility and flexibility of the educational process. To ensure continued relevance, future studies should focus on enhancing the quality of online learning through the implementation of effective online course design methodologies, the incorporation of interactive multimedia tools and resources to enhance the learning

experience, and the development of evaluation strategies to encourage student participation and engagement in virtual environments.

The term “education” is fundamental in the teaching of engineering in virtual environments, since it encompasses all aspects related to the educational process, including curricular planning, the design of learning materials, teaching, and evaluation of learning. This concept is of particular importance in that it provides a solid foundation for the development of competencies and skills in engineering students. To maintain its relevance, future studies could explore new pedagogical methodologies and innovative educational technologies that improve the quality and effectiveness of online education in the engineering context. Additionally, research could be conducted on strategies to address the specific challenges faced by educators and students in virtual environments. These challenges include the lack of face-to-face interaction and the need to adapt educational content to the changing demands of the industry and the labor market.

The global impact of the COVID-19 pandemic has been profound, with significant shifts in education, including engineering teaching in virtual environments. The term “COVID-19” has emerged as a key reference point in highlighting the challenges and opportunities that have arisen during this period. Future research could investigate the long-term impact of the pandemic on online education and how educational institutions can effectively adapt to similar crises in the future. It could also explore how emerging technologies and pedagogical strategies can be used to improve the resilience and quality of engineering education in times of crisis.

The keyword “objectives” underscores the significance of establishing transparent and attainable objectives in engineering education in virtual environments. These objectives may encompass the development of specific skills, the promotion of critical thinking, and the facilitation of problem-solving abilities in students. Future studies could concentrate on defining and evaluating efficacious educational objectives for online engineering courses, as well as identifying strategies to align these objectives with labor market necessities and industry demands.

Virtual laboratories represent a valuable tool in the teaching of engineering in virtual environments, as they permit students to perform experiments and laboratory practices remotely. The keyword “virtual labs” underscores the significance of these platforms in engineering education, particularly in instances where access to physical laboratories is constrained. Future research could concentrate on the development and implementation of more interactive and realistic virtual laboratories and evaluating their efficacy in enhancing learning and comprehension of engineering concepts.

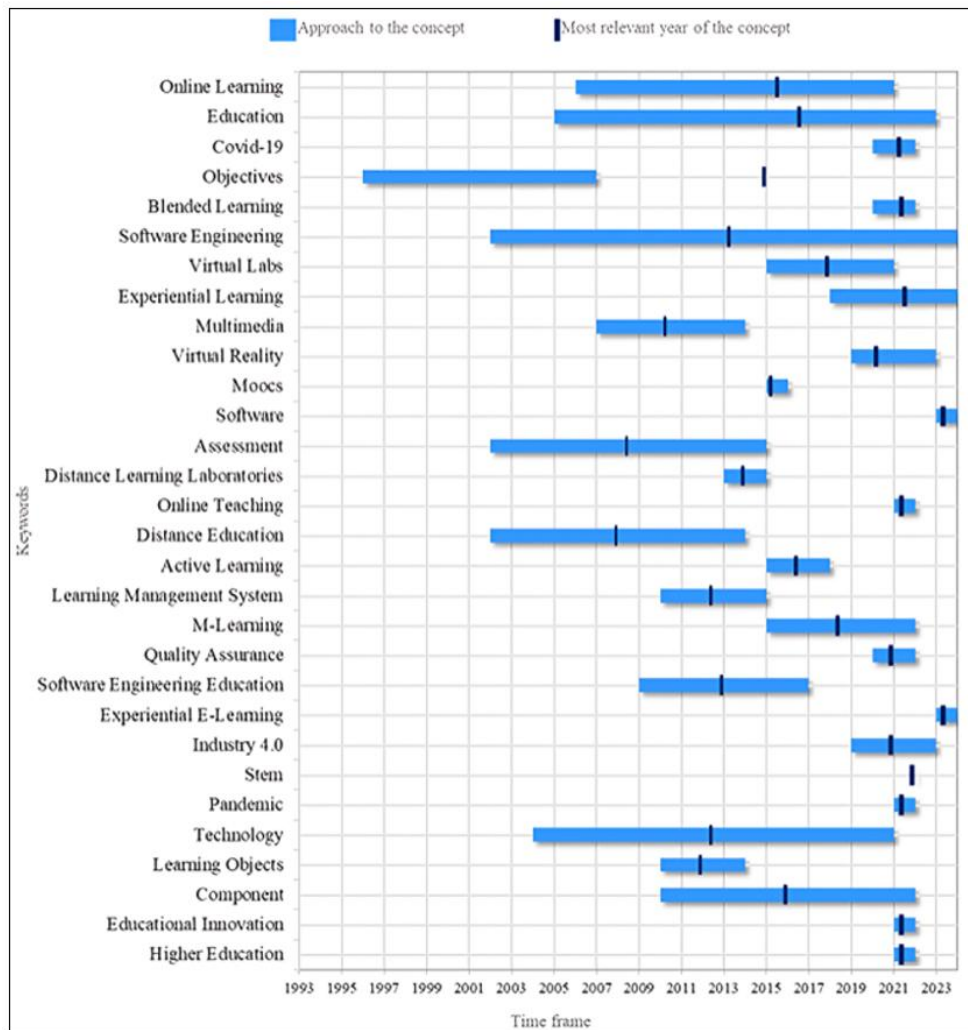


Figure 9. Research agenda (Source: Authors’ own elaboration, based on Scopus and Web of Science data)

The integration of multimedia in engineering education in virtual environments offers a multitude of opportunities to enhance the learning experience of students. The term “multimedia” underscores the significance of incorporating visual, auditory, and interactive elements into educational materials in a coherent manner. Future studies could examine the design and utilization of effective multimedia content to facilitate the teaching of engineering concepts in a more dynamic and comprehensible manner. Additionally, they could investigate the potential of multimedia to boost student motivation and engagement in virtual environments.

MOOCs have emerged as a powerful tool in engineering education in virtual environments, providing access to high-quality courses to a wide global audience. The keyword “MOOCs” highlights the relevance of these platforms in online education. Future research could delve into the effectiveness of MOOCs to teach specific engineering concepts, as well as identify strategies to improve student participation and retention in these MOOCs. Figure 9 shows the research agenda.

CONCLUSIONS

A comprehensive analysis of bibliometrics reveals several noteworthy findings. First, there has been a notable increase in the interest in this field of study, with the years 2022 and 2021 being identified as the most prolific in terms of scientific production. Additionally, a cubic polynomial growth is observed in the number of articles published, indicating a significant expansion of academic literature on the topic. Regarding the principal research references, authors such as Stefanovic, M., periodicals such as *Computer Applications in Engineering Education*, and countries such as the United States and Indonesia, which have led research in this area, are identified.

Regarding the thematic evolution, a change of focus is observed from topics such as distance learning towards more contemporary concepts such as experiential learning, mental cutting test, blended learning, and interrelationship. Likewise, dominant thematic clusters are identified, including e-learning, MOOCs, education, and others, which reflect the areas of greatest relevance in current research.

Regarding keywords, both consolidated and emerging concepts stand out, such as online learning and experiential e-learning, which reflect emerging trends and areas of interest in the field.

Finally, the research suggests that the future research agenda should focus on delving into the main concepts identified, which would help advance the understanding and improvement of engineering teaching in virtual environments in the context of constant growth of the subject. These conclusions offer a comprehensive view of the bibliometric research carried out and provide guidance for future studies in this constantly evolving field.

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